NATIONAL EXPLORATION PROGRAMME

Article 10, Decree-Law No. 84/2024

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This document was drafted with the contribution of a dedicated working group coordinated by ISPRA and composed of researchers specialized in mineral exploration, ore deposits, and critical and strategic raw materials.

With the objective of meeting the deadline for the submission of the National Exploration Programme to the European Commission, an efficient dialogue is strongly encouraged with the relevant Ministries, with the Regions/Autonomous Provinces, with other National Geological Surveys, and with the members of the Subgroup Exploration of the Critical Raw Materials Board. Such dialogue is aimed at introducing improvements to the Programme described in this document.

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1 - INTRODUCTION

The issue of securing the supply of mineral resources, essential for industrial development and for the digital and green transition, has now become a top priority in the political and economic agendas of all countries with advanced economies.

To reduce the dependency on supplies concentrated in a few countries, often politically unstable or considered at risk, the European Commission has adopted a new regulation for the safe and sustainable supply of critical and strategic raw materials (Regulation EU 1252/2024, Critical Raw Materials Act – CRMA), which entered into force on 24 May 2024.

The new European Regulation clearly outlines the strategy that the European Union intends to pursue in order to mitigate its dependence on foreign supplies of raw materials that are vital for its industrial system.

Considering the challenges associated with all supply options in a transition economy, the only effective strategy is one that integrates sustainable mining activity with circular economy practices, ecological product redesign, the search for substitute materials, and the development of partnerships with both European and non-EU countries.

No advanced economy is self-sufficient in terms of mineral supply, and the Italian situation is no different from that of many other reference economies. It is therefore neither possible nor desirable for the national strategy to aim for generalized self-sufficiency.

National strategies based on a single supply option are inevitably bound to fail.

In a transition economy, the demand for critical raw materials (CRM) is expected to increase up to tenfold or more. It is therefore unthinkable to rely solely on recycling for all CRMs. Several of these materials have extremely low recovery rates; moreover, eco-design and circular economy practices will extend the service life of technologies, which is the true goal of circularity, but this may delay the potential and much-needed substantial contribution of the recycling industry.

Italy has historically been a mining country and, for certain raw materials, it is still a significant producer. It is therefore crucial to recover a share of strategic autonomy from domestic mineral resources, varying according to the specific raw material. This goal can only be achieved through a detailed knowledge of the country's resources, which requires a new programme of general mineral exploration.

From a mining perspective, the EU Regulation requires Member States to implement a National General Exploration Programme (Art. 19) and to characterize extractive waste, including abandoned sites, in terms of their content of CRM (Art. 26).

Law Decree 84/2024, converted into Law 115/2024, incorporates several key points of the EU Regulation and assigns ISPRA's Geological Survey Department the responsibility of drafting and implementing the National Exploration Programme (NEP), which must be drawn by 24 May 2025.

2 – THE NATIONAL EXPLORATION PROGRAMME, OBJECTIVES

The NEP aims to define a comprehensive framework of the country's mineral potential by integrating existing geological and mining data with a new general mineral exploration campaign, carried out almost 30 years after the last national investment in mineral research.

The programme is therefore designed to identify the most promising areas from a mining perspective, focusing primarily on Critical and Strategic Raw Materials (CRMs) as defined by the EU, often never or scarcely explored in Italy, while also considering other raw materials of specific interest for the national industry.

In these areas, if the necessary economic, social, and environmental conditions are met, exploration permits may later be granted to national and international mining companies. These permits may then lead to mining concessions, which must be operated according to the strictest criteria of environmental, social, and economic sustainability.

It is a widespread belief that Italy does not have exploitable mineral deposits, due to scarce or depleted resources. Actually, the progressive shutdown of the metalliferous mining sector in Italy was driven more by political-economic factors than by ore geology aspects. Old mines had become obsolete and polluting, and in a global context of abundant, low-cost availability it was more convenient to rely on foreign markets. Today, however, the situation has drastically and rapidly changed: the availability of raw materials has acquired a vital importance for both the national and EU industrial systems. At the same time, sustainable mining management practices are now well established, which, while not eliminating, allow to minimize adverse impacts on the environment, on the territory, and on local communities.

A thorough assessment of national mineral resources using modern investigative techniques has therefore become imperative, given the current international geopolitical context, in which the economic (and not only economic) competition for raw materials has increased.

The NEP thus faces the challenge of convincing public opinion at all levels that sustainable mining is both possible and essential to maintain our standard of living in a fair and equitable manner. While Italy will never reach the production levels of major mining economies (Canada, Australia, China, etc.), due to its geological and territorial characteristics, it can still provide a significant contribution for several materials in reducing Italy's and the EU's dependence on foreign markets.

ISPRA and the other authorities implementing the NEP will also have the responsibility to ensure transparent and accurate communication to the population regarding both the motivations and the technical aspects of the exploration projects.

The NEP also provides the opportunity to revitalize the national mining ecosystem, oriented so far only to quarrying and industrial minerals, and to recover the educational, professional, and academic framework which, after 30 years without metalliferous mining activities, has progressively lost training capacity and attractiveness.

To define the actual presence of mineral deposits (with economic feasibility to be determined later through targeted exploration) and considering the current limited financial resources, which do not allow a full coverage of the national territory, the NEP will focus on selected areas and themes of investigation, where both orebodies and extractive waste will be jointly evaluated.

For the mapping and characterization of abandoned extractive waste, a dedicated NRRP project, URBES (URBan mining and Extractive waste information System), has already been launched. The project focuses on the recovery of secondary raw materials from urban and extractive waste.

The investigation areas/themes were selected by a working group coordinated by ISPRA, composed of some of the country's leading experts in ore deposits (already members of the National Working Table on Critical Raw Materials – Mining WG), with the goal of identifying those areas capable of providing the best results in the shortest time.

The areas were chosen based on the following criteria:

- Most promising mining potential according to previous knowledge, starting from areas identified during the RIMIN general exploration program carried out at the end of the last century.
- Presence of modern deposit studies (completed or ongoing, published and unpublished), such as research permit reports, MSc/PhD theses, scientific publications, or reports from other national/EU projects.
- Verified presence of elements never previously explored in Italy but showing strong potential based on international experience (e.g. lithium from geothermal fluids) or from earlier studies (e.g. Rare Earth Elements in fluorspars).
- Possibility of integration with other national projects (CARG, MER, URBES, etc.) and with additional research-support activities (e.g. Copernicus, SIMI).
- Opportunity to apply innovative techniques, such as airborne magnetometry, cosmic particle detection, and extensive use of artificial intelligence software.

In some cases, areas with non-listed EU raw materials were also included, if considered of interest for the national industry or for export, such as zeolites, or in view of potential future supply risks not currently addressed in the EU list. For example, molybdenum, 90% sourced from the United States and potentially affected by new US trade policies, or chromium, mainly sourced from South Africa. In these cases, the decision on their inclusion as research themes will be referred to the Committee for Critical and Strategic Raw Materials.

According to DL 84/2024, Art. 7, non-invasive research activities do not require Environmental Impact Assessment screening, while under Law 752/1982, Art. 4, *"landowners of areas subject to general exploration activities cannot oppose the execution of research works, without prejudice to the existing mining safety regulations."*

Due to the severe shortage of companies specialized in exploration of metalliferous minerals and the need to rely on the highest-level expertise in ore deposits, the programme should be carried out in collaboration with the scientific and technical community (universities, research centres, Regions/Autonomous Provinces, SNPA). The implementation of the programme will follow the most advanced international standards, also thanks to exchanges with other national exploration programmes coordinated by EuroGeoSurveys and by the CRM Board Subgroup Exploration. At the same time, ISPRA will participate in drafting the European BREF (*Best Available techniques REFerence document*) for metalliferous mining activities, the EU reference document on best techniques to reduce environmental impact.

In summary, the final objectives of the NEP are:

1) Identify new mineral resources and expand the general mineral knowledge in the most promising areas, focusing on:

- CRM deposits previously mined in Italy, such as copper, tungsten, manganese, magnesium, antimony, graphite, fluorspar, baryte, feldspar, etc.
- CRM deposits never mined or scarcely explored, such as lithium, cobalt, platinum group elements, light and heavy Rare Earth Elements.
- Non-critical raw materials that may hold strategic importance for the national supply chain (e.g. bentonite, zeolites, kaolin) or that may become critical due to new policies of allied countries (e.g. molybdenum, 90% imported from the US).

2) Provide a standardized and internationally compliant dataset to stimulate the interest of national and international companies in applying for targeted exploration permits for sustainable mining projects.

3) Revitalize the national mining ecosystem by:

- Enhancing technical and scientific competences within Public Administration (PA).
- Reviving academic education and mining schools.
- Promoting research and researchers in the mining sector.
- Establishing a National Mining Register.
- Involving small and medium-sized enterprises and freelance professionals (geology, geophysics, geochemistry) to stimulate sector growth.

- Strengthening dialogue with local authorities and communities to foster social acceptance, especially through the dissemination of Responsible Mining principles.

4) Lay the foundations for a multi-year continuation of mineral exploration.
5) Provide Italy's contribution to the EU's reduction of dependence on foreign raw materials essential for industrial development.

At the same time, through the NRRP URBES project, the recovery of **secondary raw materials** from abandoned extractive waste and other potential sources of supply will also be promoted.

The CRMs targeted, described in detail in the following chapters, include:

1) Fluorspar, Baryte, Rare Earth Elements (Southern Alps)
2) Platinum Group Elements (Os, Ir, Ru, Rh, Pt, Pd) (Eastern Piedmont)
3) Copper and Manganese (Eastern Liguria)
4) Graphite (Piedmont, Liguria, Calabria)
5) Non-conventional Lithium (Tuscany, Lazio, Emilia-Romagna)
6) Antimony (Tuscany)
7) Magnesite (Tuscany)
8) Fluorspar, Baryte, Rare Earth Elements (Lazio)
9) Feldspar, Lithium, Rare Earth Elements (Campania)
10) Feldspar, Rare Earth Elements (Sardinia)
11) Copper, Tungsten, Rare Earth Elements, Titanium (Pb-Zn-Ag districts)
12) Fluorspar, Baryte, Rare Earth Elements (Southern Sardinia)
13) Tungsten, Arsenic, Bismuth (+ Tin, Molybdenum) (SW Sardinia)
14) Copper (+ Molybdenum, Gold) (SW Sardinia)

2.1 General and Targeted Exploration

Given the possible expectations, especially in the media, arising from the implementation of the NEP, it is necessary to specify that the EU Regulation provides for a general mineral exploration, not a targeted exploration.

Mineral exploration, that is, the set of activities aimed at the identification of mineral deposits, in fact develops in two consecutive phases, which are clearly distinct in terms of objectives, timeframe, investigation methods, territorial impact and, above all, costs.

General exploration

General exploration represents the reconnaissance phase of a wide area, aimed at identifying zones with mineral potential, without undertaking particularly invasive survey methods. It is therefore the first phase of exploration and includes:

- Geological, structural, and mining surveys for mapping geological features and outcropping mineralization.
- Active geophysical investigations, including airborne and helicopter-borne sensors, to detect anomalies indicating the possible presence of orebodies.
- Remote sensing techniques, both passive (optical, thermal) and active (SAR, LiDAR), multispectral and hyperspectral, using satellite imagery or data acquired by aircraft, drones, etc.
- Highly innovative investigative techniques such as cosmic particle detection.
- Collection of rock, soil, and water samples for mineralogical, geochemical, isotopic, and spectroscopic laboratory analyses.
- Extensive use of artificial intelligence software for the analysis of both existing and newly acquired data, including 3D modelling.

ISPRA and the territorial research units will be responsible for the preliminary verification of the relevant territorial constraints in force and managed by the different land-use authorities.

Article 8 of Law 752/1982 defines general exploration as follows: *"General exploration consists in the collection of data, documentation and mining bibliography; in systematic geological-structural, mineralogical surveys and studies aimed at mineral exploration; in geological, geophysical, geochemical, geognostic, geostatic and deposit investigations; in the elaboration of all interpretative documents and the related explanatory studies."*

General exploration is conducted by the State at the national level and aims to identify orebodies in areas to be subsequently devoted, after Environmental Impact Assessment, to applications for exploration permits for targeted exploration by mining companies, with the ultimate goal of obtaining a mining concession.

In areas not included in the NEP, general exploration activities may also be carried out by mining companies through the application for an exploration permit to the competent authorities (the State or the Regions, depending on the materials being investigated).

Targeted exploration

Targeted exploration **is carried out by mining companies** and focuses on a high-potential ore deposit, with the objective of assessing its dimensions, exploitable quantities, and the economic feasibility of extraction. It therefore involves extended and highly detailed studies necessary to define, as accurately as possible, the economic potential of the mineral body. It includes:

- Excavations, trenches, and drill holes to acquire, through the investigation of collected samples, a three-dimensional analytical dataset with high-spatial density.
- Creation of 3D models to evaluate grades, extension, and geometry of the ore deposit, with reference to international reporting codes.
- Metallurgical tests to determine the most effective extraction methods.
- Feasibility and environmental impact studies to assess economic and environmental sustainability.

Article 8 of Law 752/1982 defines targeted exploration as follows: *"Targeted exploration consists of detailed ore deposit geology, geophysical and geochemical studies; in performing boreholes, open-pit and underground excavations for the exploration and delimitation of new ore deposits; in sampling operations and related evaluations; in statistical processing of data; in carrying out mining and mineral processing feasibility studies."*

Targeted exploration is a rather costly operation that may reach tens of millions of euros for a single mining project, with a very high business risk. It is a technologically very advanced activity, which, in the current national context, can only be carried out by specialized mining companies. Considering the potential impacts on the territory, targeted exploration must necessarily be subjected to Environmental Impact Assessment.

2.2 Strategic Importance of Mineral Exploration for National Security – Critical Raw Materials (CRMs)

All human activities are directly or indirectly linked to the use of the planet's resources (geo-resources in the broad sense). Since the Neolithic, the discovery of metals and alloys has enabled the creation of new tools and the development of agriculture, transportation, and the arts, delineating the path that would lead to modern societies. In parallel with the advancement of technologies and industry, the use of mineral raw materials has progressively increased over time, now affecting almost all the elements of the periodic table.

Currently, the exponential growth in demand is driven by the rapid expansion of new technologies, from consumer electronics, information technology, artificial intelligence, robotics, aerospace, to technologies for the decarbonization of the energy, transport, and industrial sectors, as well as to all other civil and military technologies of the Fourth Industrial Revolution. This decarbonized, digitalized, and robotized development model, however, requires the intensive use of a wide range of metals and non-metals, many of which are included in the lists of Critical Raw Materials (CRMs) prepared by all industrially advanced nations.

The EU list includes 34 critical raw materials, of which 17 are strategic, considered essential for its industry. Their availability, in a context of growing global demand, may become problematic as it depends on the political and economic conditions of producing countries, industrial strategies, technological evolution in resource use, the commissioning of new deposits, the search for alternative materials and sustainable product redesign, recycling and recovery rates and related technologies, as well as market trends. Producing forecasts on the future needs of CRMs is highly complex, but all estimates prepared by international organizations (World Bank, IEA, UNECE, IRENA, etc.) converge on the unstoppable growth in demand for mineral raw materials to sustain the new decarbonized and digitalized development model.

Since they are **essential to ensuring the continuity of the nation's strategic sectors** (industry, energy, defense, services, trade, etc.), CRMs play a substantial role in the security of both the country and the continent. Their shortage may result in the inability of developing a competitive industry in all high-technology sectors, including the production of advanced **defense systems**, which, in the current and worrying geopolitical context, are becoming increasingly important.

Dependence on a small number of suppliers, often located in politically unstable or potentially hostile areas, exposes Europe to possible supply disruptions due to protectionist policies of producing countries, which might also form cartels to manipulate prices and control markets by using mineral resources as a geopolitical weapon, or due to more or less predictable causes such as conflicts, natural or health events, or technological accidents. **In this context, the definition of the country's mineral potential has once again become an absolute priority.**

3 – THE ITALIAN MINING SITUATION

3.1 The geological and ore deposit context of the Italian territory

The description of the geological framework of the Italian territory is particularly complex; within a relatively small area, many diverse geological features coexist together with active endogenous and exogenous processes. The geological evolution of Italy ranges from the early-Paleozoic orogens to the opening of the Tethys oceans in the Mesozoic and the subsequent closure of these oceanic inlets during the Alpine and Apennine subductions (Figure 1).

The Italian crust is continental, except for the Tyrrhenian abyssal plain and the Ionian Sea. Its maximum thickness occurs in the Alpine chain (about 50–60 km), while the minimum is along the Tuscan and Lazio coastal belt.

From a geographical and geological perspective, it is possible to schematically distinguish: the former European basement (Sardinia), the Alps (Northern and Southern), the Apennines, the major plains (Po Plain, Tavoliere delle Puglie) and minor plains, and the varied volcanic districts, which also include numerous insular and submarine groups.

The pre-Alpine basement is well exposed in the Alps, in Sardinia and locally in Calabria and Sicily. It consists of variously metamorphosed sedimentary successions, associated with scarce Caledonian and much more widespread Variscan igneous rocks. The post-Variscan stratigraphy, from the Permian to the Cretaceous, shows in Italy the features of a passive margin, with the typical sedimentary sequences. The inversion and relative motion between the European and Adriatic plates began during the Cretaceous and generated compression at the western margin or dextral transpression at the northern margin of the Adriatic plate.

The spatial and temporal evolution of the Alps and subsequently of the Apennines during the Tertiary is documented by clastic sediments, flysch, and molasse deposits that overlapped the previous passive margin sequences.

From the Triassic to the Recent, several magmatic episodes of different geodynamic significance occurred in Italy. The most significant are: the calc-alkaline magmatism of the Middle Triassic and the rhyolitic-trachytic and basaltic, both effusive and subvolcanic, of the Eocene–Oligocene in the central-eastern Southern Alps; the Tertiary calc-alkaline magmatism that characterized the Oligo-Miocene rift in Sardinia; the Plio-Quaternary volcanism, with variable characteristics, occurring in Sardinia, in several districts of Central and Southern Italy, and in the Aeolian Islands.

All these phenomena are reflected in the lithological features of the different Italian regions. The Alpine regions, from Piedmont to Lombardy, Trentino-Alto Adige, Veneto, and Friuli, are characterized by a combination of lithologies including the metamorphic–magmatic rocks of the basements of the different Alpine thrusts, the extensive sedimentary covers from the Permo-Triassic to the Oligocene–Miocene, and the widespread sediments of the plains (Po-Adige-Piave plain). In Piedmont, the northernmost lithologies are the pre-Triassic crystalline rocks and, partly, the Mesozoic ophiolitic-sedimentary series, included in the Penninic tectonic units, separated by the Canavese and Centovalli Lineaments (the westernmost part of the Insubric Line) from the late- to post-Variscan southern igneous rocks and the associated carbonate–dolomitic and terrigenous sediments from the Anisian to the Eocene. Further south are the late orogenic molasse and the alluvial deposits of the Po Plain. In Liguria, ophiolitic deposits are common, associated with deep-sea sediments, both of Jurassic age.

In the easternmost regions, from Lombardy to Friuli, the Tonale–Giudicarie–Pusteria–Gail Lineament (the easternmost part of the Insubric Line) separates, to the north, the crystalline rock units of the Austroalpine Complex from the sequences of the Southalpine Complex. The Austroalpine Units consist of various polymetamorphosed series of Paleozoic sediments and volcanosedimentary rocks, locally with autochthonous layers of Mesozoic sedimentary cover, which is only affected by the Alpine tectono-metamorphic cycle. In the northernmost areas of Lombardy and Trentino-Alto Adige, some belts of the Penninic Units crop out in tectonic windows through the Austroalpine chain.

The Southalpine Complex includes: 1) a Variscan crystalline basement, cropping out mainly along the Insubric Line, consisting of prevalent paragneisses in Lombardy and phyllites in Trentino-Alto Adige and Veneto, in both cases with intercalations of minor quartzites, porphyroid gneisses, and metabasalts; 2) a wide unmetamorphosed Permo–Miocene sedimentary cover, several thousand meters thick, consisting of both shallow-water carbonates and basinal deposits, with important carbonate–dolomitic sequences in the Dolomites. Late- to post-Variscan granitic–granodioritic bodies intruded along the Insubric Line, as well as into the Southalpine crystalline basement (mainly in Trentino-Alto Adige), as plutonic and epi-plutonic masses. Extensive effusive deposits, often ignimbritic, evolving from andesite–dacite to rhyolite (the Atesina Volcanic Platform), were produced by the same magmatic event. Along the southern sedimentary covers, subvolcanic and effusive products, from calc-alkaline to shoshonitic, of the Ladinian–Carnian magmatism are also widespread. On the margin or in the nearby Po–Adige plain, abundant alkaline-basaltic rocks (Monti Lessini–Berici) and trachy-andesitic and rhyolitic subvolcanic bodies (Colli Euganei) of Eocene–Oligocene age crop out. In the Tuscan–Ligurian–Emilian region, distinct complexes are present, including both the Ligurian Units, consisting of flysch-type successions often associated with ophiolites, and the successions of the Tuscan thrust sheets. These consist of a carbonate platform and pelagic sediments, with related flysch deposits. The deepest tectonic unit consists of the crystalline deposits (para-autochthonous) of the Apuan metamorphic carbonates. The same tectonic situation, though with strongly variable lithological types, is found in Southern Tuscany and in parts of the Umbria–Marche–Lazio–Abruzzo regions. Here, the pelagic successions of the Umbria–Marche domain crop out, tectonically juxtaposed to the carbonate platform deposits and accompanied by the overlying late-orogenic flysch deposits. The carbonate sequences extend from Abruzzo to Apulia, covered by siliciclastic flysch and coeval deposits, and in Southern Campania, by the Lagonegro basinal sequences. The successions of the Taranto Gulf area correspond to thick siliciclastic deposits belonging to foredeep accumulations of post-orogenic age. Along the Tyrrhenian coastal belt, important potassic–alkaline volcanic deposits of the southern Tuscan–Roman province occur. Potassic volcanic rocks are also present in Campania, where they form the complexes of Roccamonfina, Vesuvius, and the Phlegraean Fields. Another volcanic center is the Vulture complex, between Apulia and Lucania.

In Southern Calabria, metamorphic and magmatic lithotypes mainly produced by the Hercynian and Alpine orogenic cycles can be found. The same lithologies are recorded in the easternmost area of Sicily, the Peloritani Mountains. In Northern Sicily, the successions are mainly sedimentary, Mesozoic–Tertiary in age, and similar to those of the carbonate platforms of Southern Continental Italy. Several flysch deposits also occur, including the Numidian flysch. In Eastern Sicily, the most important volcanic complexes are related to Mount Etna, whose basaltic effusions cover much of the province of Catania. Further north, volcanism of the Aeolian arc, predominantly calc-alkaline in character, is present, while further south, that of the Hyblean Plateau occurs.

In Sardinia, most of the Paleozoic lithotypes recorded in Italy crop out. In the north, high-grade Variscan metamorphic rocks (amphibolites and migmatites) prevail, associated with syn- to post-kinematic granites. Tertiary volcanic calc-alkaline rocks occur both in the north and in the south of the island, often associated with Tertiary continental sediments. The southern part of the island is characterized by the low-metamorphic grade Paleozoic Thrust Complex. In the southwestern part of the island, Cambrian and Ordovician platform carbonates of the External Zones host significant metalliferous mineral resources.

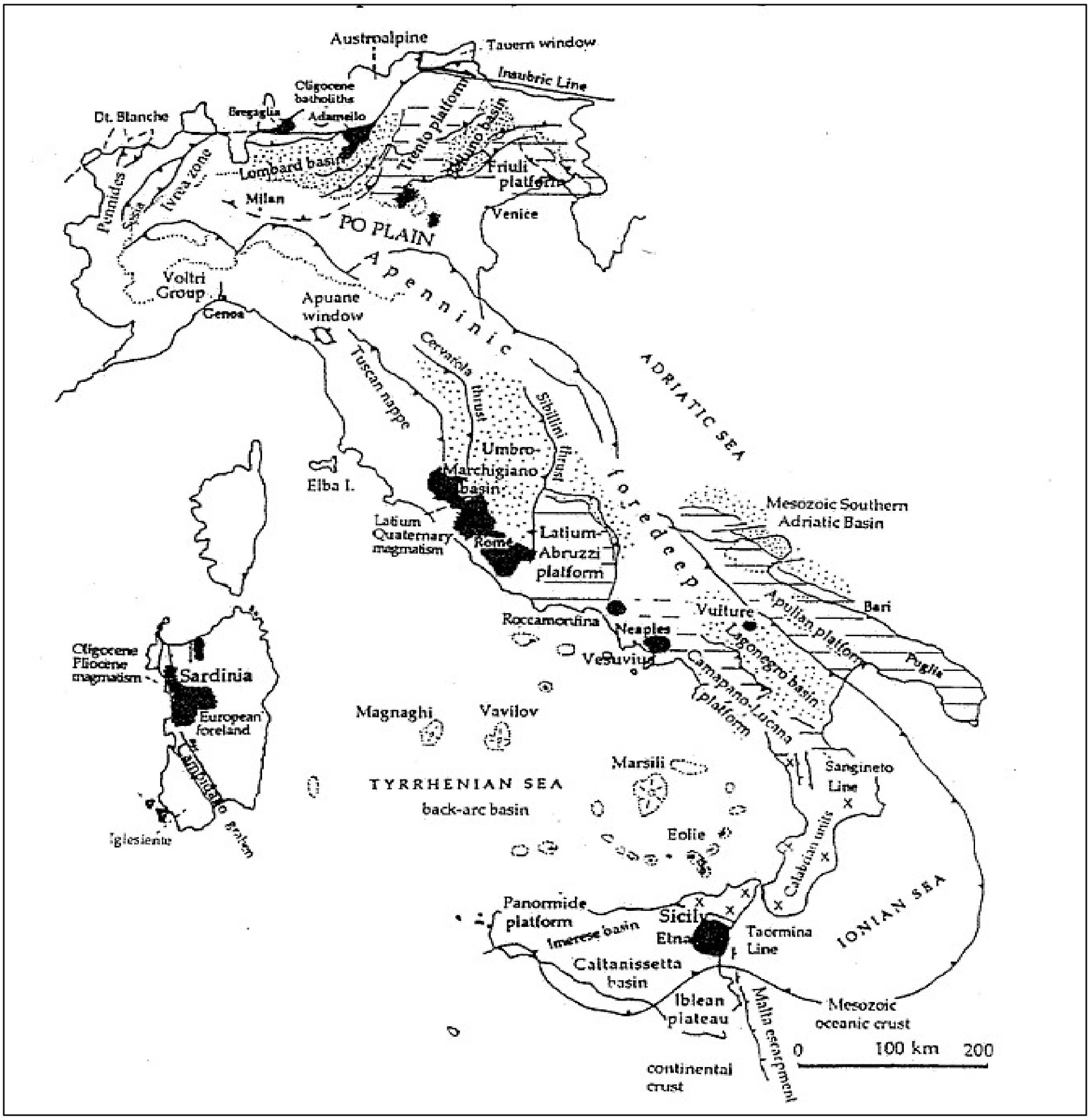

Figure 1 - Schematic representation of the main paleogeographic or structural units mentioned in the text (Doglioni & Floris, 1997).

3.2 Mines in Italy

Due to its geological features, Italy hosts numerous and diverse mineral deposits, widespread across the entire territory and intensively exploited in past centuries, particularly from the early 20th century onwards. Mining activity was common in almost the entire national territory. A total of 3,016 mining sites have been active from 1870 to the present, involving all regions, 93 provinces, and 889 municipalities. The trend was steadily increasing until the mid-20th century, except for a slight downturn between the late 1920s and early 1930s, following the adoption of Royal Decree 1927, which regulated mining activity in Italy. Thereafter, activity progressively declined, mainly due to the gradual abandonment of metallic mineral and sulphur extraction (Figure 2).

The exploitation of ore minerals was particularly intense in the Alpine arc, Tuscany, and Sardinia. Sulphur, occurring in the central Sicily, was mined for over two centuries using outdated methods essentially based on labour exploitation, including child labour (the so-called carusi). Lignite extraction characterized the alluvial plains of Central Italy.

About 900 sites were dedicated to the extraction of ore minerals, concentrated on the so-called "base metals," which were the main commodity used in the steel industry in the last century (mainly iron, lead, zinc, copper, antimony, manganese, aluminium). Mining of precious metals (gold and silver) also developed to some extent, dating back as far as Etruscan times. By contrast, many of the raw materials currently considered CRMs were scarcely mined or even explored, due to the limited interest at the time, although some (such as cobalt, lithium, titanium, and probably also light Rare Earth Elements) are certainly available in potentially significant quantities.

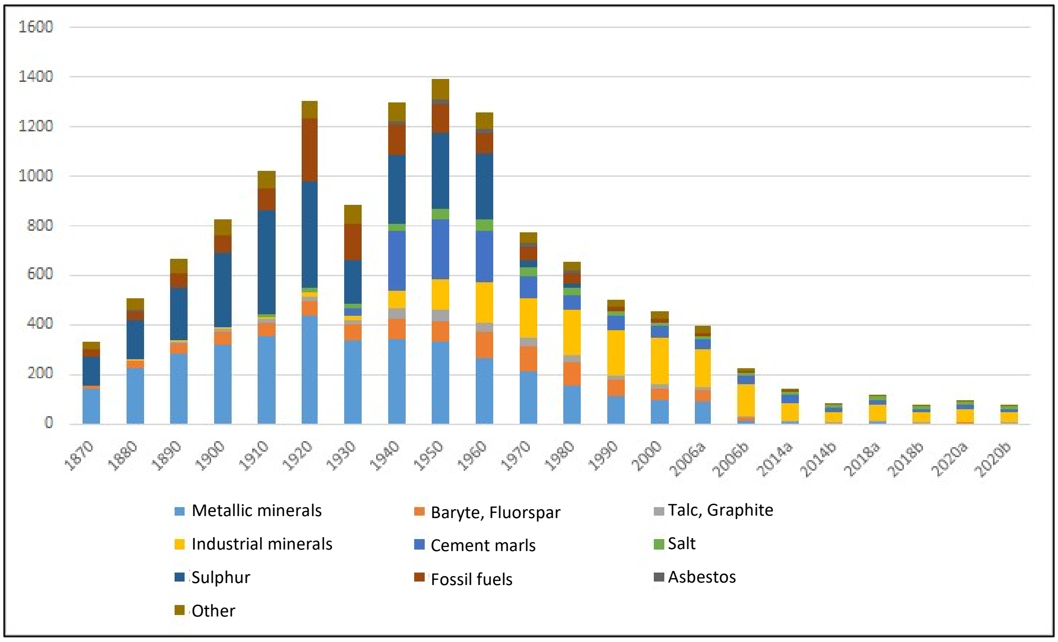

Figure 2 - Active mining sites in the national territory during the period 1870-2023, by type of extracted mineral.

A different situation applies to industrial minerals, particularly those used in the ceramic sector, for which Italy continues to be a major producer and a continental leader. However, national information on the presence of mineral bodies potentially exploitable for economic purposes (deposits) remains largely unchanged since 1973 (Figure 3), with subsequent updates carried out under the general mineral exploration programme conducted by the Ministry of Industry between 1982 and 2005.

In 2023, out of 94 mining concessions still in force, 76 are actually in production, mainly in Sardinia, Piedmont, and Tuscany.

Current productive activity is essentially linked to mines of ceramic and industrial minerals (feldspars, kaolin, refractory clays, bentonite, bleaching earths), which are particularly widespread in the Sardinian granitic areas, and to cement marl deposits, distributed along the Apennine chain and in the Lombard-Venetian Prealps. Rock salt is extracted from the mines of the Volterra area and the Agrigento district, while sea salt comes from the saltworks of Southern Sardinia. No information is available on the saltworks present in other Italian regions, which do not follow the same concession procedure as in Sardinia. The extraction of ore minerals is currently non-existent. The planned reopening of the lead–zinc–silver mine of Gorno (Bergamo) is still blocked at the Environmental Impact Assessment stage, while the Giacurru magnetite mine (Nuoro), although having completed the administrative procedure, has not yet resumed production. The Genna Tres Montis fluorspar mine (Silius, South Sardinia), where part of the extracted material will also include galena (the main lead ore), is about to resume operations.

The only CRMs currently extracted in Italy are fluorspar and feldspars. These are non-metallic CRMs but are widely used in the industrial sector.

In 20 of the active mines, located in Piedmont, Tuscany, Calabria, Lazio, and Sardinia, feldspar is extracted, a mineral essential for the ceramic industry, in which Italy is the European leader. Its criticality is related to the strong dependence on Turkey, from which the EU imports more than 60% of its needs.

Two mines hold concessions for the extraction of fluorspar (in the municipalities of Bracciano and Silius), a CRM of particular importance in the steel industry, electronics, and batteries. In particular, the underground fluorspar mine of Genna Tres Montis (South Sardinia), will be one of the most important in Europe and will provide a significant contribution to reducing dependence on China. Other former fluorspar mines worth reconsidering under current market prices are located in the Bergamo, Brescia, and Trentino areas, as well as in Sardinia and Lazio.

In the same areas, significant barite deposits are also found, an important mineral for the paper, chemical, and mechanical industries. Graphite deposits are known in the Turin area, in Savona, and in the Sila (Calabria).

As for metallic CRMs/SRMs, Italy is completely dependent on foreign markets, although several of them were exploited in the past within the national territory (Figure 3). Many of these mining sites, closed essentially due to lack of profitability, should now be reconsidered with modern criteria of exploration, extraction, and according to the current market trends.

Copper deposits, an essential mineral for all modern technologies, are already known in the Metalliferous Hills, in the Ligurian-Emilian Apennines, in the Western Alps, Trentino, Carnia, and Sardinia. In several sites, manganese was extracted, especially in Liguria and Tuscany. Tungsten is documented in Calabria, in Eastern and Northern Sardinia, and in the Central-Eastern Alps, often associated with lead-zinc. Cobalt is documented in Sardinia and Piedmont, where the Punta Corna deposit is considered of European importance. Magnesite occurs in Tuscany, and magnesium salts in the Venetian Prealps.

The confirmed titanium deposit in the Savona area is well known, as are the environmental issues that preclude its open-pit extraction. Small amounts of bauxite, the main ore for aluminium production, occur in the Central Apennines but in larger quantities in Apulia and especially in the Nurra (Sassari) zones, where the Olmedo mine, the last metalliferous mine to be closed in Italy, is still in good condition, at least in the upper levels. The bauxites of Olmedo, like other bauxite deposits, may contain potentially exploitable amounts of REE, which are also certainly present in many fluorspar deposits, such as Genna Tres Montis.

The presence of lithium has been confirmed in significant amounts, especially in the geothermal fluids of Tuscany, Lazio, and Campania.

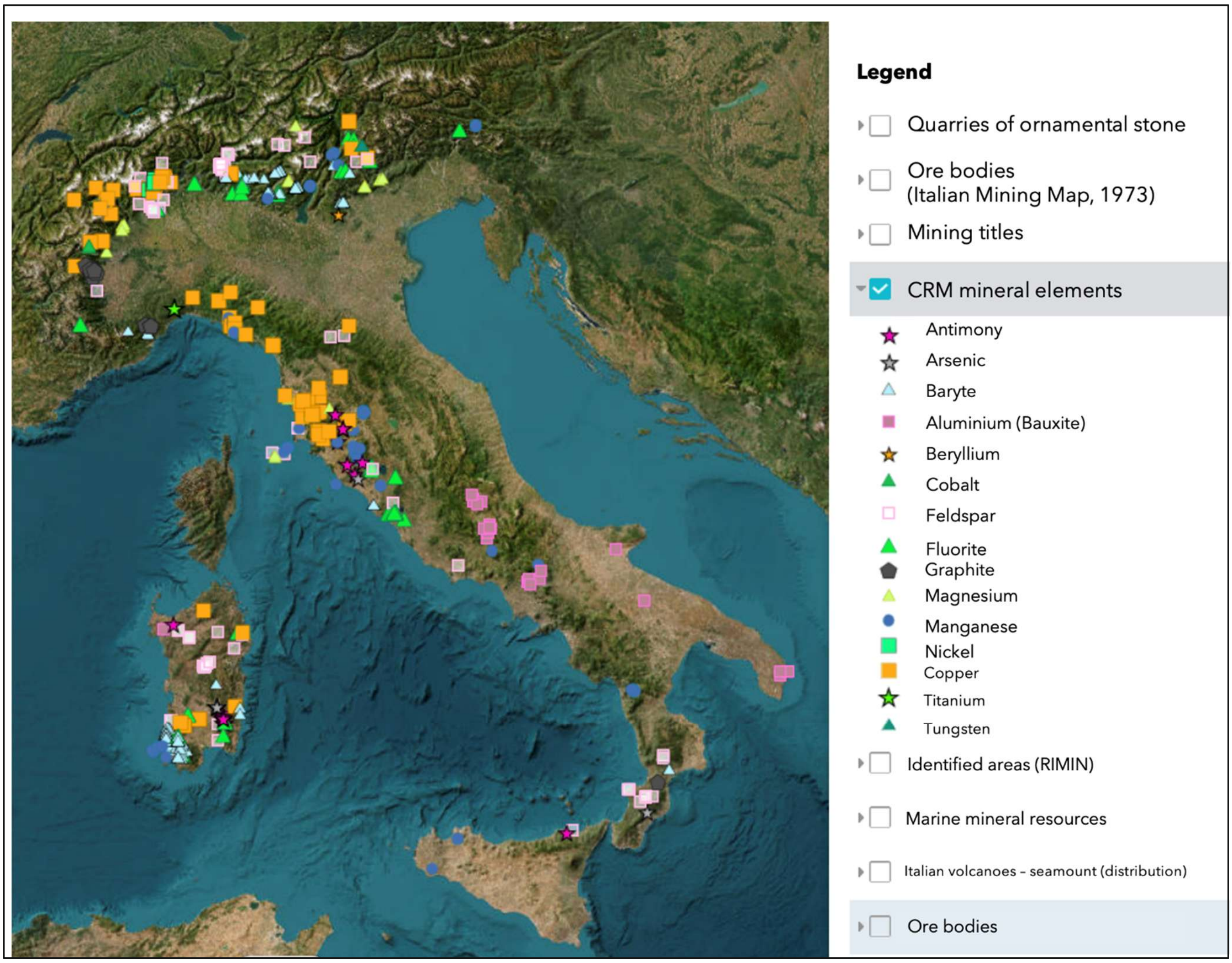

Figure 3 – Mine sites exploiting CRMs in the period 1870–2023.

As a result of the renewed interest in mineral resources, several exploration permits are currently in force for the assessment of a potential resumption of mining activity at former ore deposits, especially in the Piedmont and Lombardy Alpine arc. There is also significant interest in the possible exploitation of geothermal brines in the volcanic areas of Lazio, which show very high lithium and other element contents, with six exploration permits already granted. Sulphur production, which had characterized Sicily for centuries, was completely discontinued from the 1980s, while asbestos extraction was prohibited in the 1990s under Law No. 257/1992.

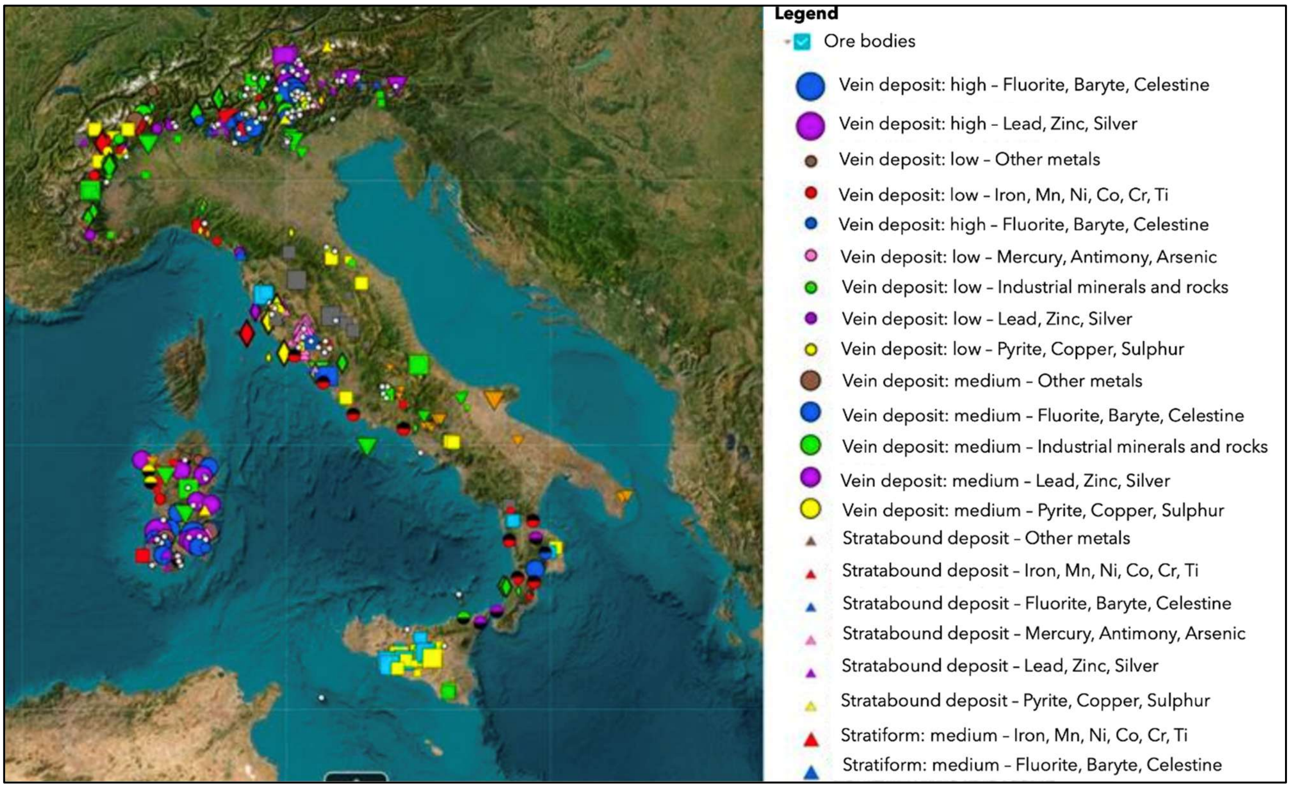

Figure 4. Orebodies in Italy; symbols are proportional to their known size, as reported in the Italian Mining Map of 1973.

The total production in 2022 amounted to about 15.7 million tonnes and was almost evenly distributed among the geographical areas. In Central and Northern Italy, cement marl extraction predominates, while in the South and Islands industrial minerals prevail, particularly in Sardinia. Overall, the exploitation of marl and industrial minerals accounts for more than 80% of national production. From an ecological and health risk perspective, today's active mines are less impactful than those of metallic minerals, whose waste contains high concentrations of pollutants. With the new NRRP RepowerEU – URBES, integrated into the NEP, ISPRA will begin the detailed mapping and characterization of abandoned extractive waste with the aim of quantifying the amounts of CRMs present and identifying best practices for their recovery.

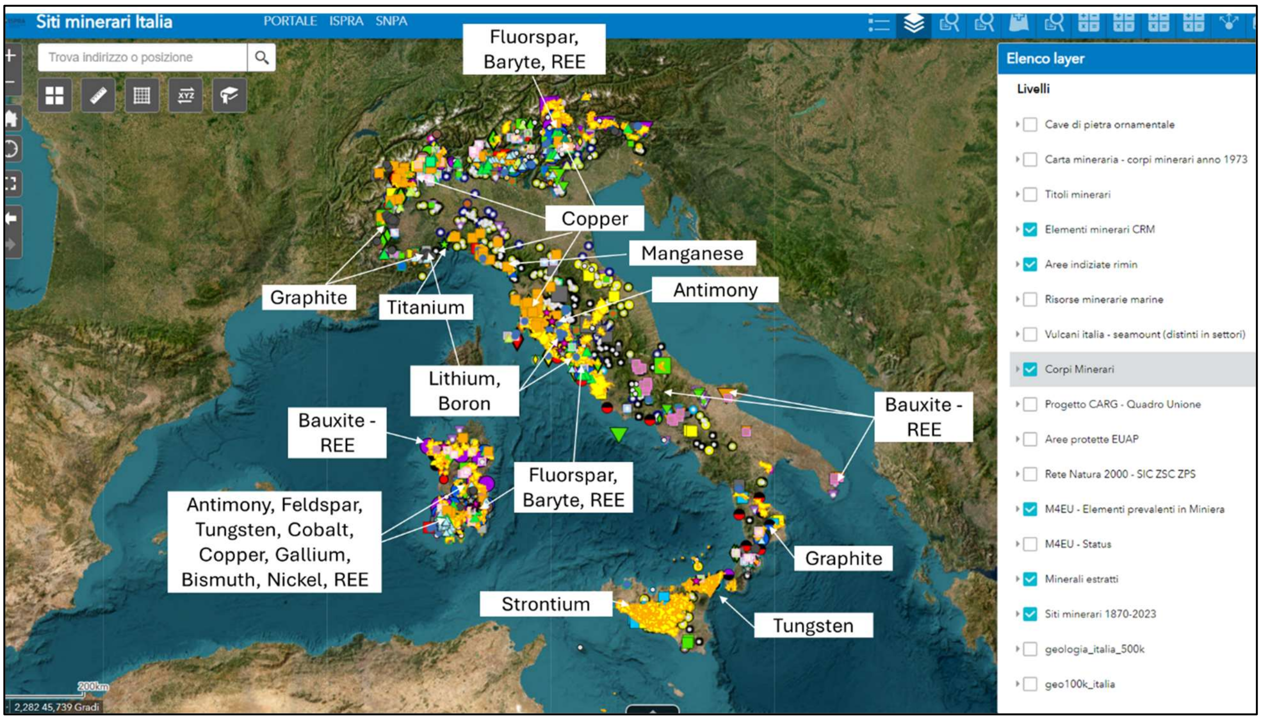

Figure 5. Map of areas with the highest potential for CRMs, based on the aggregation of existing data.

3.3 Extractive waste

Closed or abandoned mining activities prior to Legislative Decree 117/2008, which regulates the management of extractive waste, left behind large amounts of mining wastes stored in disposal facilities (waste rock piles and tailings ponds), in some cases of considerable size. In the Sardinian mining district, the most important in Italy, approximately 70 million cubic meters are present, with a consequent high environmental impact.

These closed and abandoned extractive waste facilities are a major concern in both Europe and Italy, as they often contain high concentrations of toxic and carcinogenic elements whose mobility and dispersion may pose environmental (soil, water, ecosystems) and health hazards. Many of the potentially hazardous elements are also CRMs. Therefore, the localization and characterization of extractive waste serve a dual purpose: to assess the possible environmental and health impacts of such waste, and to define the quantities of potentially recoverable materials, in line with circular economy models and environmental–health risk mitigation. These deposits may, in fact, represent an important source of secondary raw materials. In general, they show a good potential, sometimes with high mineral grades, as in the case of the red muds of Monteponi (Iglesias), which are already known to contain an average of 7–8% zinc. In several cases, the storage deposits also contain significant amounts of substances included in the current CRM list (e.g., Co, Cu, Ni, Bi, V, Sb, Ta, REEs). In addition, they may contain other substances which, although not considered critical, are of strong interest as secondary raw materials in the ecological transition industry (e.g., Zn, Au, Ag). However, much still needs to be done in terms of characterization and forecasting for the total reuse/recovery of these deposits. Currently, the available information concerns only their potential or actual hazard in terms of both ecological-health risks and static-structural stability. Because of their content in metals and in substances used in processing (e.g., cyanide), extractive waste can give rise to serious contamination of environmental matrices (soil, air, surface and groundwater) through phenomena such as wind erosion, water erosion, acid drainage, etc. In several cases, the waste disposal facilities are now dilapidated and in precarious static-structural conditions. The need to monitor extractive waste disposal facilities, in order to prevent the many incidental, even catastrophic, events that have affected them in various parts of the world and also in Italy (Val di Stava, 1985), led the European Commission to issue Directive 2006/21/EC "on the management of waste from extractive industries," requiring each Member State to produce an inventory of hazard sources within its territory by 1 May 2012, with periodic updates.

Italy transposed the European Directive through Legislative Decree No. 117 of 30 May 2008, which establishes, as its purpose, the measures, procedures and actions necessary to prevent or to reduce as far as possible any negative effects on the environment, as well as possible risks to human health, resulting from the management of waste produced by extractive industries (Art. 1).

Legislative Decree 117/2008 requires extractive industries to adopt a specific Extractive Waste Management Plan, but activities carried out prior to its entry into force are excluded from its scope.

The same Decree also provides for the creation of the National Inventory of Category A extractive waste facilities, which currently represents the only national source of information on the presence of extractive waste, although limited to a single data point for each mining site. It is therefore necessary to carry out detailed mapping of all waste deposits, which may number several hundred for a single mining site (Figure 4), and of different origin.

Unlike other Member States, which included mapping and characterization of extractive waste within the funding of their National Exploration Programmes, in Italy, although addressed in this document in compliance with Regulation (EU) 1252/2024, these latter were separately founded under a specific NRRP project called URBES (URBan mining and Extractive waste information System).

Since the issues of potential deposits and of extractive waste produced by former mining activities are inevitably interconnected, the two projects, although focused on different aspects of mining activities, will work together and share information while maintaining a clear division between their budget lines.

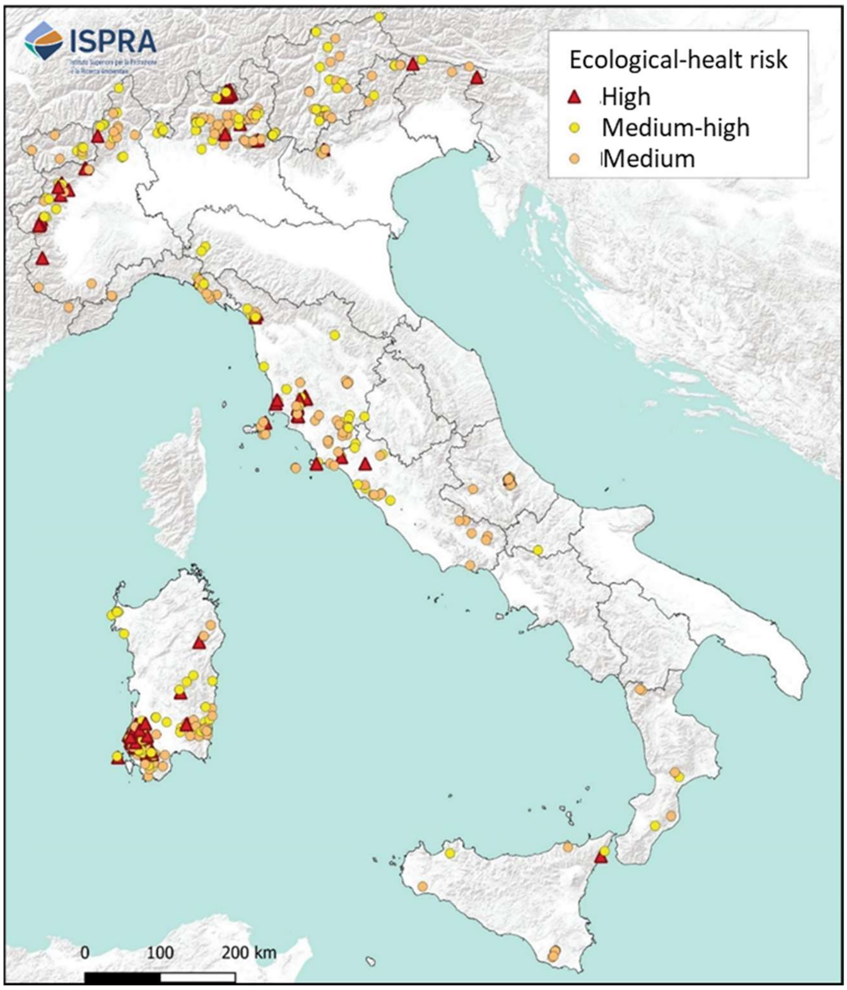

Figure 6. Mining sites with the presence of extractive waste deposits hazardous to the environment (ISPRA 2024)

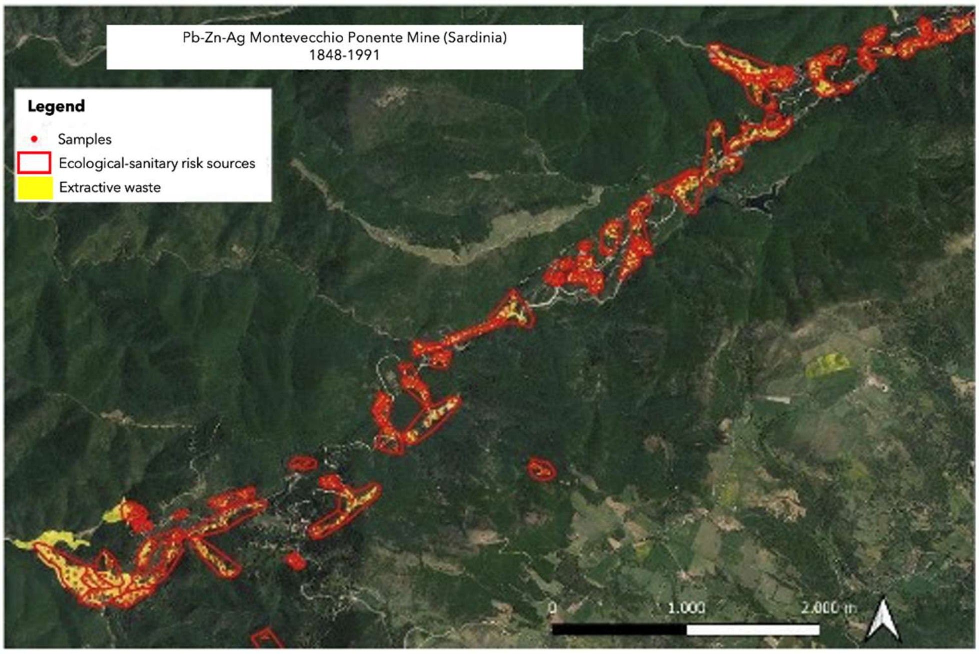

Figure 7. Pb-Zn-Ag Montevecchio Ponente mine (Sardinia), with 130 waste dumps roughly containing 3 million m³ of material; analytical data are available only for topsoil.

3.4 Mineral exploration in marine areas (Decree-Law No. 84/2024, Article 3(8)).

The issue of seabed mining is a matter of international debates, especially in relation to the still poorly understood effects on the marine ecosystem. On the other hand, if carried out with the utmost attention to mitigating negative impacts, the exploitation of marine resources could become a valid alternative to land-based supply of critical materials for our economic development.

Before discussing extraction, and in line with the Italian and European position expressed in the relevant international regulatory fora (International Seabed Authority), a prolonged research phase is required, aimed not only at defining the available resources but also at developing methods for exploitation, mitigation and restoration, as well as a cost–benefit analysis, as the basis for a thorough environmental impact assessment.

The issue of seabed exploitation, especially in environmentally sensitive areas of high value such as the Mediterranean seabed, should therefore be included in a broader discussion to be carried out also within the framework of European and international regulations. Regarding the reference in Decree-Law No. 84/2024 to the mining map, it should be noted, as stated by ISPRA during a Parliamentary hearing, that this National Mineral Exploration Programme does not currently envisage, given the financial resources available, further investigations of the seabed. The data contained in the GeMMA mining database refer to surveys already carried out during specific marine research campaigns. These data mainly concern deposits of marine sands located on the continental shelf off the coastal areas, some seabeds adjacent to volcanic islands, and some Tyrrhenian submarine volcanoes (Figure 8 - Figure 9).

As stated later in this document, ISPRA undertakes the collection of all available data on marine mineral resources, also by establishing collaborations with other ongoing projects such as the NRRP MER project and with other institutions that may hold relevant information (CNR, OGS, etc.).

Figure 8 - Seabed and seamount sampling sites assessed by the RIMIN project.

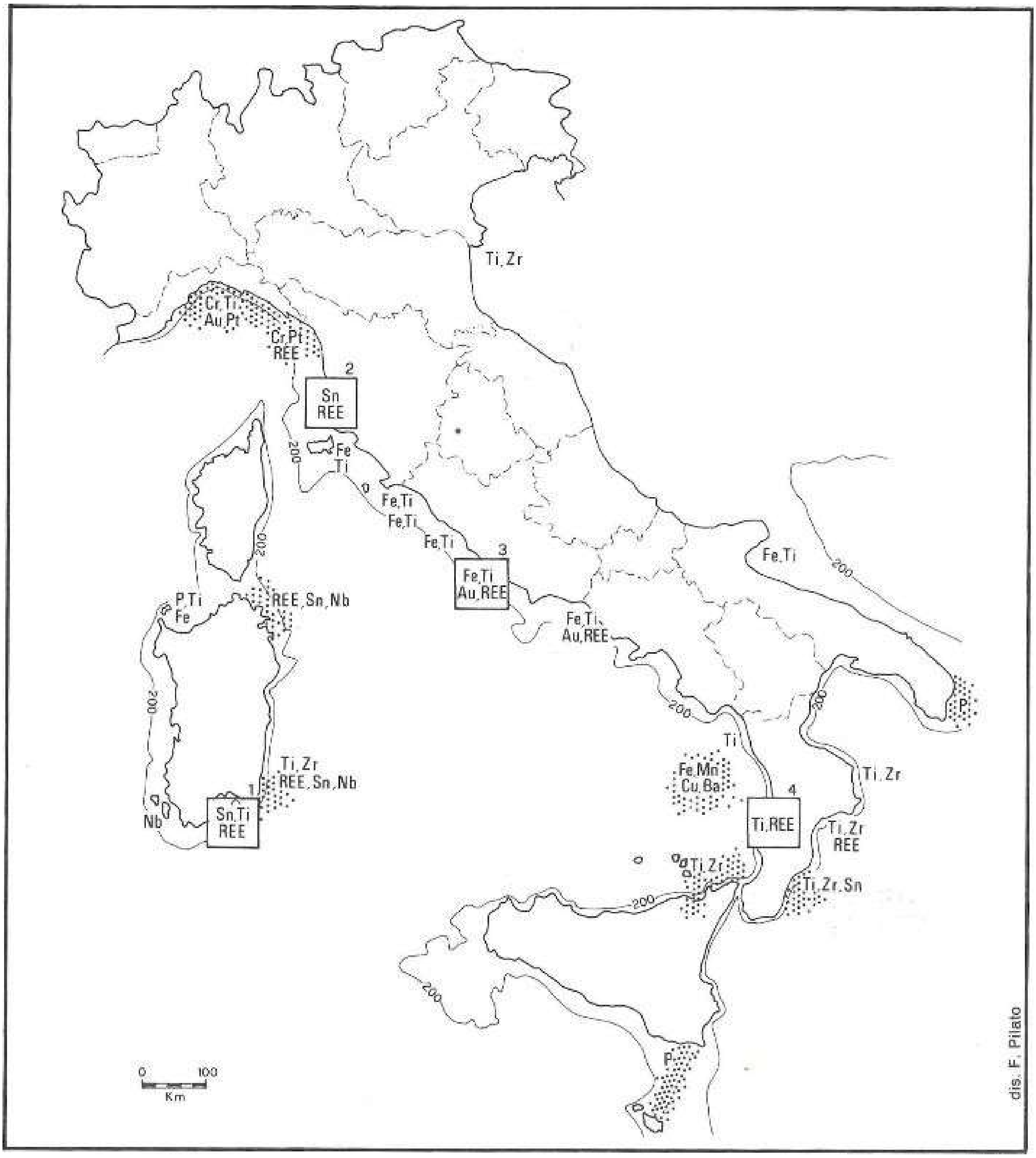

Figure 9 - Synthesis of the results from the studies conducted during the RIMIN project.

4- DATA ACQUISITION AND MANAGEMENT

4.1 - Data Acquisition and Processing

As planned by the activities reported in the description of the exploration areas in Chapter 6, the methods of data acquisition and management are very similar to each other and follow a predefined path at the planning stage, in order to achieve homogeneity of information at the national level. Any use of specific acquisition methodologies is exposed in the description of the investigation areas.

The general criteria are therefore as follows:

1. reprocessing of existing datasets;
2. processing of new data;
3. integration of both, to identify the potential of mineral deposits in greenfield and brownfield areas;
4. preliminary evaluation of the economic potential.

Most of the research concerns regions where mining operations have previously taken place and where planned greenfield and brownfield activities overlap. Unless explicitly specified, the following criteria are therefore to be considered valid for both greenfields and brownfields.

1) Recovery and reprocessing of existing Data

This activity focuses on maximizing the information extracted from data already available for each investigation area.

Considering the situation of Italy, where at the end of the last century an extensive and costly general mineral exploration programme (RIMIN) was carried out, the recovery of the data produced is an essential and indispensable activity, as is their re-evaluation based on modern ore deposit geology concepts.

a) *Acquisition, review and digitization of pre-existing data:*

Greenfield: Collection of all available datasets from national, regional and local archives, including geological maps, reports, academic publications, remotely sensed images (satellite, aerial), geophysical surveys (magnetic, gravimetric, electromagnetic, radiometric, muonic), geochemical surveys (stream sediments, soil, rock), and any historical exploration data (drilling logs, assays).

Brownfield: Acquisition, if available, of detailed operational records from past mining activities, including mine plans, data regarding productions, processing methods, waste characterization studies (geochemical, mineralogical), environmental monitoring, historical explorations around the mining site, and any available geophysical and geochemical surveys.

In several mining sites, remediation procedures for the removal of environmental issues related to extractive waste are ongoing, planned, or have already been completed. The integration between remediation activities and mineralogical characterization aimed at the recovery of CRMs should be discussed and evaluated with the competent national and regional remediation authorities.

b) Data Quality Control

Quality control procedures will be implemented to identify and address errors, inconsistencies, and distortions within each dataset. This includes verification of geographic accuracy, data completeness, analytical precision, and consistency in units and data formats. These latter will be standardized under the supervision of the CTS. Where possible, re-sampling at the same locations is planned in order to verify the reliability of pre-existing data.

c) Reprocessing of geological, geophysical, geochemical, remote-sensing and economic data

Available geological maps and cross-sections shall be digitized and georeferenced using dedicated artificial intelligence software.
The creation of reliable 3D geological models requires extensive subsurface data; therefore, the recovery of drill logs, their analyses and, where possible, the original cores is a priority.
Geophysical datasets, when available, shall be processed with advanced techniques to improve signal-to-noise ratios, enhance resolution, and derive maps of relevant physical properties (e.g., magnetic susceptibility, density, electrical resistivity, chargeability). This may include filtering, levelling, gridding, and advanced transformations (e.g., analytic signal, tilt derivative for magnetics; inversion for density or resistivity models).
The integration of geological and geophysical data can support the reinterpretation of geological structures and lithological units based on current knowledge and help identify further remote-sensing and geophysical actions.
Geochemical datasets shall be analyzed using statistical and spatial techniques to identify anomalous concentrations of target and tracer elements. This includes basic statistics, data analysis (histograms, box plots, scatter plots), spatial mapping of elemental distributions, multivariate statistical methods (e.g., principal component analysis, factor analysis) to identify geochemical associations and potential mineralization signatures.
For extractive waste, geochemical and mineralogical data, where available, must be re-evaluated to quantify the concentrations and mineralogical distribution of critical materials. This may involve recalculation of assays, reinterpretation of mineralogical

relationships, and potentially the application of machine learning techniques to identify patterns and predict the distribution of CRMs within the waste body.
The analysis of economic data through the recovery of historical production records is extremely useful for understanding the possible spatial distribution of the extracted ore, potential zones of residual mineralization, or low-grade areas that were not mined. In the case of extractive waste, knowledge of the production methods and periods can guide the search for CRMs in the deposits.

2) Processing of newly acquired Data during exploration campaigns

For each investigation area, common workflows must be followed, with possible improvements and additional procedures depending on the survey methodologies.

a) Data acquisition and quality control

In each area, the protocols defined by the Scientific and Technical Committee (CTS) for data acquisition must be implemented. These include accurate GPS localization for all samples and survey points, protocols for sampling, handling, and storage of samples, and their shipment to analytical laboratories. Quality control of the reliability of the instruments used is also included.

b) Processing of geological, geophysical, geochemical and remote-sensing data

Geological, structural, and petrographic surveying is the fundamental element and must be carried out using common or compatible legends and representation criteria defined by the Geological Survey of Italy. For areal, linear, and point representations in GIS environments, open-source software should be used. Lithology, alteration, mineralization, and structural features must be described. In the initial survey stages, simple hammer sampling is planned, followed by mini-cores collected with portable drill rigs in the most promising areas. All sampling must be supported by portable instrumentation (e.g., XRF, gamma-ray detectors, UV lamps) useful for defining mineralogical composition.

Newly acquired geophysical data must be processed using appropriate software and techniques, with application of corrections, filtering, and advanced processing to generate high-resolution maps and 3D models of relevant physical properties. For example, airborne electromagnetic (AEM) data can be processed to create deep resistivity sections and 3D resistivity models. For extractive waste, data from geophysical surveys specifically designed for waste characterization (e.g., electrical resistivity tomography, induced polarization) must be processed to map internal structure, humidity content, and the potential presence of conductive or chargeable materials associated with CRM enrichment.

Geochemical data obtained from laboratory analyses of rock, soil, and stream sediment samples must be processed using statistical and spatial techniques to identify new geochemical anomalies and refine those already known.

QA/QC data (blanks, standards, duplicates) must be used to assess the accuracy and precision of analytical results. For extractive waste, it will be necessary to apply a more detailed sampling grid after the first characterization phase, in order to better delineate the areas with the highest CRM contents within the waste dump.

Advanced spectral analysis techniques (e.g., spectral unmixing, target detection) must be applied to the new high-resolution remote-sensing images (satellite, aerial, or drone) aimed at mapping geological features, alteration zones, and potentially identifying spectral signatures related to mineralization or CRM enrichment in the waste dumps.

3) Integration of pre-existing and newly acquired data:

All available information will be used to build robust conceptual models, where possible, for identifying the potential of mineral deposits using the following criteria:

a) Georeferencing and GIS Data Integration:

Integration of all georeferenced data (geological maps, geophysical grids, geochemical point data, remote-sensing images, drill hole locations, waste deposit boundaries) into the national GeMMA mining database.

b) Spatial Data Analysis and Overlay:

Spatial overlay analysis to identify areas where multiple indicators of mineralization coincide. For example, overlapping geochemical anomalies with favorable geological structures, alteration zones identified by remote sensing, and geophysical anomalies.

c) Geological and Geophysical Modelling 3D:

All relevant data (surface geological maps, structural interpretations, geophysical inversions, and subsurface data) will be used to create comprehensive 3D models of geology and subsurface physical properties. This enables the visualization and analysis of potential orebodies and their geological controls.

For extractive waste deposits, 3D models will also be developed, incorporating drill holes, mineralogical data, and geophysical properties to identify the spatial distribution of CRMs. Historical production data are also important for understanding how CRM distribution may be correlated with past mining activities and processing methods, in order to trace CRM enrichment pathways in waste and potentially identify more concentrated zones.

d) Targeting of Geochemical Anomalies:

By integrating geological, geophysical, and remote-sensing data, efforts will be made to correlate geochemical anomalies with the geological context, also to develop predictive models for mineralization based on spatial relationships between geochemical signatures and other geological features.

e) *Automated learning and Data Based Modelling:*

Machine learning algorithms (e.g., artificial neural networks, support vector machines, random forests) will be applied to identify patterns and complex relationships within the integrated data sets that may not be evident through traditional methods. These can be used for mineral prospectivity mapping in greenfield areas and to predict grades and CRM distribution in brownfield areas.

f) *Mineral Prospectivity Mapping (MPM)*

MPM models based on integrated data sets will be developed by assigning weights to different knowledge layers (geology, geophysics, geochemistry, remote sensing) according to their known association with the target mineral deposit type. Layers will be combined using fuzzy logic, Boolean logic, or data-driven approaches to generate maps highlighting areas with high mineral potential.

g) *Generation and prioritization of TARGET:*

Based on the results of the integrated data analysis and modeling, a prioritized list of targets for further investigations (e.g., geophysical surveys and drilling) will be generated. Prioritization will take into account available evidence, geological context, accessibility, and potential economic viability.

4) Evaluation of economic potential

The preliminary estimate of the economic potential of possible primary deposits and CRM recovery from extractive waste will be carried out in a second phase, upon completion of the exploration activities and, in the case of extractive waste, following the mapping and characterization process of closed or abandoned waste facilities, as described above.

Its detailed definition includes metallurgical testing, assessments of environmental and social impacts, operating costs, capital costs, market analysis of the recovered CRMs, financial analysis, and evaluation of technical and market risks. This activity lies outside the basic activities conducted by ISPRA and must be considered the responsibility of the mining companies interested in the investment.

4.2 Data management: The national mining database

Article 19 of Regulation (EU) 1252/2024, among the actions to be undertaken to implement the national exploration programme, also provides in paragraph 2(e) for the "reprocessing of existing survey data in order to identify any previously undetected mineralization containing critical raw materials and carrier minerals of critical raw materials." This provision was incorporated into paragraph 8 of Article 10 of Law No. 115/2024, which ISPRA complied with on 24 July 2024 by opening to the public its national mining database. The GeMMA database (Geological, Mining, Museum, Environmental) contains information on all mining sites exploited in the country since the Unification of Italy, from which a homogeneous mining dataset can be obtained. The geodatabase (Figure 10) has been developed in full consistency with the European Mintell4EU database and represents the access point to a series of specific databases already completed or under development. However, this activity should not be considered completed but rather in continuous evolution as the recovery of pre-existing information progresses, also through specific agreements with other data-holding institutions. This activity of recovery, analysis, and validation of the existing information assets has constituted the knowledge base for the identification of areas to be subjected to new analyses within the framework of the general exploration programme.

Figure 10 - GeMMA Database Home page[2]

The M4EU_ISPRA geodatabase is based on a consolidated reference model derived from the European project MINERALS4EU (Minerals Intelligence Network for Europe), adapted to the specific needs of the Italian context. This model constitutes an advanced technical framework designed to integrate and manage geospatial and complex attribute data related to mineral resources. The technical structure of the database has been enhanced to ensure robustness, scalability, and compliance with international standards.

4.2.1 Database structure

The adopted model inherits the main features of the MINERALS4EU schema, enriched with functionalities specific to Italy. It consists of a series of interconnected spatial layers and relational tables, implemented on PostgreSQL with the PostGIS extension for geospatial support. The main technical features include:

1. Table relationships: link information on mining sites (e.g., location, type of resource) with operational data (e.g., activity status, extraction period).
2. Spatial indexes: optimize geospatial queries, reducing response times for large-scale territorial analyses.
3. Validity domains: impose constraints on attribute fields, ensuring consistency and accuracy of data.
4. Controlled vocabularies: ensure semantic interoperability through defined standards, including:

   ✓ https://inspire.ec.europa.eu/applicationschema/mr-core: INSPIRE application scheme for mineral resources.

   ✓ http://inspire.ec.europa.eu/codelist/: INSPIRE code lists for terminology standardization.

   ✓ https://data.geoscience.earth/ncl/: geoscientific vocabularies for technical classifications.

   ✓ http://resource.geosciml.org/classifier/cgi/: CGI geological classifications.

   ✓ http://www.minerals4eu.eu/codeList/unfc/: UNFC system for resource and reserve classification.

The choice of PostgreSQL/PostGIS is motivated by its ability to manage large spatial datasets, offering functionalities such as geometric queries, spatial indexing, and compatibility with OGC (Open Geospatial Consortium) standards. The database supports complex operations, such as spatial analysis of resource distribution and correlation between geochemical and geological data. In addition, the model is scalable: new layers or tables can be added without altering the existing structure, making it suitable for future expansions.

[1] Mineral Intelligence for Europe (Mintell4EU) - GeoERA

[2] https://sinacloud.ISPRAmbiente.it/portal/apps/sites/#/miniere

4.2.2 Content of the Geodatabase

The content of the Geodatabase derives from a multi-year activity of census and updating, initiated with the Census of Mining Sites conducted by ISPRA between October 2002 and March 2006. This census mapped all mining sites active during that period, including those still operational or with valid concessions. The sources, both direct and indirect, include:

- ✓ Census records of DICMA (1989).
- ✓ Annual reports of the Mining Service (1877–1983).
- ✓ Bulletins of the Rivista Mineraria Siciliana (1960–1990).
- ✓ Gazzetta Ufficiale and Regional Official Bulletins (BUR) for mining decrees.
- ✓ Concession registers of the former Mining Districts, where available.

The scope covers solid minerals of the first category (Article 2, Royal Decree No. 1443 of 29/07/1927), with particular focus on Critical Raw Materials (CRMs) and Strategic Raw Materials (SRMs).

The integrated content includes:

- National distribution of sites: the *miningfeatureoccurrence* layer defines resource types (e.g., metallic or industrial minerals) and geographical locations, with varying degrees of coordinate accuracy.
- Site properties: the mine table records operational details, such as periods of activity (start and end dates), current status (active, abandoned, under concession), and other technical characteristics.

A cornerstone of the database has been the continuous effort to define and implement integration processes for data originating from different databases, with the goal of consolidating a unified and interoperable national Geodatabase. All databases accessible to ISPRA have been considered, covering a wide range of historical, operational, and geoscientific data on Italian solid mineral resources. This effort involves standardization of formats, resolution of semantic conflicts, and alignment with INSPIRE controlled vocabularies. The integration process is still ongoing, with the reconstruction of mining waste deposits and their quantitative assessment identified as the main challenge. The databases taken into account include:

1. Database of Abandoned Mining Sites (1870–2023) (ISPRA): This database, the starting point of the M4EU_ISPRA Geodatabase as described below (Integrated Content), collects historical data on abandoned mining sites over more than 150 years. Integration required a complex georeferencing process, often based on archival textual descriptions lacking precise coordinates, and harmonization with the miningfeatureoccurrence layer to define geographical locations and resource types.

2. Database of Active Mines (ISPRA-Istat-Regions): Collects data on operational mines, in cooperation with Istat and the Regions. The integration process is ongoing, with the goal of data standardization.
3. Database of Active Exploration Permits (ISPRA-Istat-Regions): Records ongoing exploration permits, including geographical areas and authorized entities. The integration process provides for the alignment of coordinates with the EPSG:25832 system and incorporation into spatial layers.
4. Database of Known Italian Mineral Deposits: digitization of the Carta Mineraria d'Italia, editions of 1927 and 1973 (ISPRA). Derived from the digitization of historical Mining Maps. The process includes vectorization of paper maps, correction of projection errors, and import of georeferenced data.
5. Inventory of Closed/Abandoned Extractive Waste Facilities (ISPRA): Developed in compliance with Legislative Decree No. 117/2008, this inventory contains data on mining waste dumps and tailings storage facilities, aimed at assessing ecological-health and static-structural risks. Risk category classification was carried out jointly by ISPRA and the Regions and is primarily intended for contaminated site remediation procedures. The quantitative assessment of the materials present, in terms of CRMs/SRMs, is the responsibility of the URBES project, described later.
6. Database of the ReMi Network of Mining Parks and Museums (ISPRA): Collects data on mining sites of cultural and touristic relevance, i.e., disused mining areas that over the years have undergone protection and enhancement processes in Italy, including the four National Mining Parks established by decrees of the current MASE in the 2000s. The process involved the addition of specific attributes.
7. RIMIN Database - General Mineral Exploration (MASE-UNMIG, 1982-2005): Includes geochemical, geophysical, and mineralogical data. Partial integration has begun, but further efforts are required for full incorporation due to the complexity of the format.
8. Database of Marine Mineral Resources (MASE-UNMIG, 1982-2005; ISPRA): Contains information from sampling carried out during the RIMIN programme, mainly referring to coastal placer deposits of metalliferous sands. Data concerning submarine volcanoes in the Tyrrhenian area have also been included.
9. Database of Ornamental Stone Quarries (ISPRA): Identifies the main quarries producing lithotypes for ornamental use listed in UNI ISO 14440. Several of these also contain critical materials.
10. Database of Official Geological Mapping: includes geological and mining data derived from:
    - CARG, Geological Map of Italy at 1:50,000 scale and original surveys at 1:10,000 scale: detailed maps integrated as support layers for geological contextualization.

- Geological Map of Italy at 1:100,000 scale and original author surveys at 1:25,000 scale: digitized and harmonized to correlate deposits with lithological features, through raster-to-vector conversion and INSPIRE alignment.
- Geological Map of Italy at 1:500,000 scale.

11. National Geochemical Database (ISPRA, under revision): provides chemical analyses of mineral resources, largely derived from RIMIN data, with preliminary integration and mapping into the geosciml.org vocabularies still in progress.
12. National Geophysical Database (ISPRA, under development): contains the location and, where available, the results of geophysical surveys of potential mining interest.
13. Digitization of historical and statistical data from the archives of the Geological Survey of Italy (ISPRA, under revision): includes historical statistics and reports, with integration in progress.
14. Database of Protected Areas (MASE, ISPRA): contains georeferenced information on the 871 protected natural areas listed in the official MASE register (national and regional parks, state and regional nature reserves, marine protected areas) as well as areas protected under Natura 2000.

4.2.3 GeMMA and the Mineral Exploration Projects of the NEP

Within the GeMMA mineral resources portal, a dedicated section is being developed for the research projects in the areas with the highest mineral potential, identified as priorities in the NEP and described in Chapter 6 of this document.

The NEP section of the portal refers to 14 pages corresponding to the areas of investigation. Each page is linked to the national deposit and mining database and contains the description of the geological, deposit-related, and mining context, accompanied by appropriate cartographic representation highlighting areas already subject to mining activities (brownfields). The presence of any type of protected areas will also be highlighted, given the evident repercussions both on exploration activities and, above all, on potential future operational exploration and subsequent exploitation. The areas will also be connected to the geological, geomorphological, hydrogeological, and territorial databases of the Geological Survey of Italy and the National Environmental Information System, in order to provide a comprehensive overview of the territorial framework, also in view of possible environmental impact assessments.

In the initial phase, the pages will report the data available from the literature but are designed to incorporate the progress status of Phase 1 activities, including the final evaluation of the results obtained and any continuation of research in Phase 2 and Phase 3.

The provision of data to external users must be agreed with MASE, also taking into account the possible presence of documentation subject to copyright (scientific publications) and of any sensitive and non-disclosable data. For all investigation areas, information on existing extractive waste will also be reported, with links to the dedicated platform on secondary raw materials currently under development within the framework of the NRRP URBES project (see Section 3.2). Similarly, the other areas related to extractive waste described in Chapter 6 will be addressed.

4.3 - Integration and Harmonization of the NEP with Other Ongoing Projects

In order to avoid inefficiencies and multiple and/or redundant funding, it is considered necessary to review national, local, and EU projects that may present similarities with the NEP and provide useful information for understanding the national mineral potential. As a first step, it is therefore deemed essential to establish a comparison with the following projects managed by ISPRA or other entities:

CARG: Geological Map of Italy 1:50,000

Geological mapping at semi-detailed scale is of fundamental importance for reconstructing the structural framework that may influence and determine the presence of mineralized areas. A specific task is planned for the revision of survey and graphical representation criteria of mineralization and mining sites in the new standard CARG sheets. This will allow the inclusion, in the official State geological maps, of some basic information elements related to existing mineralization, useful in view of future mineral-oriented surveys.

In this regard, a specific experimental Geomining sheet at 1:50,000 scale is being developed in one of the most significant Sardinian areas from a mining perspective (Guspini, Iglesiente). A dedicated working group (WG) between ISPRA and the University of Cagliari is already active and responsible for carrying out the project. The "Guspini" sheet is also preparatory for defining the legend to be applied to future and expected geomining sheets.

NRRP URBES Project

The project aims to map and characterize sources of secondary raw materials derived from extractive waste of past mining and quarrying activities, stored in closed and/or abandoned facilities, fully in line with the provisions of Article 27 of EU Regulation 1252/2024. URBES is significantly linked to the NEP, as it operates on former mining sites that were the territorial expression of deposit occurrences.

The objectives of the projects are, of course, very different: on the one hand, the recovery of secondary raw materials, and on the other, the definition of the potential of natural deposits. However, in many cases the investigation areas will overlap. In this context, particular attention will be paid to avoiding any expenditure conflicts and/or double funding for the same activities, while also aiming at virtuous synergies and the maximization of research for sites of common interest.

NRRP MER Project

Within the framework of the MER project, activities are planned for the characterization of marine areas also from a mineralogical perspective, as well as high-resolution geophysical surveys (gravimetric), LiDAR, and multibeam surveys (for submerged areas) of coastal zones. The project also includes the mapping of about 79 seamounts, located beyond 12 nautical miles in the Ligurian Sea, the upper and lower Tyrrhenian Sea, the Strait of Sicily, the Sardinian Sea, the Ionian Sea, and the southern Adriatic Sea, at depths ranging between 200 and 2000 meters. For this purpose, remotely operated vehicles (ROVs) will be used, capable of recording high-definition video and equipped with high-resolution acoustic instruments.

In addition to providing geological and mineral data, MER's activities are fundamental for understanding submarine ecosystems and for assessing the environmental impact of potential applications for mineral exploration permits on the seabed, particularly when involving environmentally sensitive areas such as Mediterranean seamounts.

The NEP coordination will establish agreements with the MER coordination in order to acquire, share, and integrate useful information into their respective databases.

CNR-ISSMC Industrial Minerals Database

The CNR–ISSMC has developed a substantial database on ceramic and industrial minerals present in the national territory. Some of these are critical (feldspars, fluorspar), while others represent a significant component of the national economy, to the extent that they could be considered strategically important under Article 14-bis of Decree-Law No. 84/2024 (e.g., bentonites, kaolin, zeolites). ISPRA and CNR have already initiated a memorandum of understanding for the sharing of this information.

Regional Databases, GeoSciences IR, and ISTAT Quarry–Mine Database

Almost all regions have organized information related to extractive activities into specific databases, which, however, are highly heterogeneous. Through an initiative carried out by ISTAT and ISPRA in recent years, a statistical survey methodology has been defined, resulting in more homogeneous data on ongoing extractive activities. The census is currently conducted by ISTAT, and steps will be taken to ensure data sharing.

Regional databases also collect information on past activities and on the geological characteristics of investigation areas, as well as data on current or previous exploration permits. Some Regions/Autonomous Provinces (e.g., Friuli-Venezia Giulia, Trento) are conducting a new census of historical mining activities in line with the national GeMMA database. ISPRA has long maintained a consolidated relationship with regional authorities responsible for extractive activities, and their involvement in the NEP operations is considered essential.

The regional data available have already been implemented in the GeMMA database developed within the GeoSciencesIR Research Infrastructure coordinated by ISPRA, which will be updated and enhanced within the NEP, including in terms of its functionalities and capabilities. The GeoSciencesIR e-learning platform already hosts several products, as described in the training plan chapter.

Satellite and aerial remote sensing projects

ISPRA has consolidated a framework agreement with ASI and the University of Pavia for the use of optical satellite imagery aimed at multi- and hyperspectral analyses. It is therefore possible to acquire PRISMA data to be applied initially to the investigation areas already identified, with the purpose of calibrating spectral libraries (where already available) as well as developing new ones, also with a view to extending the survey to the entire national territory.

Other project initiatives currently under evaluation, such as that of the Politecnico di Torino (*Hyper-Twin*), if approved, will certainly be taken into account, and agreements in this regard have already been established. Opportunities to undertake European projects within the framework of EIT Raw Materials are also being considered.

Geological Service of Europe (GSEU)

The National Exploration Programmes required by Regulation 1252 have generally been assigned to the Geological Surveys of the Member States. These Services are gathered within the GSEU Network, where discussions are underway on the drafting of programmes and implementation methods, in which ISPRA is actively participating. Constructive dialogues have also been initiated with some neighbouring countries (Switzerland, Slovenia), aimed at harmonizing cross-border areas and participating in joint projects.

Integrated Monitoring System (SIM) NRRP MASE

Particular attention will be given to those basic datasets already foreseen in other national initiatives, such as geomatic LiDAR acquisitions and nationwide geophysical (gravimetric) surveys provided for under SIM.

Other projects

Throughout the activities, any projects identified as potentially relevant or interacting with the NEP will be duly assessed, and collaborative actions will be undertaken.

5.- ORGANIZATION OF THE PROGRAMME

The National Exploration Programme is structured into three phases, of which only the first is currently funded. Phases 2 and 3 are therefore to be considered only subject to the availability of new resources. It should be noted, however, that the general trend in other Member States is to adopt multiannual planning of activities.

- Phase 1 (July 2024 – May 2026), initiated following Decree-Law No. 84 with an initial version of the national mineral database and the launch of the new NEP after its submission to the European Commission. It is dedicated to completing the national mineral database and carrying out the planned investigations in the areas with the highest mineral potential. Funded with an allocation of €3.5 million.

Phase 1 general exploration is therefore carried out at two levels:
National level:

- acquisition of all available information with nationwide coverage.

Local level:

- Satellite and aerial imagery analysis: interpretation of remotely sensed data to identify geological structures, terrain anomalies, and surface alterations that may indicate the presence of mineralization.
- Detailed geological mapping: field-based geological surveys to define lithology, stratigraphy, geological structures, and any outcropping mineralization.
- Rock sampling: collection of rock samples from outcrops (surface and underground) and mining waste dumps for petrographic and geochemical analyses, including the review of historical samples and drill cores, where available.
- Detailed geochemical prospecting: systematic sampling of rocks, soils, and stream sediments.
- Targeted geophysical surveys: use of geophysical methods (e.g., induced polarization, electrical resistivity, reflection seismics) to investigate the subsurface.
- Muon radiography: in specific areas, the potential of this survey method will be tested to determine the extent of mineralization.

Since this is field-based research, the specific investigations may vary depending on the geological and mining context, logistical and territorial conditions, and available resources. Phase 1 survey areas also include all existing extractive waste storage facilities.

It should be emphasized that, since one of the fundamental pillars of the exploration programme is its sustainability, research activities will be carried out responsibly from the outset. Reference should be made in this regard to the Communication, Training, and Stakeholder Engagement Plans. Any social opposition that cannot be mitigated through the Communication Plan could result in modifications to the programme.

The subsequent multiannual development phases, including the identification of new areas and research topics, are to be redefined with the competent Ministries on the basis of available funding and any new national needs arising from the complexity and rapid variability of current international relations.

- Phase 2 (conditional, June 2026 – May 2028), with a two-year duration, will be dedicated to refining the results obtained in Phase 1 and expanding research into areas of potential mineral interest that were not investigated in Phase 1, also on the basis of specific remote sensing activities through satellite analysis and airborne/heli-borne sensor data acquisition programmes. It will also include the continuation of extractive waste characterization. Depending on the expected potential, the existing constraints in the area, and the funding available, a specific drilling campaign may be planned to achieve a better qualification/quantification of the mineralized body, whose type, depth, and dip will be defined on a case-by-case basis.

  The activities foreseen in this phase, where applicable, will be subject to environmental assessments pursuant to Title III of Part II of Legislative Decree No. 152/2006, and to the appropriate assessment pursuant to Article 5 of Presidential Decree No. 357/1997. It should be reiterated that even in the case of drilling campaigns, this would not constitute operational exploration in the strict sense, which traditionally involves the execution of dozens of drill holes per site.

- Phase 3 (conditional, June 2028 to May 2030), with a two-year duration, will be dedicated to the finalization and, where appropriate, further development of the activities carried out in Phases 1 and 2, as well as to the expansion of research into adjacent areas or other areas of interest, also taking into account potential revisions to the EU list of critical raw materials.

Funding for Phases 2 and 3 may also be determined on the basis of the results of Phase 1, which are expected to be favorable.

The three phases are structured into four specific Lines of Activity (LA):

- LA 1 – Coordination and management: operational in Phase 1 as well as in Phases 2 and 3.
- LA 2 – National map of critical raw materials – desk activities: dedicated to the implementation of the national mineral database and articulated into three Sub-Actions (SA).
- LA 3 – National map of critical raw materials – field surveys: dedicated to the implementation of the national mineral database through field investigation campaigns.

- LA 4 – Training, communication and human resource development – green skills: dedicated to staff training and dissemination of results.

LA 1 – Coordination and management

This represents the Technical-Scientific Committee (CTS), which is responsible for the overall coordination of the project. It is composed of representatives from ISPRA, CNR, universities, and members already appointed to the Mining Working Group of the Interministerial CRM Board. The CTS carries out the analysis and evaluation of existing information in order to identify the most significant areas with respect to CRMs and SRMs to be investigated in Phase 1. It also prepares the first list of Critical Raw Materials (CRMs) and Strategic Raw Materials (SRMs) present in Italy.

The CTS develops operational procedures describing how field activities (surveying, sampling, etc.) are to be carried out. These procedures may be flexible to adapt to field conditions, but the use of common measurement units and legends will be mandatory. Where applicable, standards established by law will be followed. To avoid inefficiencies, the CTS will consider possible interactions with other projects of common interest. Through specific collaboration or data-sharing agreements with project managers, acquired mineral data will be harmonized. The CTS will also manage collaborations with European Geological Surveys.

Another task of the CTS will be the creation of an Italian mining registry, including institutions, universities, companies, and professionals operating in the mining sector both in Italy and abroad.

Upon indication of the CTS, external parties may be commissioned to draft guidelines for the sustainable management of extractive activities, including the description of Best Available Techniques (BAT) for mineral exploration, extraction, processing, reprocessing of historical mining waste, mine rehabilitation, and site restoration. Guidelines will also be prepared for the development of an environmental monitoring plan covering the pre-operational, operational, and post-operational phases, extended over a timeframe deemed appropriate.

If required, the CTS also provides support in the development of the national mining strategy, based on circularity, sustainability, efficiency, and social justice.

In Phases 2 and 3, the CTS will identify areas of potential interest that are currently not suitable for the granting of exploration permits or mining concessions, due to regulatory, logistical, or social constraints. The CTS coordinator reports to the Technical Committee for Critical and Strategic Raw Materials on the progress of the work.

LA 2 – National map of critical raw materials – Desk activity

Sub-Action (SA) 2/1 – *Data collection*

Collection, review, harmonization, and digitization of all published and unpublished geological information concerning the national territory, aimed at implementing the national database of critical and strategic materials, as a complement to the GeMMA Database of ISPRA–Geological Survey of Italy, developed within NRRP GeoSciencesIR and NRRP RePowerEU. Identification of the areas with the highest mineral potential in relation to CRMs, SRMs, other minerals potentially eligible to be included in the EU lists (e.g. Zn, Mo), and minerals of possible strategic importance for the national economy (e.g. bentonites, zeolites).

SA 2/2 – *Map updating*

Definition of the legend and guidelines for the preparation of the National Map of Critical Raw Materials. Drafting of the legend of the Map also based on a prototype for Sardinia developed within NRRP GeoSciencesIR. Review of the criteria for the new CARG sheets (Geological Map of Italy), preparation of guidelines for surveyors, and analysis of the correspondence with other projects of potential mining interest. Development of the new version of the National Map of Critical and Strategic Raw Materials, accompanied by the database and the Explanatory Notes.

SA 2/3 – *Conceptual models*

Development of new conceptual models of national ore deposits in accordance with national and international scientific literature, also based on the models developed in the Sardinia Region within the NRRP GeoSciencesIR project.

LA 3 – National map of critical raw materials – Field surveys

First campaigns of non-invasive geological, geochemical, geophysical, aerial, and satellite surveys on 14 areas significantly indicated for the presence of CRMs/SRMs deposits, prioritized on the basis of the results obtained in LA2. Acquisition of field data, sampling of materials, and subsequent laboratory analyses and technological tests. Purchase of field equipment and laboratory instruments to reduce dependence on foreign laboratories. In Phases 2 and 3, the survey campaigns will be extended to about 30 areas/themes significantly indicated for the presence of CRMs/SRMs deposits, prioritized on the basis of the results of Phase 1 and any new national needs.

Chemical, physical, and mineralogical characterization of natural and anthropogenic deposits – Analyses

Given the large number of samples required for the characterization of natural and anthropogenic deposits, a network of certified laboratories will be used. Where possible, reference will be made to the SNPA network laboratories, which are routinely subjected to Ring Tests ensuring their reliability. The use of any additional laboratories will be subject to the approval of the CTS, which will in any case prepare guidelines on the matter.

Among the methodologies for the mineralogical, chemical, and physical characterization of the target areas, the following may be used: grain-size analysis, reflected and transmitted light microscopy, bulk rock major element content (XRF), mineral phase identification (XRD), bulk rock trace element content, and qualitative and quantitative chemical analysis of constituent minerals.

LA 4 – Training, communication, and reskilling of human resources – Green skills

Development of training programs for public administration officials and professional associations on the sustainable management of georesources throughout their entire life cycle, also by using and further developing the tools and outputs available on the GeoSciencesIR research infrastructure platform.

Studies aimed at disseminating information to the general public. Design of actions to increase governmental interest and to facilitate the relaunch of university courses, technical institutes, and the training of specialized workforce. Support to specialist training events (master's programs). Organization of outreach, technical, and educational events (summer schools).

Promotion of a network of Italian and foreign training institutions to both restart academic training pathways and foster lifelong learning through master's programs and training courses for professionals and local authority technicians. Dissemination of clear and transparent information on the importance of mineral resources for economic and social development, on their environmental impact, and on mitigation systems, including comparisons with environmental and working conditions in extra-European mines.

Phase	LA		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
1	LA1-Coordination and management													
1	**SA1.1**	General project coordination												
1	**SA1.2**	Establishment of the Technical-Scientific Committee												
1	**SA1.3**	Analysis and evaluation of previous information in order to identify the most significant areas related to CRMs and SRMs to be investigated in Phase 1.												
1	**SA1.4**	Development of the first list of Critical Raw Materials (CRMs) and Strategic Raw Materials (SRMs) present in Italy												
1	**SA1.5**	Drafting of operating procedures												
1	LA 2.1- National map of critical and strategic raw materials – Data collection													
1	**SA2.1.1**	Further collection, updating, review, harmonization and digitization of all geological information, both published and unpublished, concerning the national territory for the implementation of the national database of critical and strategic materials, completing the GeMMA Database of ISPRA–Geological Survey of Italy, developed with NRRP GeoSciences IR and NRRP RePower EU.												
1	**SA2.1.2**	Identification of the most promising areas from a mining perspective, in relation to CRMs, SRMs, other potential minerals that could be included in the EU lists (e.g., Zn, Mo), and minerals of possible strategic importance for the national economy (e.g., bentonites, zeolites).												
1	LA 2.2-National map of critical and strategic raw materials – Map update													
	SA2.2.1	Definition of the legend and guidelines for the preparation of the National Map of Critical Raw Materials. Drafting of the Map Legend also based on a prototype for Sardinia developed within the NRRP GeoSciences-IR. Review of the criteria of the new CARG sheets (Geological Map of Italy), preparation of guidelines for surveyors. Analysis of the correspondence with other projects of potential mining interest.												
	SA2.2.2	Preparation of the new version of the National Map of Critical and Strategic Raw Materials, accompanied by the database and the Explanatory Notes.												
1	LA 2.3 - National map of critical raw materials – Conceptual models	Development of conceptual models of deposits in accordance with national and international scientific literature, also based on the models developed in the Sardinia Region within the framework of the NRRP GeoSciences-IR.												
1	LA 3 - National map of critical and strategic raw materials and associated database. Field survey campaigns	First **non-invasive** geological, geochemical, geophysical, aerial and satellite surveys on about 15 areas/topics significantly indicated for the presence of CRMs/SRMs deposits, prioritized on the basis of what was developed by LA2. Acquisition of field data, material sampling and subsequent laboratory analyses and technological tests. Purchase of field equipment and laboratory instruments useful to reduce dependence on foreign laboratories.												
1	LA 4-Training, communication and human resource requalification - Green skills													
1	**SA4.1**	Development of training programs, dedicated to public administration officials and professional associations, on the sustainable management of geo-resources throughout their entire life cycle.												
1	**SA4.2**	Studies for the dissemination of information to the general public.												
1	**SA4.3**	Development of actions to increase interest at the governmental level and to facilitate the resumption of university courses, technical institutes, and the training of specialized workforce.												

Figure 11 - Timeline of Phase 1 Activities

6 – NATIONAL EXPLORATION PROGRAMME – SURVEY AREAS/THEMES

In accordance with Regulation (EU) 1252/2024, the National Exploration Programme (NEP) is based on the analysis of two potential sources of Critical and Strategic Raw Materials (CRM/SRM):

1. Primary deposits
2. Anthropogenic deposits (extractive waste) derived from the exploitation of primary deposits.

In many cases, research will also involve the re-evaluation of historical deposits using modern investigative methods. Although the two dimensions are closely interconnected, they will be managed under separate funding streams, with ISPRA ensuring rigorous allocation of resources.

6.1 Potential Primary Deposits

Based on the priority selection criteria described in Chapter 2, 14 survey areas/themes have been identified. These are outlined below according to geographical distribution and are shown in Figure.

NORTH-EASTERN ITALY (LOMBARDY-TRENTINO ALTO ADIGE)

1) Fluorspar (± baryte ± rare earth) Southern, Central, and Eastern Alps

Fluorspar–baryte district of the Southern Alps (Lombardy–Trentino Alto Adige). Mineralogical, textural, and geochemical studies; estimation of available resources; verification of rare earth element (REE) content; mapping and characterization of extractive waste.

NORTH-WESTERN ITALY (PIEDMONT-LIGURIA-LOMBARDY) + CALABRIA

2) Platinum Group Metals (PGM) – Eastern Piedmont

Focus on the Ivrea–Verbano zone, particularly the Finero complex, where significant chromite mineralization with PGMs (Ir, Ru, Rh, Pt, Pd) is documented. This area is currently not covered by active exploration permits, offering potential for new investigations.

3) Copper and manganese mining districts of Eastern Liguria

The project targets two historic mining districts in Eastern Liguria (copper and manganese), partly overlapping with ophiolitic complexes. Activities include the acquisition and reprocessing of airborne electromagnetic (AEM) geophysical data, census and mapping of waste deposits from major mines end a detailed analysis of the spatial distribution of copper and associated elements of potential interest.

4) Graphite project: Calabria, Piedmont, Liguria

Assessment of the most significant graphite deposits in these three regions. Planned activities include a detailed mapping of graphite-bearing levels and quartz successions, geochemical analyses of host rocks, sampling and petrographic/stratigraphic/mineral-chemical analyses, definition of graphite crystallinity and purity and mapping and characterization of extractive waste.

CENTRAL ITALY AND NEIGHBOURING REGIONS

5) Unconventional lithium resources in Italy (Tuscany, Lazio, Campania, Emilia Romagna, Marche, Piedmont, Lombardy, Trentino-Alto Adige)

Development a conceptual model for lithium resources in both fluids (geothermal, thermal) and rocks (sediments, metasediments, volcanics, granites) within the Alps–Apenninic orogenic system.
Geochemical modelling of the lithium (and boron) cycle from the post-Variscan phase to current geothermal systems; identification of areas with favourable potential for fluid and rock-based lithium exploitation.

6) Maremma Antimony District (Tuscany)

Reassessment of residual antimony-bearing epithermal deposits in the historic Maremma district (Tafone, Montauto, Macchia Casella). 3D geological modelling of ore bodies; evaluation of distal low-Sb zones; development of a genetic model linking these deposits with the Amiata geothermal system; evaluation of gold potential; mapping and characterization of extractive waste

7) Magnesite deposits in central Tuscany

Study of residual magnesite deposits hosted in serpentinites (Castiglioncello, Malentrata–Monterufoli Querceto). 3D modelling of ore bodies; evaluation of distal low-Mg portions; assessment of lateral and deep extensions; exploration of possible undiscovered bodies; development of a conceptual metallogenic model; mapping and characterization of extractive waste.

8) Fluorspar (REE ± baryte) mineralization from the Roman Comagmatic Province (PCR) (Lazio)

Targeting the potassic alkaline volcanic systems of the Latera, Bracciano, and Sacrofano districts.
Objective: re-evaluate historical knowledge on low-grade REE-bearing fluorspar deposits using modern methods; mapping and characterization of extractive waste.

9) Industrial minerals and critical elements in quaternary volcanic rocks in the Campania Region.

Assessment of the extractive potential of industrial minerals (feldspar as CRM; zeolites as strategic minerals) and their associated contents of critical elements (e.g., REEs, lithium). Activities include mapping and characterization of extractive waste.

SARDINIA

10) Feldspar, REE and industrial minerals in the rocks of the acid magmatism of Sardinia

Research on CRM and industrial minerals in lithotypes associated with acid magmatism (e.g., Hercynian greisen in Sulcis, Gallura, Monte Linas; Oligo-Miocene volcanics; Ordovician porphyroids). Includes mapping and characterization of extractive waste.

11) Mixed sulphide mineralization (Cu-Pb-Zn ± Ag), W and REE and Ti of Funtana Raminosa district (central Sardinia)

Deposits: more than 55 sulphide ore bodies identified since 1975, often enriched in silver and gold, with ~500,000 tonnes of ore partially exploited in the 1980s. Confirmed presence of tungsten, titanium, and REEs. Use of VNIR drone surveys for REE exploration; mapping and characterization of extractive waste.

12) Hydrothermal mineralization at Fluorspar-Baryte and REE, Centre-South Sardinia.

Most fluorspar and baryte deposits in Sardinia (except Silius) were abandoned in the 1980s–1990s after limited surface exploitation. Objective: reassess these underexplored deposits using current methods and prices, focusing also on REE potential. Study areas: Bruncu Molentinu, Castel Medusa, Santa Lucia. Includes mapping and characterization of extractive waste.

13) Tungsten granite-related mineralization (tin, arsenic, bismuth, molybdenum), South-Western Sardinia.

Targeting tungsten mineralization associated with granites of Monte Linas and Monte Tamara massifs, known for high fluorine enrichment and specialized tungsten mineralization (up to 12% W).
Mineralization types: skarn, greisen, veins, hydrothermal systems. Study also covers critical elements of current strategic interest (e.g., Mo under new US policies). Activities: geochemical studies, muon tomography in tunnels, mapping and characterization of extractive waste.

14) Copper, molybdenum and gold mineralization from the 'Soglia di Siliqua' and the Cixerri Valley, South-West Sardinia.

Reassessment of known Cu–Mo–Au mineralization, with potential for additional shallow, high-grade bodies and possible sub-intrusive stocks beneath pyroclastic and sedimentary cover in the Cixerri Valley. Activities: airborne electromagnetic (AEM) surveys for 3D modelling; mapping and characterization of extractive waste.

6.2 Extractive Waste Deposits

The URBES NRRP project aims to identify and map potential sources of secondary critical raw materials, with a primary focus on extractive waste. In Italy, several thousand extractive waste deposits exist, with a conservative volumetric estimate exceeding 150 million m^3. The complete characterization of all deposits is incompatible with the strict URBES project deadlines, which require finalisation of the IT platform by December 2025 and completion of data entry by June 2026. The IT platform implementation anticipates the deadlines established in Article 27(6) of Regulation (EU) No 1252/2024, which required database construction by November 2026 and full implementation by May 2027. Conversely, the delivery of the first representative geochemical sampling dataset by May 2026 is consistent with regulatory requirements.

The dedicated platform will subsequently be established, incorporating information derived from literature and preliminary field characterization campaigns. It is expected that all storage facilities, including waste piles and settling ponds, will be mapped. However, detailed characterization will initially target only the most representative sites. Site prioritisation for characterization will be guided by evidence from published and grey literature, including regional reports updating ISPRA's extractive waste inventory. Close cooperation is also envisaged with operating companies, which under Regulation 1252 are required to characterise their extractive waste for critical raw material content.

Priority abandoned deposits for investigation have been selected not only for their potential CRM content but also for their relevance to mitigating or remediating environmental impacts associated with metal release into soil, water and ecosystems. As established by DL 84/2024, for former mining sites already under remediation, mapping and characterization will be aligned with ongoing remediation activities, to ensure sharing of both existing and newly acquired information among the competent authorities. In all areas included in general mining research, abandoned storage facilities will also be systematically assessed and mapped.

In addition, in the first analysis, other priority sites are:

NORTH-EASTERN ITALY

1) *Raibl (UD)*

   One of Europe's most important Pb-Zn mines, exploited since Roman times. It hosts more than 4 million m^3 of extractive waste, with relevant zinc content (1.6 %) in waste piles (Raibl I, II, III) and in the Monte Re tailings pond. Gallium and germanium are confirmed. Strong regional interest in recovery (FVG Region).

2) *Monte Avanza (UD)*

Waste like Raibl, with multiple piles along the slopes. Manganese waste also occurs at the Monte Cocco site, although in smaller volumes.

3) *Salafossa (BL)*

Several piles and settling ponds. The main ore mineral is sphalerite, with subordinate galena, pyrite and marcasite. Sphalerite contains Ge, As, Ni, Tl and Cl; galena is enriched in arsenic and antimony.

NORTH-WESTERN ITALY

4) *Gorno (BG)*

District between Val Seriana, Val di Riso and Val Brembana, with Zn-Pb-Ag (plus fluorspar and baryte) stratabound-type deposits. Main mineralization: sphalerite, galena, pyrite, marcasite, chalcopyrite and silver sulphide. Detailed mapping of waste rock and tailings is planned. Estimated content: 25,000 t Zn and 4.5 t Ga.

5) *Pestarena (VCO)*

Several ponds and ponds containing extractive waste and auriferous ore treatment before 1950; safe presence of As, Cn, Hg, Pb, Tl.

6) *Libiola and Gambatesa (GE)*

Historic Mn oxide (braunite) deposits, largely abandoned by 1960 except for a few mines closed between 1990 and 2011. Remaining resources and landfill bodies (e.g. Cassagna, Stratale, M. Zenone) require evaluation. Other potential CRMs: V, As, Co, REE. Copper sulphide deposits (chalcopyrite) were abandoned by 1962; about 30 mining sites are located in the Petronio, Gromolo and Graveglia valleys. Large tailings remain at Libiola. Active acid mine drainage reveals recoverable Cu, Cr, Ni, Ag, Fe and REE. Detailed mapping of landfill bodies in Val Graveglia (GE) and Cerchiari (SP) is foreseen.

7) *Valmalenco and Val d'Ossola (SO, VCO)*

Potential recovery of Ni from awaruite (Fe-Ni alloy) in serpentine processing waste (SO). Awaruite, highly magnetic, is ideal for Ni extraction. Assessment of waste volumes, distribution and particle size is planned. In Ossola gneiss, recovery of REE (monazite, allanite) is possible, with potential Nb and Ta.

CENTRAL ITALY

8) *Metalliferous Hills (LI, PI, SI, GR)*

Multiple extractive waste deposits at former mining sites, some already subject to remediation. To be evaluated together with Ministry of Environment and Energy Security (MASE) and the Regions to coordinate measures in areas declared contaminated or under remediation.

SOUTHERN ITALY AND ISLANDS

9) Sicily

Numerous waste deposits linked to historic sulphur extraction. Discussions are ongoing with the Region, the University and the School of Mining in Caltanissetta. to define possible priority characterization measures for the multiple storage facilities of extractive waste. Potential CRMs include strontium (celestine) and magnesium, alongside other materials of interest to chemical, pharmaceutical and agri-food industries (mixed alkaline salts).

10) Montevecchio Ponente e Levante, Ingurtosu-Gennamari (SU)

Hundreds of extractive waste facilities in Arburese, with waste piles, hydro-gravimetric residues and flotation sludges. Pb-Zn-Ag low-temperature hydrothermal vein mineralization may yield Pb, Zn and REE ± Ba. In a first phase, characterization will focus on the most significant deposits.

11) Assemini (CA)

Flotation sludges from processing ores of the Silius mine. Mineralization is Pb-Zn-Ag with F-Ba. Potential recovery of Pb, Zn, F, Ba and REE.

12) Fluminimaggiore (SU)

Multiple deposits with hydro-gravimetric residues, flotation sludges and waste piles. Characterized by F-Ba hydrothermal veins and Pb-Zn-Fe skarn mineralization. Potential recovery of Pb, Zn, F, Ba, As and REE.

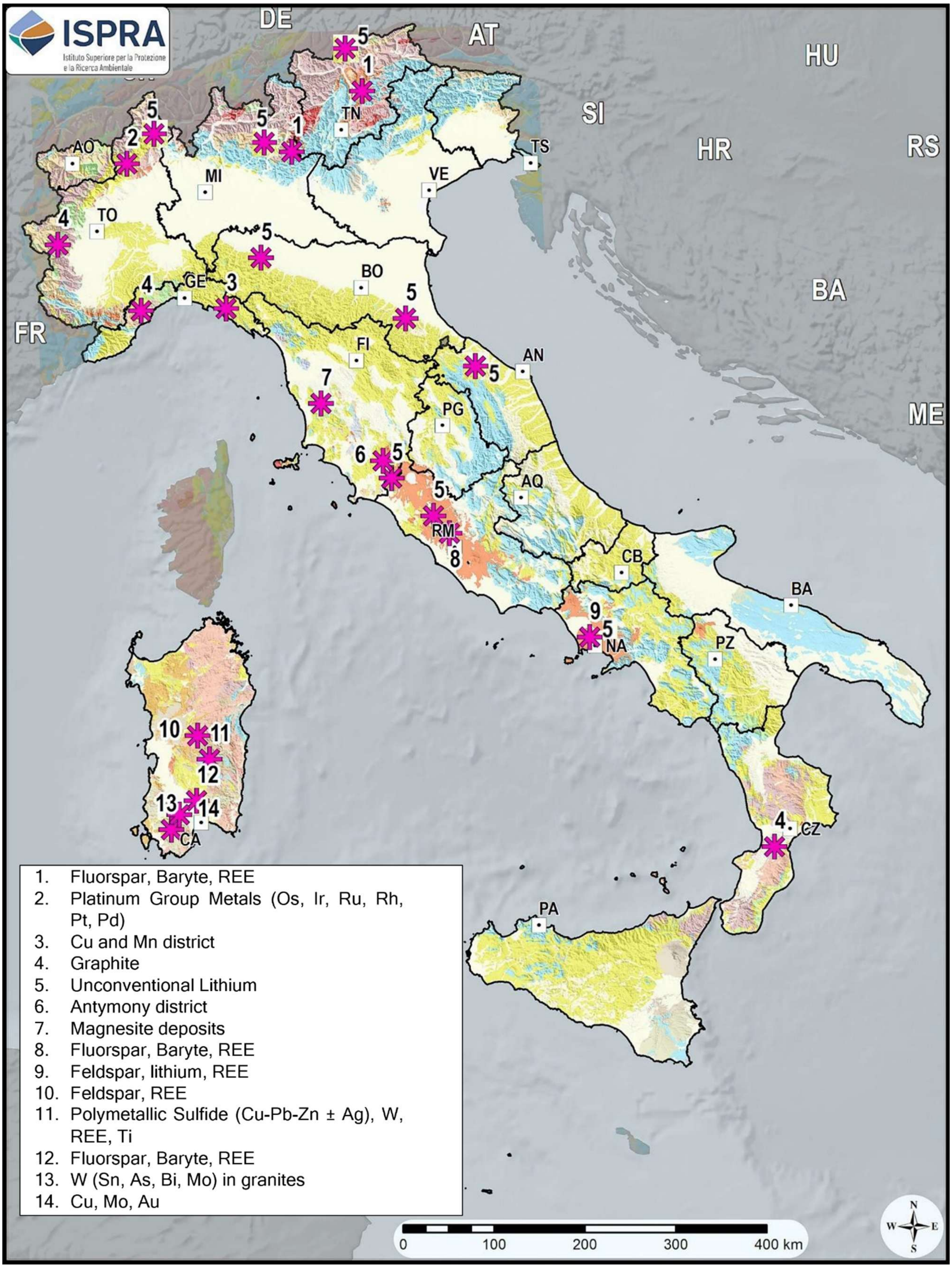

Figure 12 – Localisation of study areas/themes

PHASE 1 SURVEY AREAS

1) FLUORSPAR (± BARYTE ± REE) MINERALIZATION OF THE SOUTHERN CENTRAL AND EASTERN ALPS

State of the art:

Main raw materials: fluorspar;

Critical Raw Materials: fluorspar, baryte, Rare Earth Elements;

Strategic Raw Materials: Rare Earth Elements

Other possible Raw Materials: Pb, Zn (Cu)

Ore geology: The Southern Alps are well known for widespread fluorspar mineralization, many of which have been mined in recent decades. The most significant occurrences are concentrated between Trentino Alto Adige and Eastern Lombardy. Except for minor stratabound deposits, which extend further north into the Carnic Alps, the mineralization consists of hydrothermal vein-type bodies where fluorspar is often associated with variable amounts of polymetallic sulphides (Pb, Zn, Cu, Ag) and baryte. Regional studies carried out in the 1960s and 1970s (e.g. Bakos et al., 1972) suggest a genetic link between these deposits and two regional magmatic cycles: the post-Variscan Permian and the Triassic.

Mines: The fluorspar vein deposits of the Southern Alps were mined extensively from the 1980s until the early 1990s. The most important operations were located in the provinces of Trento and Bolzano (Vallarsa di Laives and Corvara mines) and in the provinces of Brescia and Bergamo (Torgola, Presolana, Paglio Pignolino mines), with additional deposits in Varese (Brusimpiano, Valvassera–Valganna, Porto Ceresio). Cumulative production until the early 1970s was estimated at 4.25 Mt of fluorspar (RIMIN, 1987).

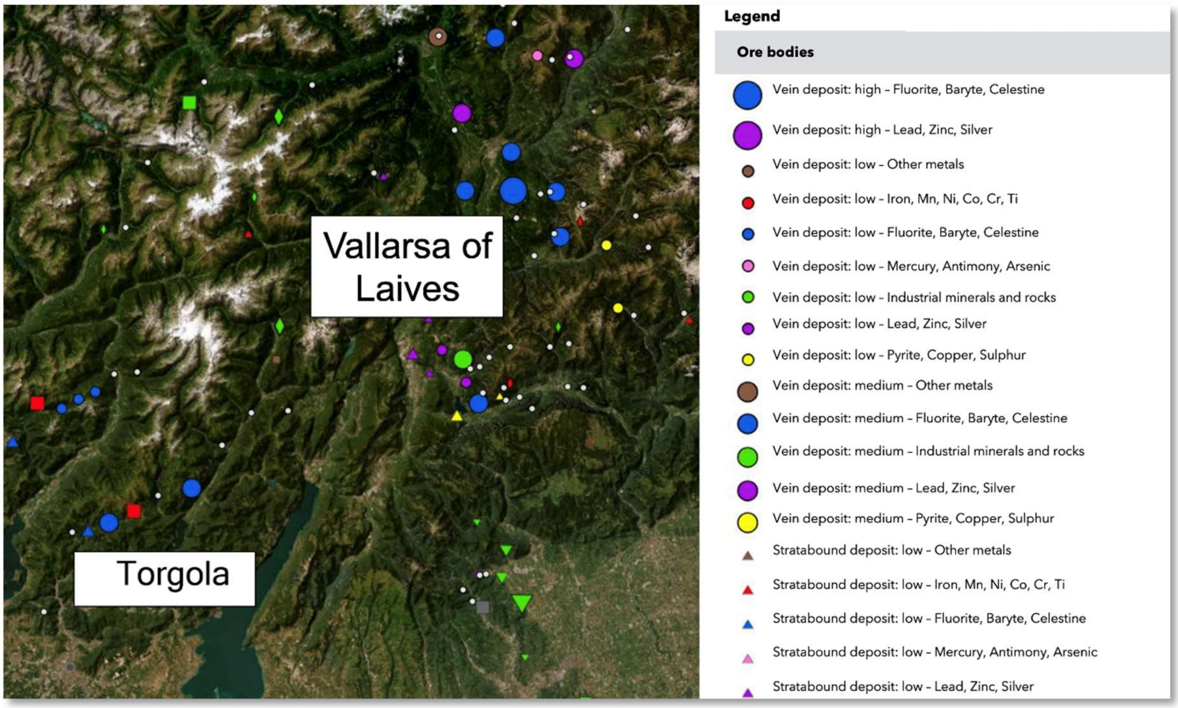

Figure 13 - Location of the southern Alps survey sites on the metallogenic map

Potential of the area

The recommendations of the RIMIN programme's final report (1987) were never implemented, so the extent of possible fluorspar reserves in the area are uncertain. Available estimates suggest residual resources of only a few hundred thousand tonnes in some major deposits. Although these volumes may appear sub-economic today, the potential prosecution of mineralized bodies into adjacent areas, the existence of deeper extensions in unexplored zones, and the possible enrichment in Critical Raw Materials (CRMs) such as Rare Earth Elements (REEs) justify renewed investigation. Previous studies focused mainly on fluorspar, baryte and base metals (Pb, Zn, Cu), with no systematic exploration for REEs. The recent recognition of significant REE concentrations in a similar post-Variscan fluorspar vein deposit at Silius (Sardinia; Mondillo et al., 2016), now being prepared for re-opening, highlights the potential of Alpine fluorspar systems. Considering the region's long and intense multiphase hydrothermal history, systematic re-examination may reveal previously overlooked REE-bearing phases. Positive results could justify a broader strategic and tactical exploration campaign.

Activities

1) REVIEW OF PREVIOUS STUDIES

Collection and critical assessment of previous work, mostly represented by mining technical reports with limited scientific studies, often outdated. These materials will be re-analyzed and reinterpreted using modern deposit models, producing a synthesis aligned with the objectives of the National Exploration Programme.

2) FIELD ACTIVITY

Targeted soil and waste sampling will be carried out to represent the mineralized systems. The aim is to construct a modern conceptual model for fluorspar deposits of the Southern Alps, encompassing both the main districts (Torgola, Presolana, Vallarsa di Laives, Corvara) and smaller fields (Upper Valsugana, Varese district), thereby covering both Permian and Triassic types. Guidance for sample selection will be based on literature review. As mines are inactive, samples will be collected primarily from mine waste and, where accessible, from safe underground workings. Historical specimens from the University of Padua (Department of Geosciences) and the University of Milan (Department of Earth Sciences) will supplement field material. At least 10 representative samples per deposit are expected in this first phase. LABORATORY ANALYSIS AND DATA PROCESSING

Analyses will confirm the presence, concentration and distribution of CRMs, with particular focus on REEs. Planned methodologies include:

- petrographic studies using optical and electron microscopy;
- bulk geochemical analysis (XRF, XRD, ICP-MS);
- microanalyses and elemental mapping of major/minor elements (EDS-WDS) and trace elements (LA-ICP-MS);
- data integration to evaluate REE distribution relative to deposit type, host lithology and mineral paragenesis.

The University of Padua and University of Milan are equipped with laboratories for most of analyses. A new innovative BEX imaging detector will complement Padua’s existing electron microscope, enabling accurate detection and quantification of minor REE-bearing mineral phases. LA-ICP-MS and other specialized methods will be outsourced to partner institutions or accredited laboratories.

3) DATA MANAGEMENT AND RETURN OF RESULTS

All outputs will follow the standards defined by the project coordination (Chapter 4). Progress will be documented in quarterly reports. At project completion, a comprehensive report will summarize results, assess deposit potential, and outline methodologies for subsequent exploration phases. Data will be transmitted to ISPRA according to CTS standards.

Possible Extension in Phases 2–3

Depending on the results, further exploration may include:

1. targeted drilling and advanced surveys to refine deposit geometry;
2. expanded sampling and analytical campaigns to characterise paragenesis, textures, structures and genesis;

3. resource and reserve evaluation based on recognised international codes (e.g. UNFC, JORC).

Expected Impacts

Phase 1

Scientific, Technical and Social:

- Improved understanding of Alpine fluorspar/baryte metallogenesis and associated REEs.
- Enhanced use of regional and archival data.
- Revision of conceptual models, opening possibilities in previously neglected areas.
- Training of specialists and researchers, strengthening national expertise in mineral exploration.
- Revitalisation of the Follador Mining School (Agordo), enhancing local professional skills.
- Engagement with communities through transparent dissemination of sustainable mining practices, countering negative legacies of past operations (e.g. Val di Fiemme).

Phases 2–3

Scientific, Economic and Environmental:

- Assessment of lateral and deep prosecutions of the deposits through advanced surveys.
- Development of innovative exploration technologies, including AI-based predictive models.
- Cross-border collaborations with Austrian and Swiss universities and Geological Services.
- Attraction of domestic and foreign investments based on exploration outcomes.
- Regional economic diversification, potentially revitalising related industries.
- Growth of local enterprises supporting exploration services.
- Creation of new professional opportunities.
- Dissemination of methods to minimize the environmental impact of exploration activities.

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2) *PLATINUM GROUP METALS (OS, IR, RU, RH, PT, PD) IN EASTERN PIEDMONT*

Platinum Group Metals or Elements (PGMs or PGEs, part of the noble metals group) are listed as critical in all EU Critical Raw Materials (CRM) list. In the most recent one, they are classified as both *critical* and *strategic*, ranking third overall in terms of economic importance. The present project focuses on an area of Eastern Piedmont characterized by PGM enrichment within a favourable metallogenic context, where these elements occur in association with chromium – itself ranked by the European Commission as a raw material of comparable economic importance.

State of art

Main Raw Materials: PGM (osmium, ruthenium, iridium, rhodium, platinum, palladium) + Cr + (Ni-Cu-Co);

Critical Raw Materials: PGM, Ni, Cu, Co, Bi.

Strategic Raw Materials: PGM, Ni, Cu, Co, Bi.

Other raw materials: olivine.

Location: Eastern Piedmont: Val Vigezzo, Val Cannobina, Val d'Ossola, Val Strona, Omegna, Val Sesia and side valleys.

Geology: The area of primary interest is the Finero mafic–ultramafic complex, a mantle-derived body composed of low-altered peridotites that were hydrated through metasomatic processes. This complex is a part of the Ivrea–Verbano Zone, which represents one of the most complete cross-sections of continental crust in Europe, hosting numerous magmatic bodies and dykes, many of which are mineralized (Figure 14).

Ore geology:

At Finero, the core unit is dominated by fertile peridotites (Figure 14), within which numerous bodies of massive chromitite occur in dunite pockets. The richest chromitite concentrations are found in the Alpe Polunia area, located in the central part of the complex. Chromitites exhibit significant PGM anomalies, often in the range of several hundred ppb according to literature, with a predominance of Os, Ir, Ru and Rh. Ni–Fe–Cu sulphide mineralization with PGEs also occur within the main plutonic body and deeper crustal sections. The most enriched occurrences are linked to hydrated ultramafic intrusions such as pipes, sills and dykes, which are distributed across Valle Strona di Omegna and the upper and middle Val Sesia (including lateral valleys) (Figure 15). These intrusions are typically composed of coarse-grained pyroxenites and peridotites, rich in brown amphiboles (fluoro-pargasite type), phlogopite, ilmenite, apatite (Cl-F), and carbonates. They frequently show disequilibrium textures indicative of interaction with volatile-rich metasomatic melts (H_2O, CO_2, etc.).

The enrichment of Ni–Fe–Cu sulphides range from centimetric nodules to impregnations and disseminations, occasionally forming massive aggregates, often accompanied by metasomatic mineral phases. PGMs, particularly Pt and Pd, are associated with Bi–Te phases finely disseminated within the sulphides.

Mines

The only recorded mining activity in the Finero area concerns the historical exploitation of the Finero olivine quarry. During the 1940s, chromium exploration was undertaken within the fertile peridotites, delineating an area for a possible mining concession that was never developed. To date, no systematic prospecting has ever been conducted for PGMs. This omission is particularly significant after the recent, substantial increases in the prices of osmium and rhodium, currently among the most valuable metals, with rhodium priced at nearly ten times the value of gold. The Ni–Cu sulphide–PGE mineralized bodies in the main plutonic mass and associated crustal intrusions were the subject of numerous mining operations, most of them underground, which ceased before the end of the last century. More recently (2015), these intrusions were targeted by an Australian mining company (Nyota Minerals Ltd.), which conducted airborne geophysical surveys and prospecting. The results highlighted extensive magnetic anomalies across several sites. In addition, recent scientific studies have further advanced understanding of magmatic processes, the metallogenesis of critical metals, and the controlling factors in ore deposition.

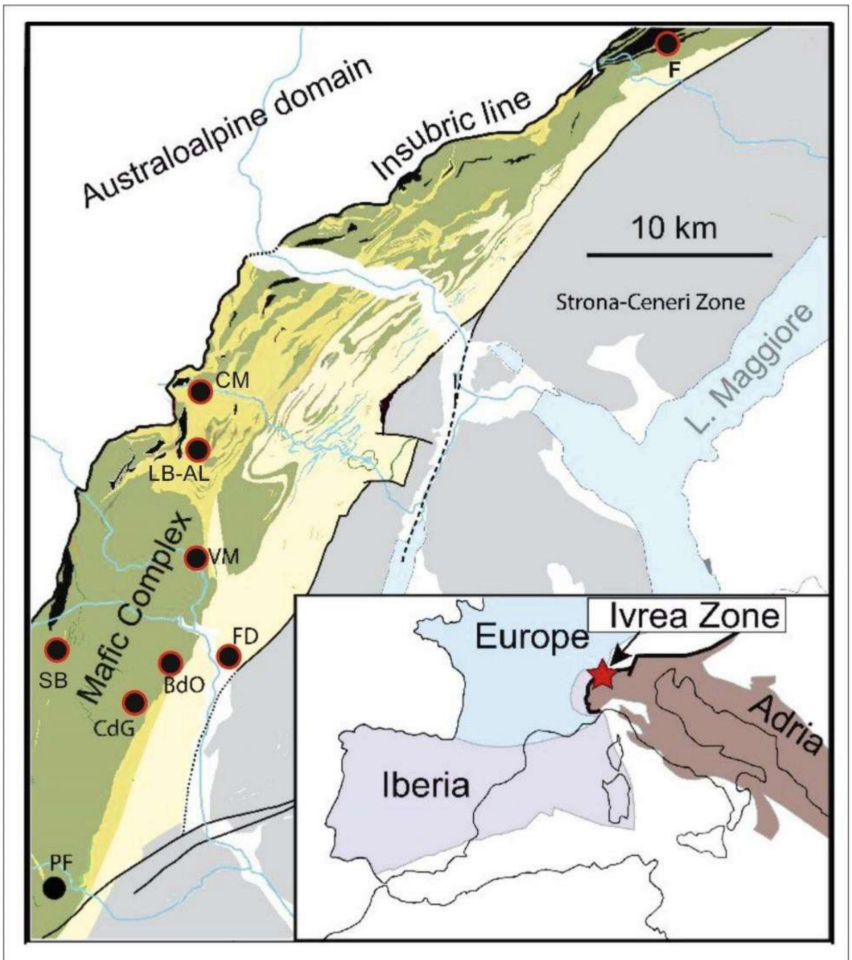

Figure 14 – Simplified geological map of the Ivrea-Verbano area, with the location of the Finero complex and the ultramafical intrusions enriched in Ni-Fe-Cu-PGE sulphides. Abbreviations:

F: Finero complex; Cm, Campello Monti; LB-AG, La Balma-Monte Capio/Alpe Laghetto, VM, Valmaggia; SB, Sella Bassa, FD, Doccio FEJ; BdO: Bec d'Ovaga; CdG, Gavala Castle; PF, Piancone la Frera. Colours - dark green: mafic rocks (Ivrea-Verbano mafic complex and amphibolites basement); black: ultramafic rocks; dark yellow: Sudalpin Basin (deep crust) in granulitic facies; pale yellow: Sudalpine basement (deep crust) amphibolite facies; blue levels: marble; pale grey: Sudalpine Basement in green shist facies (Strona Ceneri area).

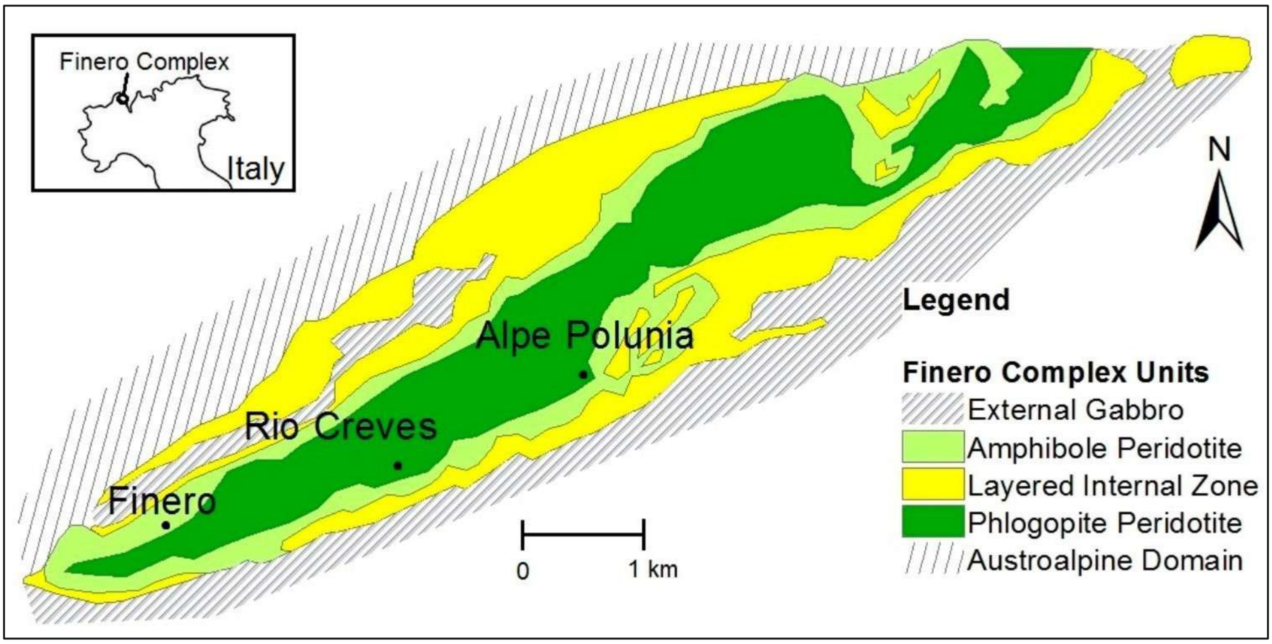

Figure 15 - Simplified geological map of the Finero complex, Ivrea Verbano. The nucleus (in dark green), consisting of phlogopite peridotite, has many chromititic bodies enriched in PGMs.

Project

The project focuses primarily on the Finero area, which is of particular interest for the potential extraction of both PGMs and chromium, with olivine as a possible by-product. As this is a greenfield setting, no systematic exploration campaign has ever been undertaken. The initial objective is therefore to acquire baseline information to assess potential mining interest. Preliminary bibliographic studies will enable data collection and screening, in order to select the most promising sites within the Ivrea–Verbano Zone for subsequent field and laboratory investigations. The work phases are outlined below in chronological order.

1) EVALUATION AND SUMMARY OF PREVIOUS STUDIES

A substantial number of publications and technical reports of varying ages exists for this area. These will be collected, critically assessed, revised and reinterpreted considering the modern ore deposit models and the most recent scientific literature. The synthesis will focus on aligning past information with the objectives of the National Exploration Programme.

2) FIELD ACTIVITY

New field surveys will be carried out in the selected areas, with the aim of detecting ore bodies of potential economic interest and collect representative samples for laboratory testing.

3) LABORATORY ANALYSES

A laboratory investigation campaign will verify the presence, concentration and distribution of PGMs and associated economically relevant metals. The work will be carried out using both university laboratories and specialized external facilities. Planned methodologies include:

- study of hand specimens and petrographic analysis under optical microscopy;
- whole-rock geochemical analyses (e.g. XRF, XRD), complemented by portable field instruments where appropriate;
- targeted assays (e.g. fire assay–INAA) to quantify PGM concentrations.

4) DATA MANAGEMENT AND RETURN OF RESULTS

All outputs will follow the standards defined by project coordination and by the criteria established in Chapter 4. Progress will be documented in quarterly reports. At the end of the investigation, a comprehensive report will provide an overview of the results obtained, the potential of the investigated areas, and recommendations for subsequent exploration phases. Outreach of scientific results will also be ensured within the overall framework of the National Exploration Programme.

Possible extension in Phase 2 and 3

Depending on the outcomes of the initial survey, further exploration may include:

1. Extending investigations to other areas of the same geological context showing significant PGM potential;
2. Prosecution and further investigation of the areas through new drillings;
3. Expanding the analytical programme to obtain detailed data on deposit characteristics (textures, paragenesis, structures, genesis), essential for conceptual modelling and resource evaluation;
4. Assessment of resources and reserves using international standard procedures.

Expected impacts

Phase 1:

Science, mining and technology:

- Improved understanding of metallogenic processes in Ni-Cu sulphide-PGE orebodies.

- Expansion of knowledge through systematic use of regional and local archives.
- Revision of conceptual models, potentially extending research into areas previously disregarded.
- Training of specialized researchers and professionals, reinforcing national expertise in mineral exploration.
- Revitalisation of the Follador Vocational Mining School in Agordo, with enhanced local technical and professional capacity.
- Public engagement and dissemination of accurate information on sustainable mining practices.

Social impact:

- Revitalisation of the Follador Vocational Mining School in Agordo, with an increase in local technical and professional skills
- Dialogue with the public and dissemination of scientifically correct information on the sustainability criteria for extractive activities

Phase 2-3

Science, mining and technology:

- Assessment of the possible lateral and deep extention of deposits, based on planned surveys and insights.
- Development of innovative technologies for the exploration and extensive application of
  artificial intelligence
- Scientific collaborations between national and cross-border universities/EPRs with researchers from the Geological Service and Swiss universities.

Economic and social:

- Increased investment in the mining system as a result of the provision of basic elements on deposits in the study area
- Attracting foreign investment stimulated by exploration results
- Regional economic diversification with possible restart of further sectors of activity
- Increasing interest in mining with more visitors to mining parks/museums
- Stimulating the creation and growth of local businesses supplying goods and services for mineral exploration
- Training of new local professionals, graduates, and associations of professionals specializing in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and spreading of criteria and methods to minimize environmental impacts caused by mineral exploration activities

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3) COPPER AND MANGANESE MINING DISTRICTS OF EASTERN LIGURIA

The project aims to assess the mining potential of selected sites through the application of multiple exploration methodologies, adopting a modular approach. The two districts share a common geological framework, consisting of the extensive ophiolitic complexes of Eastern Liguria, whose emplacement is related to different phases of the Apennine orogeny. Despite this shared geological setting, the metallogenetic processes, mineralization styles, and associated critical raw materials (CRMs) and other metals are distinct and district-specific.

Both copper and manganese districts experienced significant mining activity, with dozens of mines exploited mainly during the 20th century. In the case of manganese, however, limited operations continued until the early 2000s. The geographical proximity, and in some cases the partial overlap of the two districts, allows for the optimisation of prospecting procedures and the efficient use of airborne geophysical exploration techniques, thereby maximising results in terms of both costs and time.

State of the art:

COPPER DISTRICT

Main Raw Materials: copper and manganese

Critical Raw Materials: Cu

Strategic Raw Materials: Cu

Other raw materials: Zn, Ag, further CRM in addition to copper to be evaluated

Location: Eastern Liguria: Val Gromolo, Val Petronio,

Geology: The copper sulphide deposits of Eastern Liguria are concentrated within the ophiolitic sequence of the Val di Vara Supergroup, Bracco–Val Graveglia Unit. They correspond to volcanogenic massive sulphide (VMS) type mineralization, genetically linked to the oceanic stages of the Ligurian–Piedmont Ocean. (Figure 16)

Ore geology: The ore deposits comprise both massive and stockwork-type mineralization, with dominant chalcopyrite and pyrite, often accompanied by sphalerite. These minerals occur in various stratigraphic levels within the basaltic volcanic sequences, reflecting the complexity of the hydrothermal systems controlling ore deposition.

Mines: Approximately thirty disused mines are concentrated in a relatively restricted area encompassing the Graveglia, Gromolo and Petronio valleys, in the hinterland between Chiavari and Sestri Levante (Province of Genoa) (Marescotti et al., 2018). Among these, the Libiola and Monte Loreto mines stand out as the most significant from historical, archaeological, and productive perspectives.

The Libiola mine, active from 1864 to 1962, produced over one million tonnes of sulphide ore (pyrite, chalcopyrite ± sphalerite), with copper grades ranging between 7 and 14 wt%. The five main waste-rock deposits associated with the mine still host significant concentrations of Cu, as well as other metals such as Zn, Cr, Ni, and Ag.

MANGANESE DISTRICT

Main Raw Materials: manganese;

Critical Raw Materials: Mn

Strategic Raw Materials: Mn

Other raw materials: to assess the presence and concentrations of other CRMs

Location: Eastern Liguria: Val Graveglia, Val di Vara

Geology: The deposits of Mn oxides are largely concentrated inland of the Jasper Formation of M. Alpe (Val di Vara Supergroup, Bracco-Val Unit Graveglia). These are primary Mn mineralization, related to hydrothermal processes of the Ligurian-Piedmontese Ocean, which were affected by recrystallization and thickening during the tectonic-metamorphic phases) of Apennine orogeny (Late Cretaceous-Cenozoic) (Lucchetti et al., 1990) (Figure 15).

Ore geology: stratiform mineralization occur either in alternating hematite and jaspers levels or in massive, multi-decametric lenses, located at the nucleus or along the limbs of the main fold structures (Cabella et al., 1998; Marescotti & Frezzotti, 2000). All deposits consist of Mn oxides.

Mines: most of the mines are located between the Val Graveglia and Val Petronio, in the hinterland between Chiavari and Sestri Levante (Genoa). The Val Graveglia mining district was the main Italian pole for the extraction of Mn, with a Production of more than 1,200,000 metric tons of Braunite ore with a Mn grade between 30 and 45 wt%. It includes 13 main mines in an area of approx. 50 km^2 (Gambatesa, Molinello, Cassagna, Nossiglia, Pontori, M. Bossea, M. bianco, Vallebona, Statale, Balarucca, M. Porcile, M. Zenone and M. Alpe – the last three also known as the "mines of the Three Mountains"). Most of these deposits were exploited between the second half of the 1800s and the 1960, with the exception of the Gambatesa mine which was definitively closed in 2011.

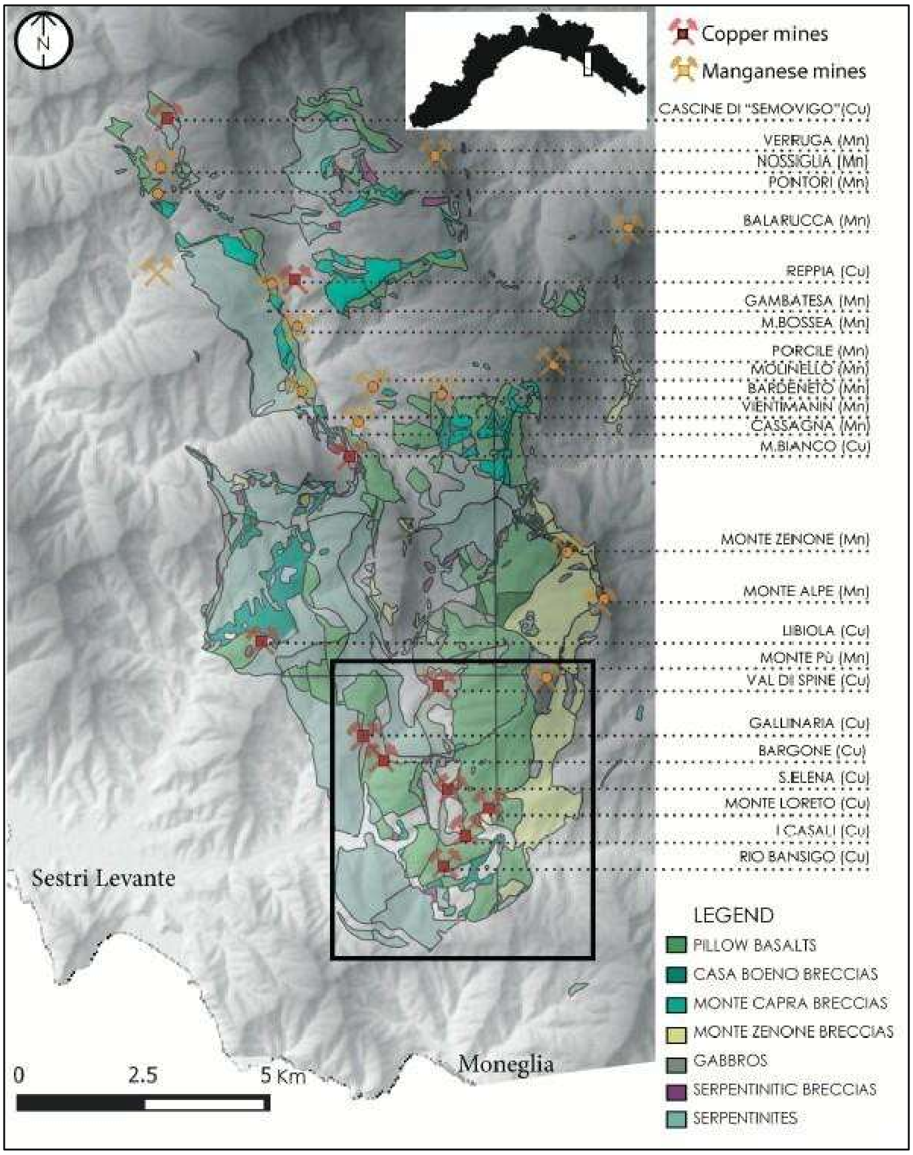

Figure 16 - Geological map of Eastern Liguria locating of the main manganese and copper abandoned mines. The box shows the most interesting area for copper prospecting.

Project

The implementation of the exploration plan aims to optimize cost-effectiveness through the joint application of exploration methodologies, exploiting synergies between the two districts and, above all, their geographical proximity and partial overlap. Activities are organised according to a conceptual sequence of time priority, although, considering the available timeframe, different phases may partly overlap.

1) EVALUATION AND SUMMARY OF PREVIOUS STUDIES

Previous studies will be collected, screened, selected, summarized and reformulated. For both districts, this represents more or less a number of recent publications and technical reports. All collected material will be critically reviewed and reprocessed considering the latest scientific knowledge on the relevant deposit types. A synthesis will then be produced and aligned with the objectives of the National Exploration Programme.

2) AIRBORNE EM

The districts under investigation represent a pilot area for the application of Airborne Electromagnetics (AEM) technology, combined with magnetic surveys (MAG), to explore both brownfield and greenfield targets. AEM is widely used in Europe, America and Oceania as a key tool for mineral exploration and it is characterized by several advantages:

- innovative methodology calculating underground electrical resistivity;
- large-scale coverage of survey areas (100–400 resistivity models per km^2, over >100 km^2);
- rapid data acquisition, covering several tens to hundreds of km^2 per day;
- Penetration depth from a few metres to 300–400 m;
- high resolution (lateral: tens of metres; vertical: a few metres near the surface);
- sensitivity to conductive horizons and dispersed mineralization;
- non-invasive, no health risks, no need for property access permits;
- excellent cost–benefit ratio in both brownfield and greenfield exploration;
- easy integration with ancillary geochemical, geological and hydrogeological data.

The application of AEM in Eastern Liguria will allow mapping of favourable geological structures, potential orebodies and the hydrogeological framework, also supporting geohazard assessment. Airborne surveys will be complemented by ground-based electromagnetic measurements with portable instruments, ensuring higher resolution (depth 50–100 m) in selected target areas, including mining waste deposits.

3) FIELD ACTIVITY

Field surveys and sampling campaigns will be carried out in selected portions of the districts, focusing on the census, mapping and mineralogical/geochemical characterization of both the most relevant mining landfills and the outcropping orebodies.

4) LABORATORY ANALYSIS

Laboratory investigations will verify the presence and concentration of critical raw materials (CRMs) and other metals of potential economic interest. Analyses may include:

- petrographic study of hand samples and thin sections;
- particle size distribution analysis;
- bulk chemical–mineralogical analyses (XRF, XRD), with possible integration of portable field instrumentation.

5) DATA MANAGEMENT AND RETURN OF RESULTS

All products will be made in line with project coordination standards and the criteria set out in Chapter 4. Quarterly reports will monitor progress toward results. At the end of the programme, a detailed report will provide a comprehensive overview of the results obtained, the potential of the surveyed areas and guidelines for subsequent exploration phases. Geophysical data and models will be shared in a QGIS-compatible format through a dedicated plugin for geophysical data visualization.

Possible extension in Phase 2 and 3

Depending on results, further activities may include:

1. Expansion of the study area in order to completely cover both districts.
2. Prosecution of investigations with targeted ground surveys and measurements.
3. Enhancement of the analytical survey plan to obtain critical data on deposit characteristics (textures, paragenesis, structures, genesis).
4. Assessment of resources and reserves through international standards.

Expected impacts

Phase 1:

Science, mining and technology:

- Improved understanding of metallogenic processes of sulphide-bearing deposits in Liguria and the Northern Apennines.
- Recovery and re-evaluation of past knowledge using local and regional archives.
- Revision of conceptual models, with potential extension of research to areas previously excluded.
- Training of specialized researchers and professionals in mineral exploration.
- Testing and validation of airborne geophysical techniques, with potential extension to other areas in Phases 2–3.

Social impact:

- Strengthened dialogue with the public sector and dissemination of scientifically reliable information on sustainable mining in environmentally sensitive Ligurian areas.

Phase 2-3

Science, mining and technology:

- Assessment of lateral and deep extensions of orebodies.

- Development of innovative exploration technologies, including AI-assisted interpretation.
- Improvement of methodologies for extractive waste characterization and potential recovery.
- Reinforcement of collaborations among national universities, research institutes and regional authorities

Economic and social:

- Increased investment in the mining sector based on new geological evidence.
- Attraction of foreign investment driven by exploration outcomes.
- Regional economic diversification, with positive repercussions on complementary sectors.
- Growth of interest in mining heritage, attracting visitors to mining parks and museums.
- Stimulation of local enterprises providing services to exploration activities.
- Training of new professionals and specialized associations in mineral exploration.
- Job creation.

Environmental impacts:

- Development and dissemination of criteria to minimize environmental impacts of exploration.
- Mitigation and potential remediation of legacy environmental issues associated with mining waste

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4) GRAPHITE PROJECT: CALABRIA, PIEDMONT, LIGURIA

1. CALABRIA GRAPHITE: DISTRICTS OF MONTEROSSO CALABRO AND OLIVADI

The project aims to carry out preliminary mineral exploration investigations to assess the mining potential of graphite mineralization in the districts of Monterosso Calabro (VV) and Olivadi (CZ), including the nearby localities of Polia and San Vito. Both areas were historically the site of mining activities (notably the Piano dell'Acqua and Riga mines), which continued until their final closure in the second half of the 20th century.

From a geological point of view, the two districts are located within the rocks of the Variscan basement and the successions of the Serre Massif. The aim of the project is not only to evaluate the extent and quality of graphite deposits but also to define the possible presence of other Secondary Raw Materials (SRMs) and Critical Raw Materials (CRMs) associated with graphite mineralization

State of art

Main Raw Materials: Graphite;

Critical Raw Materials: Graphite, vanadium?;

Other raw materials: PB, Zn, Mo

Location: Calabria, Monterosso Calabro (VV); Olivadi (CZ)

Geology: Monterosso Calabro/Olivadi (Figure 16): Graphite mineralization is hosted in graphitic shale of the continental Varisican crust consisting of mafic and felsic granulites, stratified gabbric intrusions (metagabbros), metaperidotites and metasediments. They overlap with migmatitic paragneiss and intercalations of metabasites, marble and orthogneiss (Paglionico & Piccarreta, 1978; Schenk, 1984; Acquafredda et al., 2006, 2008; Fornelli et al., 2011; Festa et al., 2024). In particular, graphytic shale are hosted in gneiss and migmatitic paragneiss (Schenk, 1984; Melograni, 1823). Based on preliminary analysis and geological context, the type of graphite occurring here can be classified as 'Crystalline flake graphite deposits' (Simandl et al., 1992), usually associated with paragneiss and marbles that have undergone amphibolitic- and granulitic-facies metamorphism.

Ore geology: the mineralization is hosted in graphitic shists. Graphite crystals display variable grain sizes, from fine to coarse. Localised graphite "veins" cutting across host rocks have been described (Melograni, 1823). Graphite commonly occurs in association with quartz, mica, garnet and feldspar. In the Monterosso Calabro area, quartzite samples with massive graphite mineralization and associated sulphides (notably pyrite) have been documented, often characterized by extensive alteration patinas (Figure 18).

Mines: historical graphite exploitation was concentrated at the *Piano dell'Acqua* mine (Monterosso Calabro) and the *Riga* mine (Olivadi). Data on mineralization grades are limited and scattered. Exploration campaigns carried out in the 1960s by *Compagnia Monte Amiata* in the "Fosso Divisa" area reported a mineralized lens with 7–8% lamellar graphite and an average content of about 13% graphitic carbon. In Monterosso Calabro, entrances to the old mine workings has collapsed, and the only available material was recovered from an old ore silo. To date, no systematic exploration or preliminary investigations have been conducted in the Olivadi district.

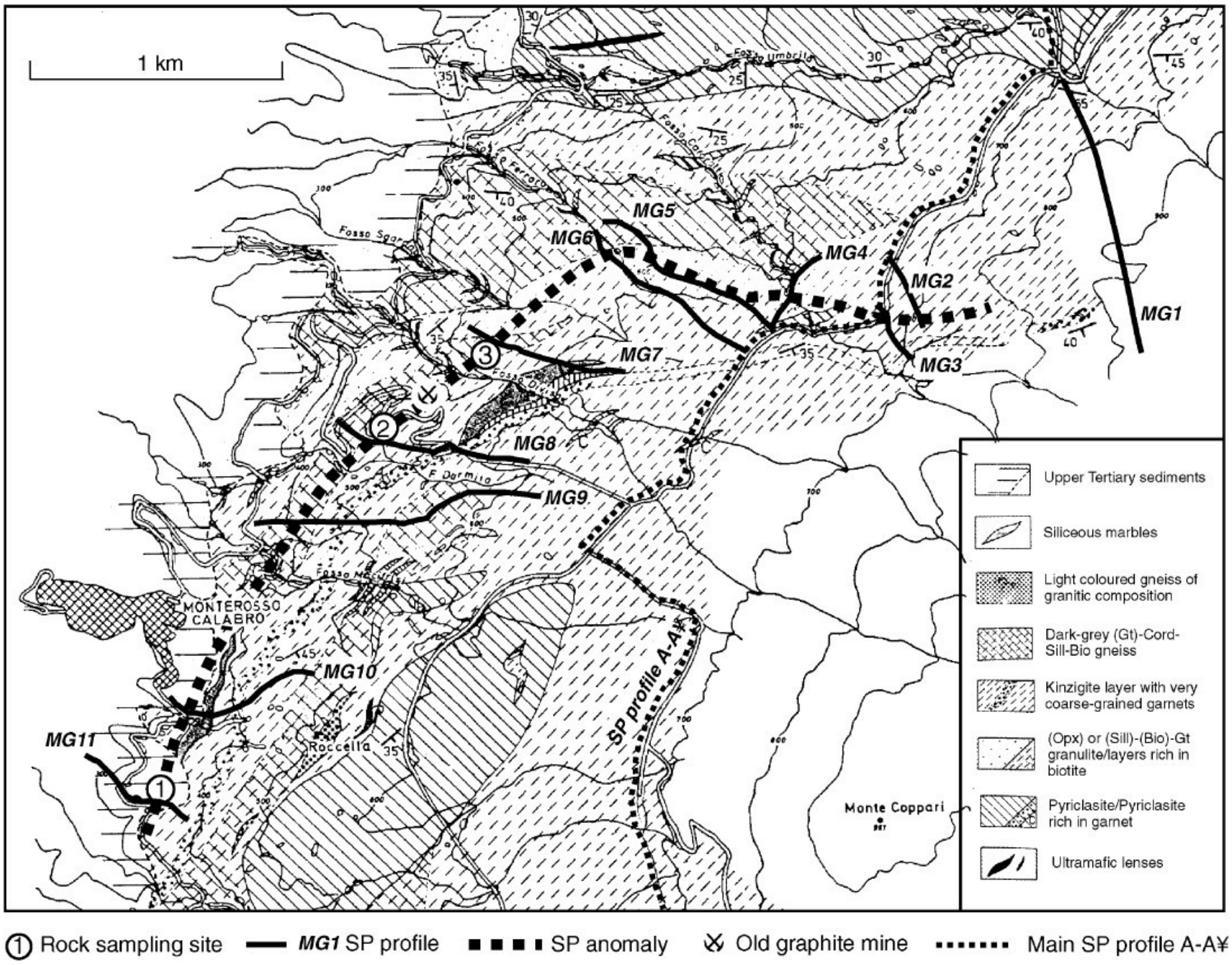

Figure 17 - Geology of the Monterosso Calabro area

Figure 18 - Graphite mineralized samples (Monterosso Calabro)

2. PIEDMONT GRAPHITE: VAL CHISONE, VAL GERMANASCA, PRAMOLLO WALLOON, GRANDUBBIONE WALLOON

The project aims to carry out preliminary mineral exploration investigations to assess the mining potential of graphite mineralization located in numerous ancient mining sites in the pinerolese valleys in Piedmont (TO). The areas have historically been the subject of significant graphite extraction under both industrial and artisanal systems until the final closure of the last Brutta Comba mine in 1983. The area of interest is geologically located in the Grafitico Pinerolese complex of the Massiccio del Dora-Maira. The project also aims to define the presence of additional SRMs and CRMs associated with graphite mineralization.

State of art

<u>*Main Raw Materials*</u>: Graphite;

<u>*Critical Raw Materials*</u>: Graphite, vanadium?;

<u>*Other raw materials*</u>: to define

<u>*Location:*</u> Piedmont, Val Chisone, Germanasca, Vallone Pramollo, Largeon Vallone and surrounding areas

<u>*Geology*</u>: The Val Chisone, Val Germanasca, Pramollo Vallone and Grandubbione Vallone areas (Figure 19) belong to the Dora-Maira Massif within the Penninic Domain of the Western Alps. The deposits of interest occur in the lower Dora-Maira unit, a mono-metamorphic succession of sedimentary origin composed of metaconglomerates, fine-grained gneiss and metapelites. These lithotypes are characterized by the presence of original organic matter metamorphosed into graphite, occurring in disseminated form or concentrated in layers and lenses. This sequence is known as the *Grafitico Pinerolese Complex*, also referred to as the *Sanfront–Pinerolo Unit*, of Carboniferous age (Manzotti et al., 2016). The rocks underwent a metamorphic peak under blueschist facies conditions, later re-equilibrated into greenschist facies.

<u>*Ore geology:*</u> graphite mineralization occurs both as regionally conformable layers of varying thickness (Figure 20 a) and as discrete bodies within metaconglomerates and/or meta-arenites (paragneiss) interlayered with metasiltites and metapelites, which are often highly enriched in graphite (graphitic micaschists) (Figure 20 b). The stratiform geometry of the mineralized bodies and the host lithologies, derived from the metamorphic transformation of carbon-rich sedimentary sequences, suggest that the deposits originated from organic matter-rich layers interbedded with sediments of different granulometry at the time of deposition, later involved in Alpine orogenic deformation and metamorphism. Based on preliminary geological analyses (Santoro et al., 2025, in press), these mineralization can be classified as *microcrystalline graphite deposits* (Simandl et al., 1992; Taylor, 2006), typically associated with highly graphitic rocks subjected to metamorphism under greenschist facies conditions.

Mines: The Val Germanasca, Val Chisone and Pramollo areas preserve clear evidence of past mining activity, including waste rock dumps, collapsed artisanal adits and walled tunnels. Graphite extraction in these valleys began in the early 19th century. Production reached its peak in the early 20th century under the control of Talco & Graphite Val Chisone company, before all operations were definitively stopped with the shutdown of the Icla–Brutta Comba mine in 1983. At that time, domestic graphite use in Italy was splitted as follows: 75% in smelters, 20% in paint factories, the rest employed as lubricants.

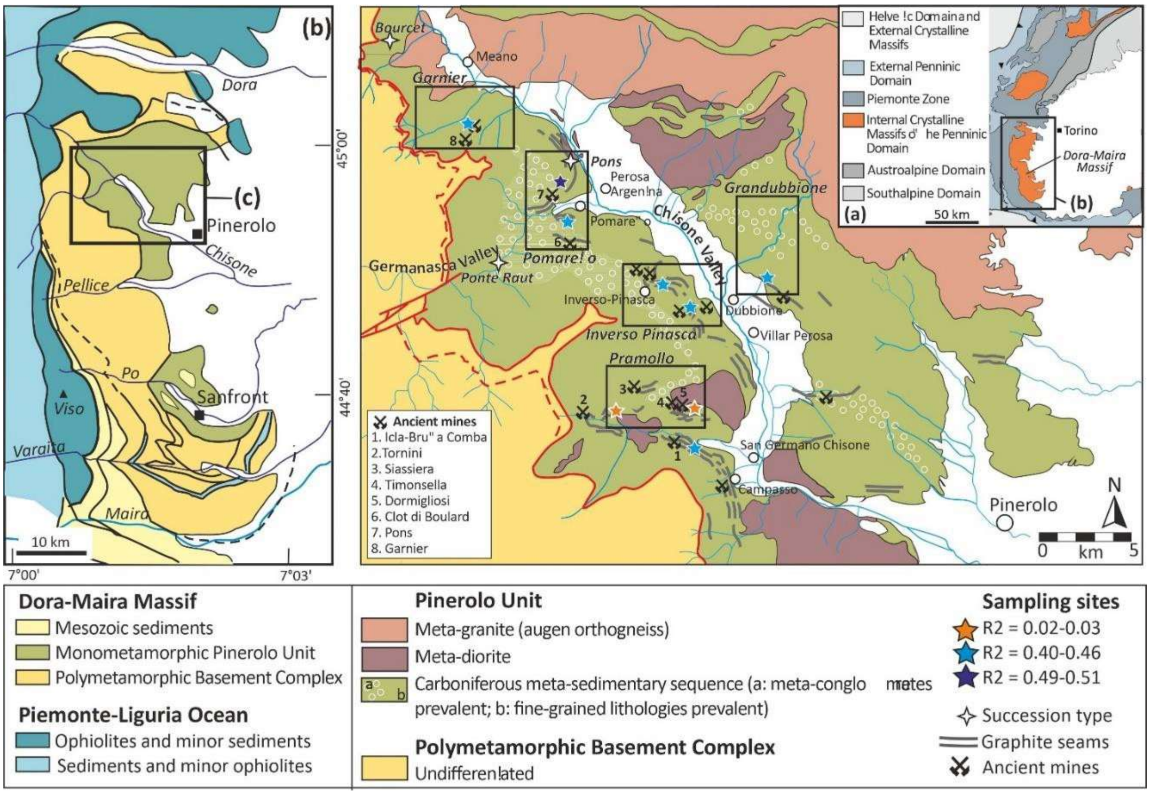

Figure 19 - Geology of the Val Chisone and Val Germanasca area

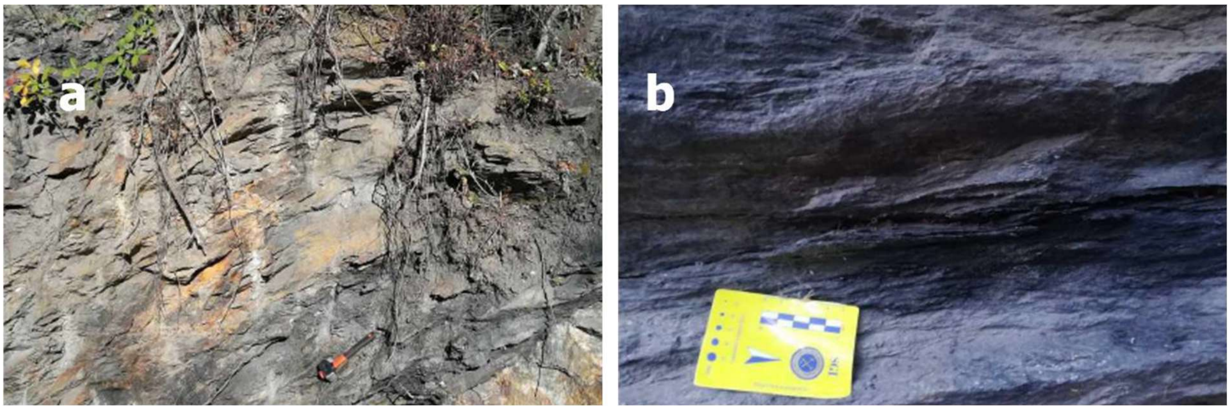

Figure 20 - Graphite mineralization

3. SAVONESE GRAPHITE: VAL BORMIDA

The project aims to conduct preliminary mineral exploration in order to assess the economic potential of graphite located in the upper Val Bormida (Province of Savona). The area was historically exploited for both anthracite and graphite until the second half of the 20th century. Geologically, the area lies within the Briançonnais domain of the Ligurian Alps. The project also seeks to investigate the possible presence of additional SRMs and CRMs associated with graphite mineralization.

State of art

Main Raw Materials: Graphite;

Critical Raw Materials: Graphite, V?;

Other raw materials: PB, Zn, Ag, Au

Location: Liguria, Val Bormida, Murialdo, Calizzato, Oseille, Mallare, Savona Province

Work planning (each of the 3 sites)

1) EVALUATION AND SUMMARY OF PREVIOUS STUDIES

Collection, review, selection and reformulation of previous studies where available. The material will be reassessed in the light of updated scientific knowledge and modern genetic and deposit models.

2) FIELD ACTIVITY

Survey and sampling campaigns in selected areas, focusing on the census and mapping of the most relevant subsurface and waste rock bodies in the mining districts, alongside the chemical and mineralogical characterization of exposed mineralized bodies.

3) GEOPHYSICAL SURVEYS

Application of on-site geophysical techniques to detect graphite-bearing bodies, including Electrical Resistivity Tomography (ERT), Induced Polarization (IP), Spontaneous Potential (SP) and electromagnetic (EM) surveys.

4) LABORATORY TESTS

Petrographic, mineralogical and geochemical analyses to determine the degree of crystallinity, the presence of CRMs and the concentration of graphitic carbon and associated metals. Methods may include:

- study of hand samples and optical microscopy;
- whole-rock geochemical and mineralogical analyses;
- particle size and crystallinity characterization.

5) DATA MANAGEMENT AND RETURN OF RESULTS

All outcomes will be produced according to project standards and criteria defined in Chapter 4. Progress will be reported quarterly. At the end of the investigation, a comprehensive report will summarize results, potential of the investigated areas, and guidelines for subsequent exploration phases.

Possible extension in Phase 2 and 3

Depending on preliminary results, further exploration may include:

1. Helicopter-borne (HEM) and high-frequency airborne magnetic surveys to extend the coverage area and identify additional targets.
2. Core drilling in priority sites.
3. Detailed laboratory analyses (petrographic, mineralogical, chemical) on core samples.
4. Beneficiation tests with recovery simulations, including crushing, milling and flotation using various techniques.

Expected impacts

Phase 1:

Science, mining and technology:

- Significant improvement in the understanding of the metallogenic processes of graphite mineralized bodies on the national territory
- Increase in past knowledge through consultation of regional and local archives
- Revision of conceptual models with possible extension of research into excluded areas based on old models
- Training of experts and researchers in the field with human capital growth specialized in mineral exploration and related disciplines.
- Testing and development of airborne geophysical techniques with possible extension to other areas of the future Phase 2 and Phase 3 programming

Social impact:

- Dialogue with the public sector and distribution of scientifically correct information on sustainability criteria for mining activities in environmentally sensitive areas of Liguria
- Integration with proposals for mining tourism, especially in Calabria

Phase 2-3

Science, mining and technology:

- Assessment of the possible lateral and deep evolution of deposits, based on planned surveys and insights.
- Development of innovative technologies for the exploration and extensive application of
  artificial intelligence
- Development of methods and criteria for the characterization of extractive waste and its possible cultivation
- Scientific collaborations between national universities/EPRs.

Economic and social:

- Increased investments in the mining system as a result of the provision of basic elements on deposits in the study area
- Attracting foreign investments stimulated by exploration results
- Regional economic diversification with possible restart of other sectors of activity
- Increasing interest in mining and increasing visitors to mining parks/museums
- Stimulating the creation and growth of local businesses for the provision of goods and services
  mineral exploration
- Training of new local professionals, graduates, and associations of professionals specializing in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and dissemination of criteria and methods to minimize impact environment of exploration activities
- Removal/mitigation of environmental concerns related to extractive waste

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5) UNCONVENTIONAL LITHIUM RESOURCES IN ITALY (TUSCANY, LAZIO, CAMPANIA, EMILIA ROMAGNA, MARCHE, PIEDMONT, LOMBARDY, TRENTINO ALTO ADIGE)

Italy has never produced lithium throughout its long mining history, yet it has considerable potential for the discovery of unconventional deposits hosted in deep geothermal fluids, granitic intrusions and volcano-sedimentary successions (Figure 21). A recent national study identified four main exploration targets (Figure 22):

1. High-enthalpy geothermal fluids of the peri-Tyrrhenian volcanic belt;
2. Low-enthalpy thermal fluids along the Apennine thrust front;
3. Cenozoic–Quaternary granites of Tuscany;
4. Permian volcano-sedimentary sequences of the Alpine Chain.

None of these targets have ever been exploited for lithium extraction, either in Italy or abroad, and they therefore represent both a scientific and an industrial challenge for the coming years. The urgent need to increase global lithium supply while diversifying production areas has triggered a real "unconventional lithium race." Active exploration and pre-production projects are already ongoing in Cornwall, France, Germany, the Czech Republic and Portugal, where lithium-rich granitic rocks are being tested, while several projects in the Upper Rhine Valley (France and Germany) have been exploring lithium recovery from geothermal fluids for years, involving both industry and academia. In addition, the potential of volcano-sedimentary successions is exemplified by the discovery in the early 2000s of the large Jadar deposit in Serbia, which, once geopolitical constraints are resolved, is expected to change Europe's role in the global lithium market.

In Italy, although the strategic importance of lithium has raised significant scientific interest, research has not yet translated into substantial industrial initiatives. These unconventional targets are inherently risky from an industrial standpoint; nevertheless, the critical and strategic nature of lithium makes it essential to accelerate exploratory efforts.

The goal of this project is to conduct a systematic and interdisciplinary general exploration programme to better characterise Italy's unconventional lithium targets and to lay the scientific groundwork for potential industrial exploration. The study will:

- directly characterise rocks and thermal waters (e.g., from springs and spas);
- indirectly investigate geothermal fluids currently not accessible for sampling;
- develop conceptual and geochemical models to evaluate lithium potential.

The project will integrate:

- geo-mineralogical and geochemical soil studies;
- petrographic, mineralogical and isotope-geochemical analyses;
- hydrothermal extraction experiments;

- studies on water-rock interaction processes and their role in lithium mobility and concentration.

This coordinated approach is expected to deliver the first comprehensive overview of Italy's unconventional lithium potential, providing a scientific basis to attract and guide mining companies toward exploration actions soon.

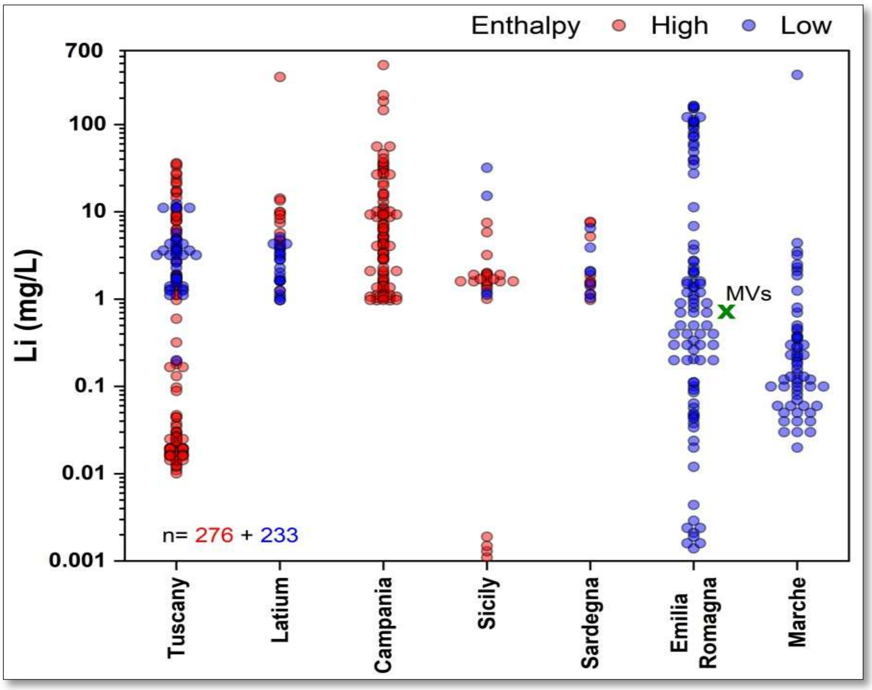

Figure 21 - Concentration of lithium in Italian geothermal (Target 1) and thermal (Target 2) fluids.

All the data available in the scientific literature will be used, as well as some new studies carried out in the context of PhD and master's thesis. For the lithium resource, there is no previous mining database or documents deposited in mining archives. All the data produced will be integrated into a database, which is necessary to obtain the conceptual genetic models of the four different mining targets. Conceptual models will provide key information to subsequently address the identification of the most favourable areas for mining companies to carry out mineral exploration activities.

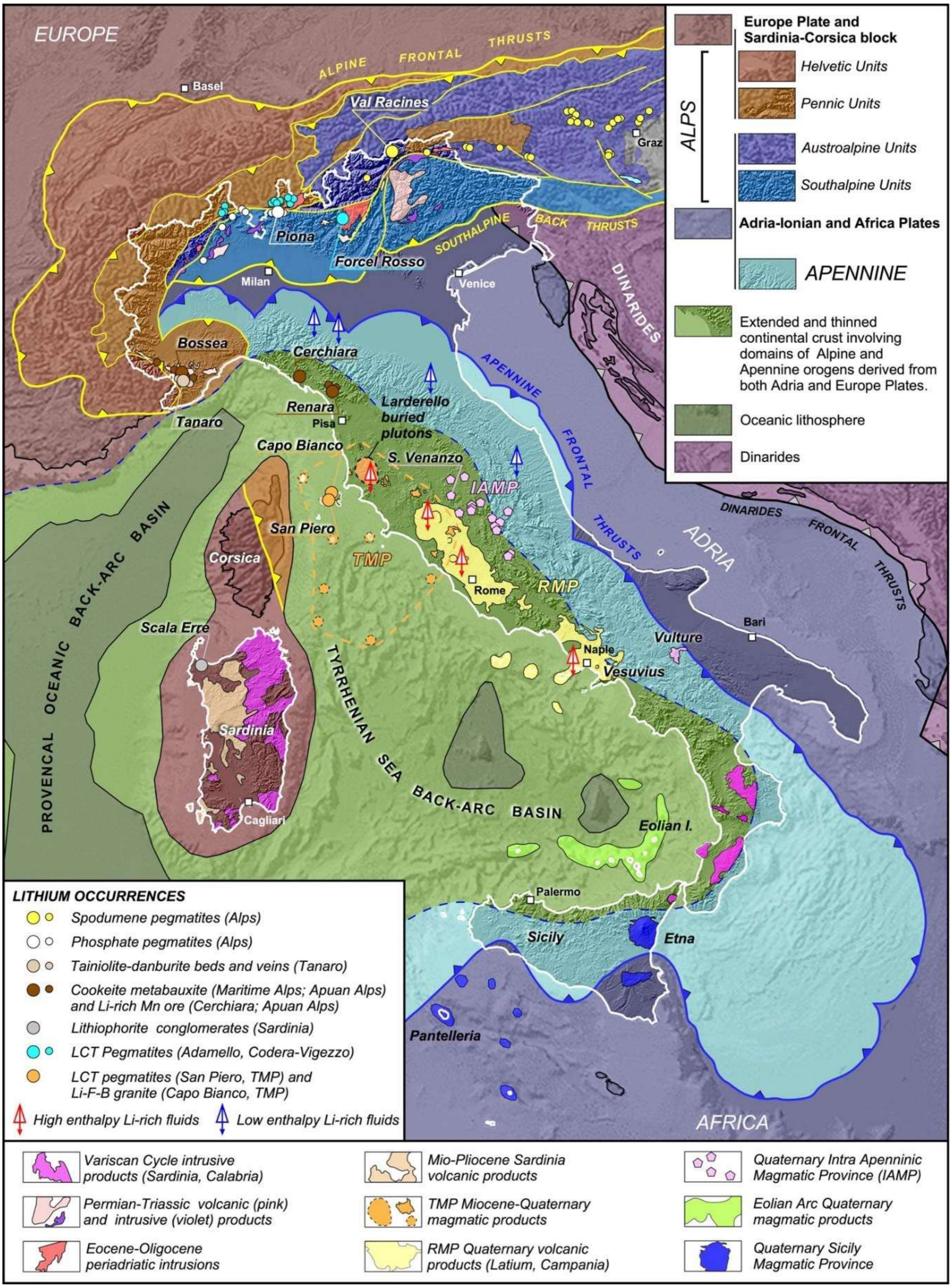

Figure 22- Italian tectonic scheme with the targets for lithium.

State of the art:

Main Raw Materials: lithium, boron;

Critical Raw Materials: lithium, boron;

Strategic Raw Materials: lithium, boron

Other raw materials: potassium, rubidium, caesium,

Location: Tuscany, Lazio, Campania, Emilia-Romagna, Marche, Piedmont, Lombardy, Trentino-Alto Adige

Geology:

Target 1 – Geothermal fluids: the area most concerned is from the volcanic complex of Vulsini (Lazio) to the Campi Flegrei (Campania). During the exploration carried out by ENEL-AGIP in the 1970-80s, geothermal reservoirs were intercepted with temperatures up to 300 °C and saline fluids with high lithium content (up to 480 mg/l). Reservoirs are hosted in the carbonate sedimentary formations that are under volcanic pyroclastic sequences.

Target 2 – thermal fluids: in this case, these are saline low-temperature fluids, associated with low-salinity waters, which emerge spontaneously, or have been intercepted in a well, in the frontal area of the Apennine Catena, between Piacenza and Pescara (e.g. Salsomaggiore, Castrocaro, Tolentino). These fluids are occasionally associated with mud volcans crossing Mio-Pliocenic and quaternary sedimentary sequences.

Target 3 – Tuscany peraluminous granites: the development of the continental back-arc of North Tyrrhenian has created the ideal conditions, starting from the upper Miocene, for the partial melting of the lower continental rind and the transfer to the surface of peraluminous granitic smelts. A large part of these magmas emplaced in the Tuscany and Ligurian units (between 6 and 2 km depth), forming granitic plutons and subvolcanic intrusions. In a few cases they fed small volcanic systems. Partial melting of the continental meta-sedimentary rind generated specialized melts rich in lithium (Figure 23), boron, rubidium, caesium, tantalum, niobium.

Target 4 – Permian volcano-sedimentary sequences: the deposition of volcano-sedimentary sequences in continental basins surrounded by volcanic buildings with evolved chemism creates the ideal context where rainfall and geothermal waters can extract lithium from the glass matrix of the volcanic component and then concentrate it in continental evaporitic settings. Indeed, much of the global lithium production comes from the Salar, and the Jadar deposit (Serbia) is probably a fossil example. The Permian volcano-sedimentary sequences involved in the Alpine arc are characterized by layers with abnormal concentrations of lithium and boron. This target completely lacks a detailed petrographic/mineralogical/geochemical characterization.

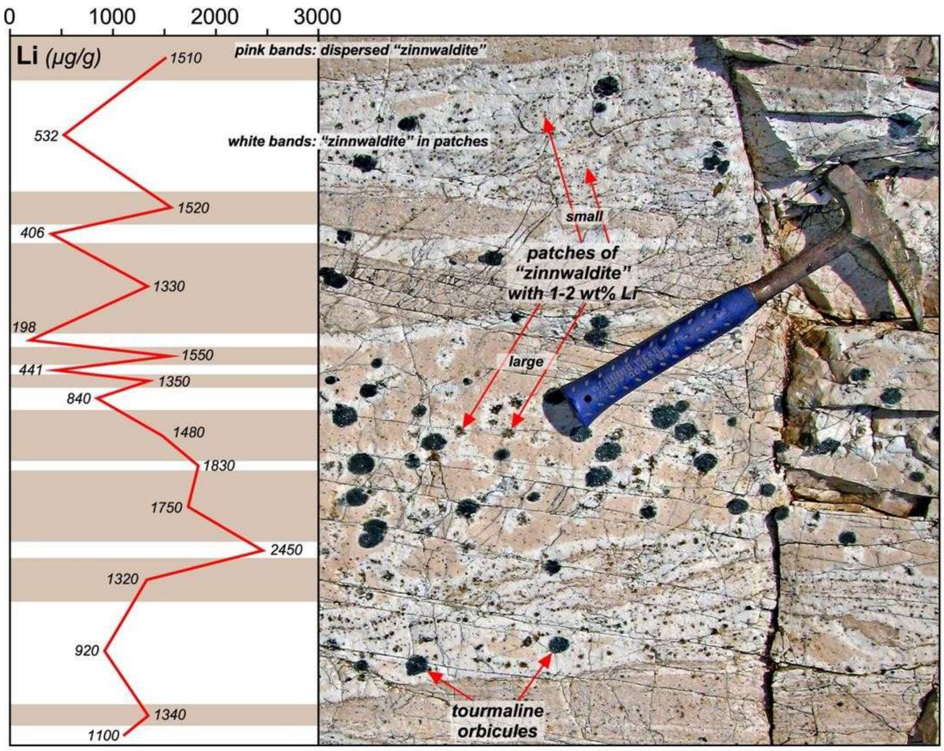

Figure 23 - Granitic ray containing lithium minerals (Tuscany)

<u>Mines</u>: there are no mines as this resource has never been exploited in Italy.

Project:

The project will initially be implemented through two parallel actions: (1) collection and digitalization phase (from archive data); (2) field exploration phase (mapping and collection of new data and samples). These two activities will be progressively and iteratively complemented by the laboratory phase (mineralogic-petrographic and geochemical analyses). All the information collected will then be integrated into the database on which the new conceptual genetic models of the four lithium targets will be developed.

1) COLLECTION AND DIGITALIZATION OF PREVIOUS DATA

Previous studies will be collected, screened, selected, summarized and reformulated. The material collected will have to be reviewed, revised and reprocessed considering the latest scientific evidence in the field of the types of mineral deposits in question. The data will then be digitalized.

2) FIELD ACTIVITY

Detection and sampling campaign in certain limited areas: Target 1 – Vulsini and Sabatini volcanic Sequences; Target 2 – northern Apennine sedimentary sequences between Berceto and Salsomaggiore; Target 3 – granitoid rocks sampled both in outcrop and underground in Tuscany; Target 4 – Permian volcano-sedimentary sequences in Piedmont, Lombardy (BG-BS) and Trentino-Alto Adige. Soil work will be supported using Portable LIBS for in-situ identification of mineral phases and for real-time measurement of lithium concentration. Detailed petrographic, mineralogical and geochemical analyses will be carried out on the collected samples.

3) LABORATORY ANALYSES

Petrographic and mineralogical analysis by optical microscopy, Scanning Electron Microscopy (FESEM-EDS, WDS and dual source eBeam + MicroXRF), cathodoluminescence and powder diffraction. Laboratory investigation campaign to verify the presence and concentration of lithium and any other associated metals (B, Rb, Cs, Ta, Nb, etc.). Geochemical analyses of rock and fluid samples will be carried out in the most advanced analytical infrastructures available in Italy (ICPMS, la- ICPMS; after milling and chemical attack and/or melting). On a selection of samples analyzed for geochemistry, isotopic analyses (Li, B, Sr, Nd, Pb, O, H, C) will be carried out in order to develop conceptual models and define the isotope footprint of the four targets, which is useful for the future management of possible exploratory/extractive activities and for defining the underlying values for land management in the event of environmental problems.

4) CONCEPTUAL MODEL

All geological, mineralogical and geochemical data collected in the four targets' key areas of the four targets will be integrated into the database and then used to define the conceptual genetic models. These latter will simplify the assessment of the most promising areas where to focus future exploratory activities.

5) DATA MANAGEMENT AND RETURN OF RESULTS

All outcomes will be produced in accordance with the standards defined by the project coordination and with the criteria described in Chapter 4.

Progress will be reported quarterly.

At the end of the investigation plan, a detailed *report* will be drawn up to provide a comprehensive overview of the results obtained, of the potential of the areas investigated and the subsequent exploration methods.

Expected results are:

a) Database of pre-existing mining/geological/geochemical data in the entire study area with integration of the new data produced by the project. Compatible with ISPRA and regional databases.

b) New geological, petrographic, mineralogical, geochemical and isotopic characterization of the resources in the four proposed targets.

c) Conceptual genetic model of the four mining targets to subsequently address the identification of the most favourable areas for mining companies to carry out mineral exploration activities.

Possible extension in Phase 2 and 3

Depending on the results of the first investigation plan underpinning this project, it will be possible to extend the study by including the assessment of lithium potential in the Variscan granites of Sardinia and Calabria, as well as the application of established and newly designed instrumental exploration and analysis methods. These operations may include:

1) Geophysical exploration (geoelectric, magnetotelluric) in limited target areas with geothermal and thermal fluids.
2) In-depth study of water-rock exchange processes by a high number of hydrothermal experiments, direct fluid lithium extraction methods and numerical modelling.

Expected impacts

Phase 1:

Science, mining and technology:

- Significant improvement in the understanding of the metallogenic processes of lithium mineralized bodies and geothermal fluids with high lithium content in Italy
- Increase in past knowledge using regional and local archives
- Revision of conceptual models with possible extension of research into excluded areas based on old models
- Training of experts and researchers in the field with human capital growth specialized in mineral exploration and related disciplines.

Social impact:

- Dialogue with the population and dissemination of scientifically correct information on sustainability criteria for geothermal fluid mining activities

Phase 2-3

Science, mining and technology:

- Development of innovative technologies for the exploration and extensive application of
artificial intelligence
- Development of geothermal fluid extraction methods
- Scientific collaborations between national universities/EPRs.

Economic and social:

- Increased investments in the mining system as a result of the provision of basic elements on deposits in the study area
- Attracting foreign investment stimulated by exploration results
- Regional economic diversification with possible restart of other sectors of activity
- Increasing interest in mining and increasing visitors to mining parks/museums
- Stimulating the creation and growth of local businesses for the provision of goods and services for mineral exploration
- Training of new local professionals, graduates, and associations of professionals specializing in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and dissemination of criteria and methods to minimize impact environment of exploration activities
- Removal/mitigation of environmental concerns related to extractive waste

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6) MAREMMA ANTIMONY DISTRICT (TUSCANY)

The project aims to reassess the mining potential of selected sites within the Maremma Antimony District (Southern Tuscany). The district ceased production in 1995 after yielding approximately 15,000–20,000 tons of antimony, corresponding to a nominal present-day value of EUR 0.4–0.8 billion. Nearly 90% of this production came from a single site, Tafone, although the district contains numerous antimony occurrences. Given its size, the area still has a high potential for detecting new orebodies. The ore extracted in the past contained between 1% and 6% Sb, with an average grade of 2.4% Sb. Mining activities stopped primarily due to political and economic decisions rather than actual depletion of reserves. Indeed, technical reports from the last two decades before closure confirm that significant parts of known reserves are still unexploited. Tuscan antimony mineralization are also frequently characterized by anomalous gold contents (0.5–a few g/t), which could add considerable value in future reassessments of the district's potential.

The project aims to:

- Reassess the residual high-grade resources of the former district by combining historical data from the Tuscan mining archives and the RIMIN database with new field surveys;
- Compile drill logs and geochemical data with mine maps and gallery fronts to reconstruct the mineralized volumes;
- Conduct new geochemical surveys and analyses to complement historical datasets;
- Develop a new 3D geological model of the orebodies in the three main sites (Tafone, Montauto, Macchia Casella);
- Extend the analysis to distal, lower-grade zones, to evaluate their potential;
- Integrate all available information into a genetic conceptual model, supporting the identification of new prospective areas.

State of the art:

Main Raw Materials*:* antimony*;*

Critical Raw Materials: antimony*;*

Strategic Raw Materials: –

Other commodities: Au

Location: Maremma, Southern Tuscany

Geology: The antimony deposits of the Maremma District occur along the subhorizontal tectonic contact between the Tuscany Nappe and the overlying Ligurian units. Mineralization is structurally controlled by both NE–SW anti-Apenninic and NW–SE Apenninic fault systems (Figure 24).

<u>Ore geology</u>: massive-disseminated mineralization and stockworks of stibnite (Sb_2S_3) with varying quantities of marcasite, pyrite, sphalerite and cinnabar hosted in brecciated and silicized volumes of carbonate rocks (Tuscany Nappe) (Figure 25). Locally areas of intense hydrothermal argillification occur, mainly developed at the expense of the clay and marnous roof sequences (cap rocks). Gangue minerals in addition to quartz and kaolinite include calcite, baryte, celestine, etc. In the studied area there are also minor Cu- Pb-Zn-Sb-Au mixed sulphide mineralization (Ponte San Pietro, Scerpene).

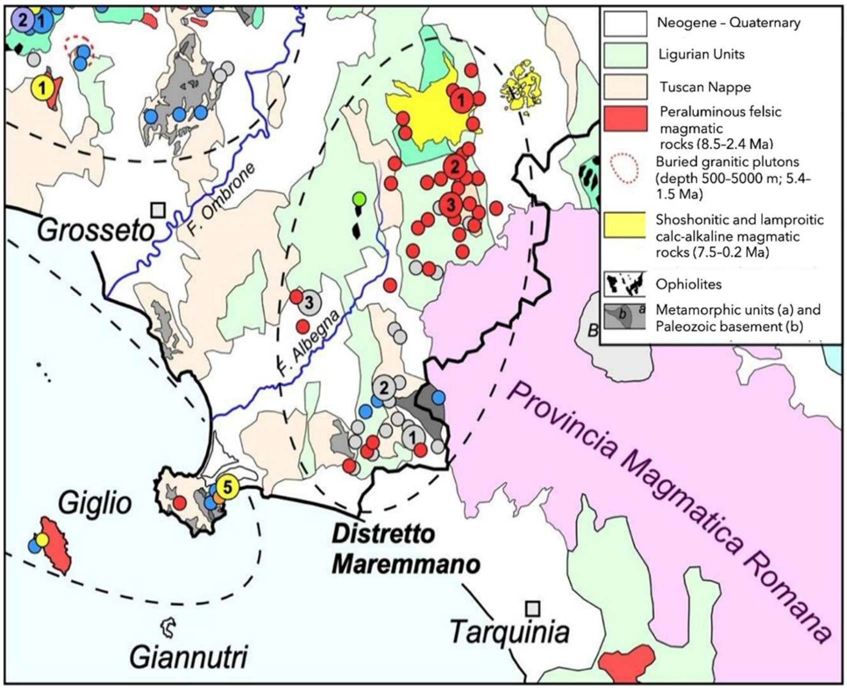

Figure 24 - Schematic geological map showing the distribution of antimony mineralization in the Maremma District (grey circles; 1: Tafone, 2: Macchia Casella). Red circles indicate the mercury mineralization of the Monte Amiata area.

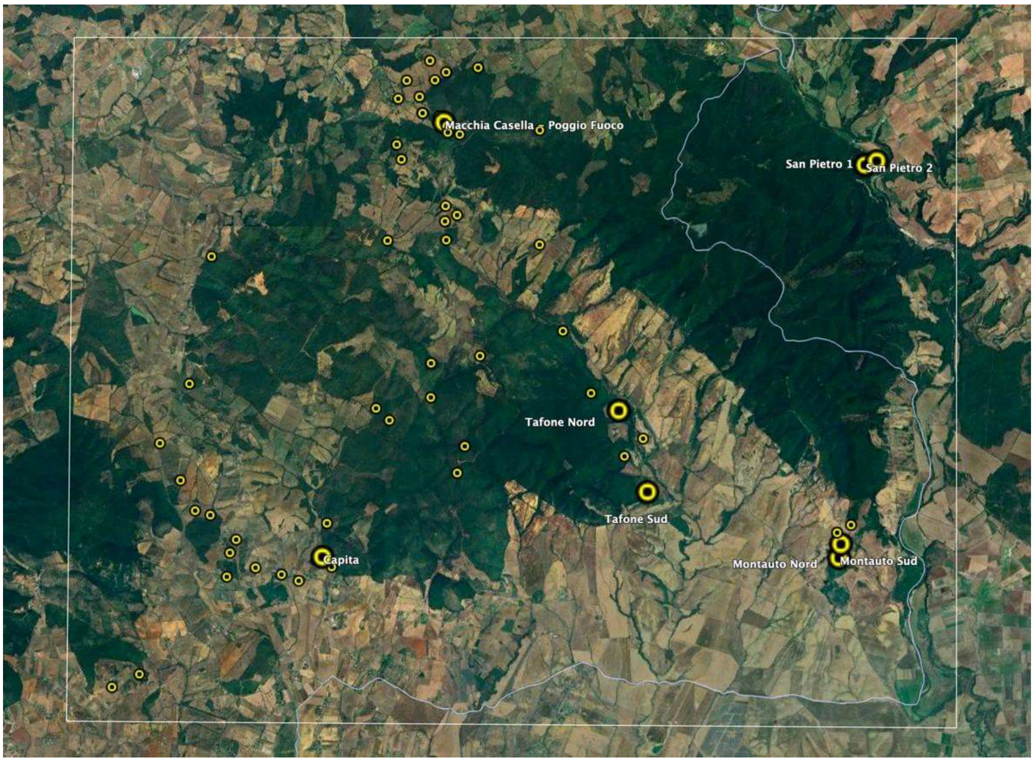

Figure 25 - Location of antimony mineworks in the Maremmano District, Tuscany.

Mines: Around 50 localities, spread over an area of approximately 200 km², where antimony mineralization are present or where traces of stibine have been reported. The three most important mines in the past were: Tafone, Macchia Casella and Montauto: As already mentioned, much of the production was supplied by the Tafone mine. The Tafone deposit was grown through two open pits (Northern Tafone and South Tafone). To the north-east of the antimony area, the mixed sulphide filter of Ponte San Pietro has been explored underground showinf high gold and silver concentrations.

Project

The project will initially be carried out through two parallel actions: (1) archive consultation and digitalization phase (collection of past data); (2) field exploration phase (mapping and collection of new data and samples). These two activities will be progressively and iteratively supported by laboratory studies (geochemical and mineralogical/petrographic analysis). All the information collected will then be merged into a 3D geological model (of some specific sites) and transformed into a new conceptual genetic model of antimony mineralization of the Maremma District.

1) COLLECTION AND DIGITALIZATION OF PREVIOUS DATA

Previous studies will be collected, screened, selected, summarized and reformulated. The Tuscany Region's mining archive contains an enormous number of reports, maps, geological sections, survey logs and chemical analyses that were produced by the mining companies which, in the past, managed exploration and extractive activities. A considerable amount of data is also available in the RIMIN archive.

In this case data refer to exploratory work carried out in the years 1980-90 to assess the auriferous potential of the Antimony District.

The material collected will have to be reviewed, revised and reprocessed in order to consider the latest scientific evidence in the field of the considered ore deposits. The data will also be digitalized. Particular attention will be devoted to the survey logs, the geological-geochemical sections carried out at the various stages of mining and each geological-geochemical surface data.

2) FIELD ACTIVITY

Detection and sampling campaign in some limited areas of the district will be carried out, focusing mainly on defining the geometries of orebodies, hydrothermal alteration zones and tectonic structures that constrain the volumes of rock subject to hydrothermal processes. The soil work will be supported using portable XRF for the in-situ identification of mineral phases and real-time measurement of the concentration of their constituent elements. These data will be used to relate the 3D geological model based on surveys, maps and past mining sections. At the same time, representative samples of the different types of antimony mineralization (massive, disseminated, stockwork) will be collected. Detailed petrographic, mineralogical and geochemical analyses will be carried out.

3) LABORATORY ANALYSIS

Petrographic and mineralogical analyses by optical microscopy, Scanning Electron Microscopy (SEM-EDS, WDS and dual eBeam + MicroXRF), catodoluminescence and dust diffractometry will be carried out. Laboratory investigation campaign to verify the presence and concentration of antimony and gold and other associated metals (Cu, Pb, Zn, Tl, As, Ba, etc.). Geochemical analyses of samples of orebodies and host rocks will be carried out using the most advanced analytical techniques available in Italy (ICP-MS, LA-ICP-MS; after milling and chemical attack and/or melting). On a selection of samples analyzed for geochemistry, isotopic analyses (Pb, Sr, Nd, B, O, H, C) will be carried out to develop the final conceptual model and to define the isotopic footprint of antimony mineralization, which is useful for the future management of possible exploratory/extractive activities and for defining the underlying values for land management in case of environmental problems.

4) GEOLOGICAL AND CONCEPTUAL MODEL

All geological, mineralogical and geochemical data collected in the three key areas of Tafone, Macchia Casella and Montauto will feed a 3D geological model that will allow easy visualization of orebodies and their relationship with tectonic structures. The 3D model will make it easier to assess the most promising areas where to concentrate future exploration activities for the identification of new, non-sharp mining bodies or the lateral and deep extension of the known ones. The 3D model will also allow calculations of the volume of high-content residues as well as low-content areas that have been discarded from past mining activities.

At the end of the investigation plan, a detailed report will be drawn up providing a comprehensive overview of the results obtained, the potential of the areas investigated and the methodologies of the subsequent exploration phases.

5) DATA MANAGEMENT AND RETURN OF RESULTS

All products will be made in accordance with the standards defined by the project coordination and with the criteria described in Chapter 4.

Quarterly reports will be provided on the progress of the work.

At the end of the investigation plan, a detailed report will be drawn up providing a comprehensive overview of the results obtained, the potential of the areas investigated and the methodologies of the subsequent exploration phases.

Expected results are:

a) Database of existing historical mining/geological/geochemical data (Sb mineralization) in the entire study area with integration of new data produced by this project. Compatible with ISPRA and regional databases.
b) 3D geological model of the three main past mining sites (Tafone, Montauto and Macchia Casella) with the corresponding calculation of the remaining high-content mineral reserves and the potential volumes of low-content ore.
c) Conceptual formation model of antimony mineralization in the Maremma district and definition of areas with the greatest potential to discover new not-outcropping bodies.

Possible extension in Phase 2 and 3

Based on the results of the first investigation plan behind this project, it will be possible to continue the exploration and application process of established and newly designed instrumental exploration and analysis methodologies. These operations may include:

1) Geophysical (geoelectric) exploration in limited areas with high potential for discovering new not-outcropping bodies
2) Geochemical and fluid inclusions studies of antimony mineralization on samples collected on a as much as possible regular grid at the scale of the entire area and in high spatial resolution transects in the three main fields, to define the district's thermal status, possible geochemical zoning and the potential identification of feeding areas for the Paleo-hydrothermal system.

Expected impacts

Phase 1:

Science, mining and technology:

- Significant improvement of understanding of metallogenic processes of antimony orebodies
- Increase in previous knowledge using regional and local archives
- Revision of conceptual models, also based on modern international outlook, with possible extension of research into previously excluded areas based on old models
- Field training of experts and researchers with human capital growth specialized in mineral exploration and related disciplines.

Social impact:

- Dialogue with the public and dissemination of science-based information on the sustainability criteria for extractive activities

Phase 2-3

Science, mining and technology:

- Development of innovative technologies for the exploration and extensive application of artificial intelligence
- Scientific collaborations between national universities/EPRs.

Economic and social:

- Increasing investments in the mining system following the provision of basic elements on deposits in the studied area
- Attracting foreign investments stimulated by exploration results
- Regional economic diversification with possible restart of other sectors of activity
- Increasing interest in mining and increasing visitors to mining parks/museums
- Stimulating the creation and growth of local businesses for the provision of goods and services for mineral exploration
- Training of new local professionals, graduates, and associations of professionals specialized in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and dissemination of criteria and methods to minimize impact of exploration activities on the environment

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7) MAGNESITE DEPOSITS IN CENTRAL TUSCANY

The project aims to investigate the mining potential of a group of mine sites located in Central Tuscany. These mines produced a significant amount of magnesite during the first half of the 20th century. Total production is not well known but is around 1.5 million tons of magnesite (at current price, a nominal value of EUR 0.2 billion). Production was mainly supplied by the mines of Castiglioncello (LI) and Querceto (SI), but smaller fields are known in many other locations. Magnesite deposits were developed and exploited during the two World Wars but were quickly abandoned for market reasons without being fully explored using modern methods (drills, geophysics). Given the size of the district, there is still a high potential to discover new bodies enriched in magnesite. The mineral extracted had a high magnesite content (70-95 % by volume), with fewer dolomite and calcedony. The mining reports of the cultivation period, and the scientific studies carried out over the last 20 years, show that significant portions of the orebodies were not exploited. The aim of the project is to reassess the residual volumes of the magnesite veins of central Tuscany using the data available in the Tuscany mining archives and in the RIMIN database. There is good mining documentation with surface maps and geological sections, but there is no exploratory survey. A positive aspect of these deposits is the good accessibility of underground environments that allow a direct view of the orebodies in depth and their 3D reconstruction. The mining data will then be enhanced with new petrographic and geochemical surveys and analyses to be carried out as part of the project. All data will be integrated into a new 3D geological model of the mining bodies of the two main mining sites (Castiglioncello, Querceto). The definition of geometries/volumes of the main high-grade orebodies (veins) will be also accompanied by evaluation of low-content magnesite stockworks at the border with the main veins.

The project aims to develop a conceptual genetic model that helps to define the likelihood of lateral and deep continuation of known vein orebodies and the potential for discovery of new not-outcropping veins.

State of art

Main Raw Materials: magnesium;

Critical Raw Materials: magnesium;

Strategic Raw Materials: –

Other *commodities*: –

Location: Central Tuscany

Geology: The magnesite ore deposits in central Tuscany are located within kilometric lenses of Serpentinite incorporated in the argillitic formation of Ligurian units. The fields consist of subvertical lines approximately N-S confined to serpentinitic lenses (Rielli et al., 2022). Their texture is consistent with deformation processes, which are located in the most competent ophiolitic formations and are linked to the extensive tectonics which affected the Apennine chain from the medium to upper Miocene (Figure 26).

Ore geology: massive veins of white or cream-colored cryptocrystalline magnesite, often brecciated and cemented by dolomite stockworks. Locally, the veins are enriched in calcedony, which occurs as late filling of cavities and as a replacement for massive magnesite (Boschi et al., 2009). The veins thickness range from few decimetres to 15 metres and in some cases (Castiglioncello) can be followed for few kilometres (Figure 27). The upper part of the veins ends abruptly against claystone by developing intensively brecciated volumes. Contact serpentinites are intensively argillified (smectite) and silicized (opal CT) and then crosscut by multiple stockwork of dolomite and magnesite.

Mines: around 20 localities, spread over an area of approximately 1 400 km^2 between the Tyrrhenian coast and Val d'Elsa. The most important mines in the past were: Castiglioncello and Querceto. The development of underground extractive complexes is limited and the base of the vein orebodies has never been reached or explored. The deep potential of these mining bodies is therefore unknown.

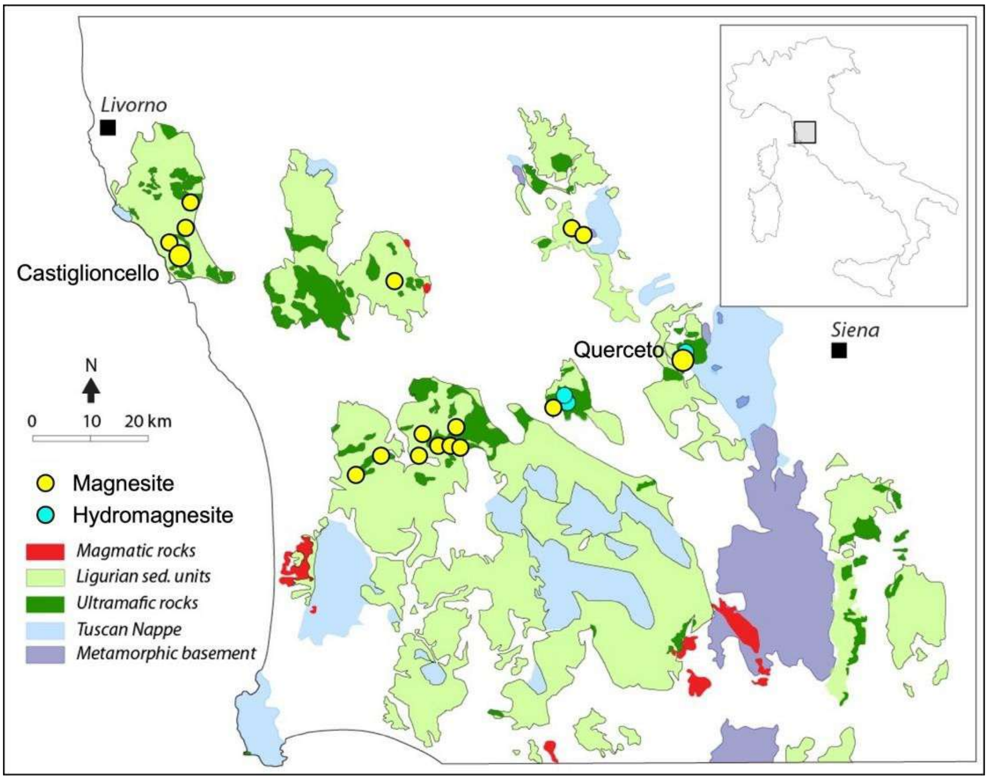

Figure 26 - Location of magnesite mineralization hosted in central Tuscany serpentinite rocks.

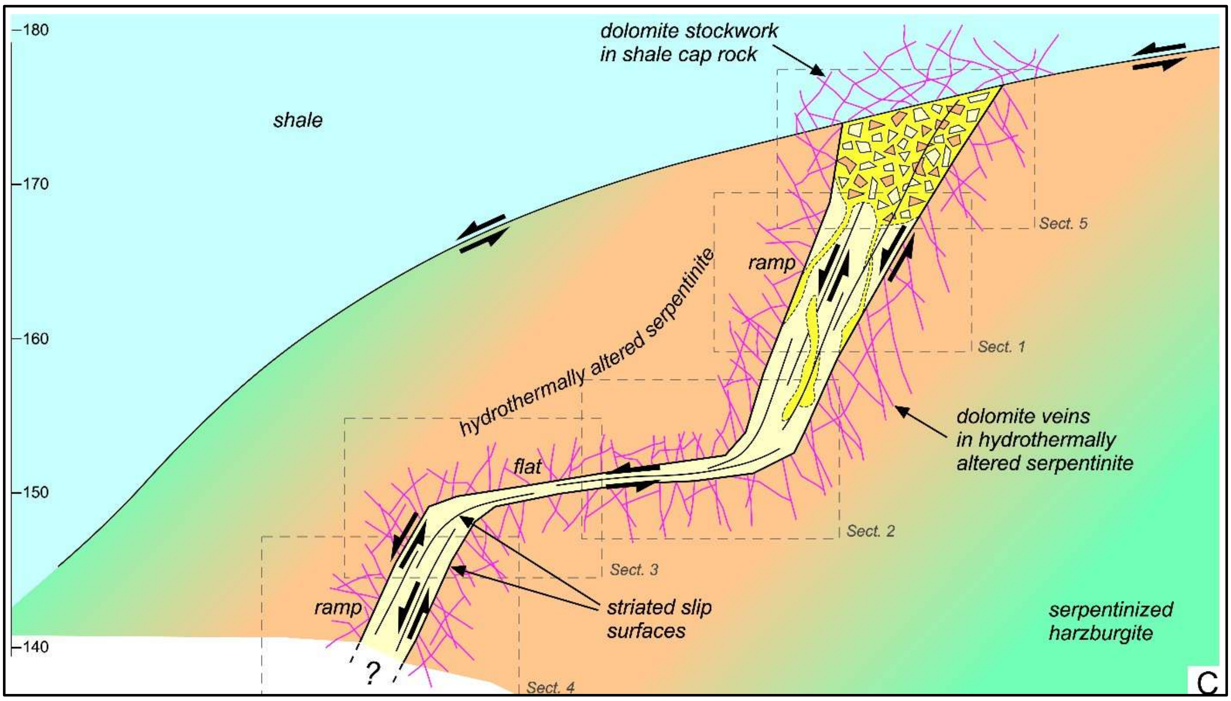

Figure 27 - Interpretative section of one of the magnesite veins in the Castiglioncello mine.

Project

The project will initially be carried out through two parallel actions: (1) archive consultation and digitalization phase (collection of past data); (2) field exploration phase (mapping and collection of new data and samples). These two activities will be progressively and iteratively integrated by laboratory studies (mineralogical-petrographic and geochemical analyses). All the information collected will then be integrated into the 3D geological model (of some specific sites) and transformed into a new conceptual genetic model of the central Toscana magnesite mineralization.

1) COLLECTION AND DIGITALIZATION OF PREVIOUS DATA

Previous studies will be collected, screened, selected, summarized and reformulated. The Tuscany Region's mining archive contains a significant amount of reports, maps, geological sections, which were produced by mining companies which, in the past, managed exploratory and extractive activities. Some reports are also available in the RIMIN archive. In this case, the data refer to the exploration work carried out in the 1980-90s to assess the auriferous potential of these hydrothermal systems.

The collected material will be reviewed, revised and reprocessed based on the latest scientific evidence in the field of the types of mineral deposits in question. The data will then be digitalized.

2) FIELD ACTIVITY

Detection and sampling campaign will be carried out in some limited areas of the district, focusing mainly on defining the geometries of mining bodies, hydrothermal alteration zones and tectonic structures that constrain the volumes of rock subject to hydrothermal processes. The field work will be supported using Portable XRF for the on-site identification of mineral phases and for the real-time measurement of the concentration of certain elements of interest. This data, together with previous information, will be used to create a strong 3D geological model of the two main locations (Castiglioncello and Querceto). At the same time, representative samples of the different types of magnesite mineralization (veins and stockworks in the host rocks) will be collected. Detailed petrographic, mineralogical and geochemical analyses will be carried out.

3) LABORATORY ANALYSIS

Petrographic and mineralogical analyses by optical microscopy, scanning electron microscopy (EDS, WDS and dual eBeam + MicroXRF auxiliary microscopy), catodoluminescence and dust diffractometry will be carried out. Laboratory investigation campaign aims to verify the presence and concentration of any other associated metals (Ni, Cr, Cu, Au, etc.). Geochemical analyses of samples of altered mineral bodies and rocks will be carried out using the most advanced analytical infrastructure available in Italy (ICPMS, LA-ICPMS; after milling and chemical attack and/or melting). Isotopic analyses (Pb, Sr, Nd, B, O, H, C) will be carried out on a selection of samples analyzed for geochemistry to develop the final conceptual model and to define the isotope footprint of magnesite mineralization, which is useful for the future management of possible exploratory/extractive activities and for defining the underlying values for land management in the event of environmental problems.

4) GEOLOGICAL AND CONCEPTUAL MODEL

All geological, mineralogical and geochemical data collected in the two key areas of Castiglioncello and Querceto will be integrated into a 3D geological model that will allow easy visualization of mining bodies and their relationships with tectonic structures. The 3D model will facilitate the assessment of the most promising areas where to concentrate future exploratory activities for the identification of new, not outcropping orebodies or of the lateral and deep continuation of known ones. The 3D model will also make it possible to calculate the volume of high-content residues as well as low-content areas that have been discarded so far from past mining activities.

5) DATA MANAGEMENT AND RETURN OF RESULTS

All products will be made in accordance with the standards defined by the project coordination and with the criteria described in Chapter 4.

Quarterly reports will be provided on the progress of the work .

At the end of the investigation plan, a detailed *report* will be drawn up providing a comprehensive overview of the results obtained, the potential of the areas investigated and the methodologies of the subsequent exploration phases.

Expected results are:

a) Database of pre-existing mining/geological/geochemical data in the entire study area with integration of the new data produced by the project. Compatible with ISPRA and regional databases.

b) 3D geological model of the two main mining sites of the past (Castiglioncello and Querceto) with related calculation of residual high-content ore reserves (veins) and potential volumes of low-content ore (stockwork).

c) Conceptual formation model of central Tuscany magnesite mineralization and definition of the potential for deep continuation of new mining bodies. Assessment of areas favorable to the discovery of new not-outcropping orebodies.

Possible extension in Phase 2 and 3

Based on the results of the first investigation plan behind this project, it will be possible to continue the exploration and application process of established and newly designed instrumental exploration and analysis methodologies. These operations may include: :

1) Geophysical exploration (ground and drone magnetometry) in limited areas with high potential for discovery of new not-outcropping orebodies or for possible lateral and deep extension of known bodies.

2) Geochemical and fluid inclusions study of magnesite mineralization on samples collected on a as much as possible regular grid at the scale of the entire area and in high spatial resolution transects in the two main fields, to define the district's thermal status, possible geochemical zoning and the potential identification of feeding areas for the Paleo-hydrothermal system.

Expected impacts

Phase 1:

Science, mining and technology:

- Significant improvement in the understanding of the metallogenic processes of magnesium mineralized orebodies
- Increase in previous knowledge using regional and local archives
- Revision of conceptual models, also based on modern international outlook, with possible extension of research into previously excluded areas based on old models

- Field training of experts and researchers with human capital growth specialized in mineral exploration and related disciplines.

Social impact:

- Dialogue with the public and dissemination of science-based information on the sustainability criteria for extractive activities

Phase 2-3

Science, mining and technology:

- Development of innovative technologies for the exploration and extensive application of artificial intelligence
- Scientific collaborations between national universities/EPRs.

Economic and social:

- Increasing investments in the mining system following the provision of basic elements on deposits in the studied area
- Attracting foreign investments stimulated by exploration results
- Regional economic diversification with possible restart of other sectors of activity
- Increasing interest in mining and increasing visitors to mining parks/museums
- Stimulating the creation and growth of local businesses for the provision of goods and services for mineral exploration
- Training of new local professionals, graduates, and associations of professionals specialized in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and dissemination of criteria and methods to minimize impact of exploration activities on the environment

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8) FLUORSPAR MINERALIZATION (REE ± BARYTE) OF THE COMAGMATIC ROMAN PROVINCE (LAZIO)

State of art

Main raw materials: fluorspar;

Critical Raw Materials: fluorspar, baryte, Rare earths

Strategic Raw Materials: Rare Earth Elements in particular La and Ce;

Other possible raw materials: V, Y

Geology: The sub-volcanic and sub-surface parts of the alkaline-carbonatitic igneous complexes are known for enrichment in various Critical and Strategic Raw Materials, such as REE, Nb, Y, fluorspar, Sc, V, Zr, etc. (Mitchell, 2015). Hydrothermal/late carbothermal activity in and around the magmatic chamber can play a key role in the concentration of these resources (Anenburg & Mavrogenes, 2018; Stoppa et al., 2019). The Roman Comagmatic Province (RCP), which includes the volcanic complexes of Vulsini, Sabatini, Cimini and Colli Albani, developed between 800.000 and 20.000 years ago, is an example of an alkaline carbonatitic province that can be a possible exploration target for strategic raw materials. Volcanic activity was effusive and pyroclastic, with plinium-type paroxsisms associated with calderic collapse. Erupted magmas are potassium alkalins up to ultrapotassic, mainly represented by tefri-phonolites, phonolites, trachytes and poorly evolved mafic rocks. Deep surveys and studies by sub-volcanic ejecta have shown the presence of syenitic intrusive bodies in the crust under the Vulfino apparatus (Barbieri et al., 1984; Perna et al., 2021). Subvolcanic carbonatites (tuffites) occur in the calderic areas of Bolsena (Forcinelle, Vulsini) and Sacrofano (Ficoreto, Sabatini; Stoppa et al., 2019). Particularly interesting are fluorspar-rich carbothermal deposits associated with carbonatites, which form both veins and larger stratified deposits.

Mines: In the Latera area (Santa Maria di Sala), the fluorspar extraction ended in the 80s, while in the Sasso area (Monte delle Fate and Pian della Carlotta) mining took place around the 70s. The situation is different in Pianciano, where mining, both fluorspar and carbonatite, continued since 1973. The volumes extracted have been increasing over the last ten years (from 95.000 to 107.000 tonnes). Production is intended solely for the cement industry, as the very fine granulometry of the ore has so far prevented the purification of fluorspar from the other associated mineralogical stages (mainly calcite and baryte) and its use for higher-value industrial applications.

Potential of the area

RCP is part of potentially rich potassium alkaline systems in REE and other Critical Raw Materials (Stoppa et al., 2016; Goodenough et al., 2016). In fact, there are carbothermal deposits in the potassium alkaline volcanic districts of Latera, Bracciano and Sacrofano.

Fluorspar (fluoritites) enriched in REE, V, Y and the presence of potential low-content REE deposits has been known since the 80s (Rimin, 1989; Locardi et. as at 1991). Fluoritites, occurring both as vein bodies (Mt area. Ceriti) and carbothermal stratiform deposits associated with carbonatites are distributed over a main band from Latera to the south-east to Bracciano and continues to the outskirts of Rome (loc. Farnesina). Other outcrops are located north of Latera (Lake Mezzano) and east of Viterbo (Pian Auta) (Mastrangelo, 1976; Zucchetti, 1972, Rimin, 1989). Overall, fluoritites associated with carbonatites can be found in an approximately 40 km wide and 100 km long area (Figure 28), although the continuity of deposits has not yet been confirmed by a detailed geological survey. The Rimin study (1989) and subsequent research (Stoppa et al., 2016, 2019) highlighted the presence of REE, mainly La and Ce, especially in stratiform carbonatitic fluorititic deposits, where concentrations can reach between 0.3 and 0.5 wt%. In addition, the presence of apatite, baryte and Ce-vanadates suggests a possible interest in the recovery of additional raw materials, including V and Y.

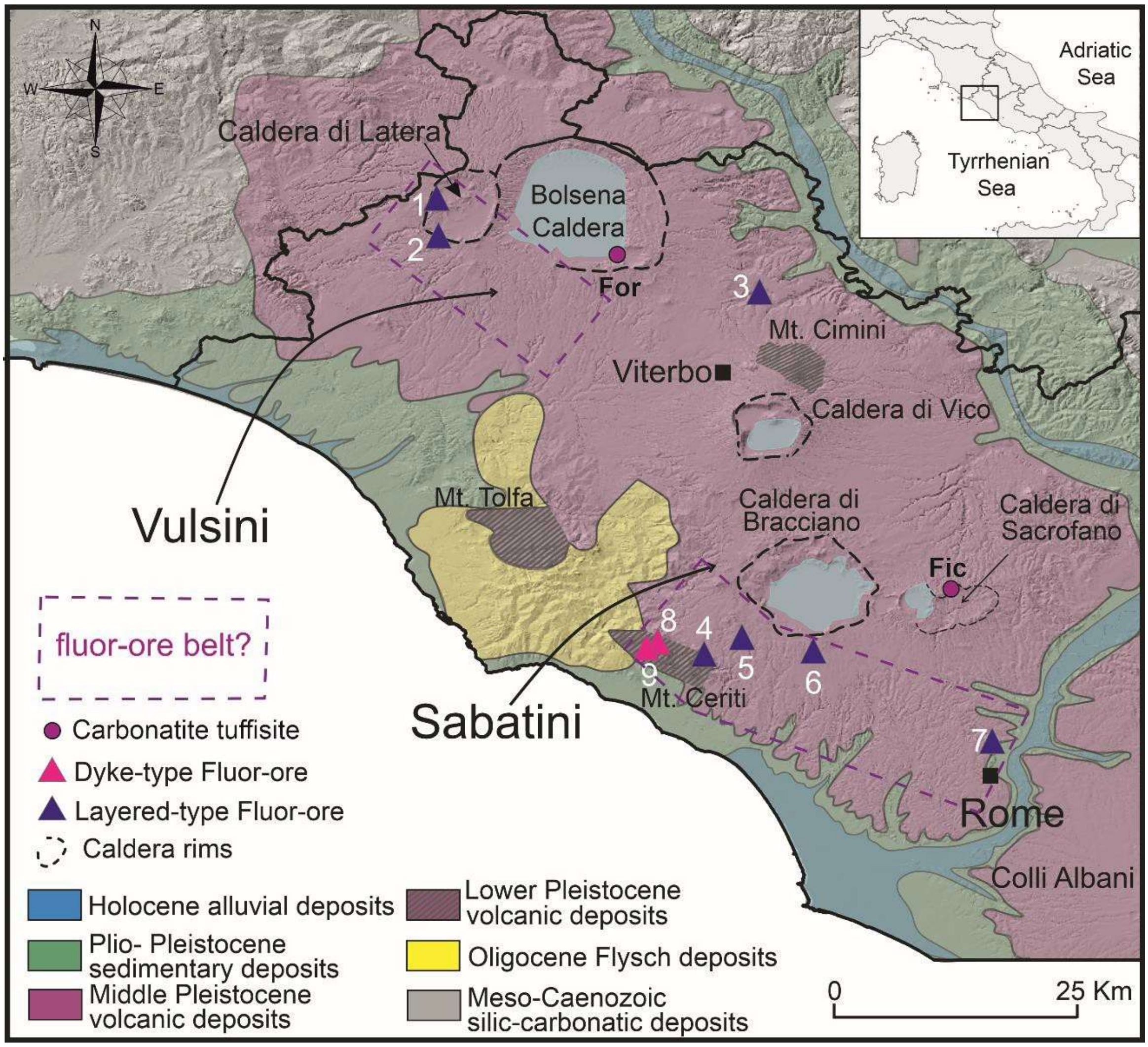

Figure 28 - Geological Sketch of the Romana Comagmatic Province (Parlapiano F., currently under submission), with areal distribution of fluoritites; 1 - Lake Mezzano; 2 - Santa Maria di Sala (and Aquaforte); 3 - Pian Aùta; 4 - Castel Giuliano; 5 - Pianciano; 6 - Cornazzano; 7 - Farnesina; 8 - Monte delle Fate; 9 - Pian della Carlotta; For - Forcinelle; FIC - Ficoreto.

Activities

1) BIBLIOGRAPHIC STUDIES

Research and critical analysis of the bibliography relating to both Lazio fluoritites and fluoritites of carbothermal origin in other geological contexts (mainly China and Brazil). Collection and processing of geological, mineralogical and geochemical data on Lazio carbonatites and fluoritites contained in the Rimin report (1989), geo-referencing of data and development of a GIS project. This project will be the basis for the planning of subsequent campaign activities.

2) FIELD ACTIVITIES

Geological survey for the purpose of locating stratiform fluorititic and carbonatitic deposits in the area between Latera and Rome and in the Viterbo area, in order to define their thickness, extent and continuity and the tectonic structures responsible for the rise of carbothermal fluids. Systematic sampling on representative sections with definition of their mineralogy, with particular detail of the fluorspar to carbonate ratio and assessment of content in baryte, apatite and vanadates. Comparison of standard sections for the definition of their characteristics in the ore geology field. Development of a thematic geological map. Preliminary estimate of quantities.

3) LABORATORY ANALYSIS

Petrographic studies with optical microscope will be carried out. Definition of a separation protocol with chemical attacks for the selective removal of the phases associated with fluorspar and the extraction of REE. Semi-quantitative SEM-EDS mineralogical analyses for the definition of the main and accessory minerals and the distribution of the REE. Preparation of compositional maps. XRD mineralogical analysis with internal standard for the definition of mineralogy of fluorititic and carbonatitic deposits, supplemented with SEM-EDS observations. These activities will be developed within the DATA laboratory of the Department of Science of the G. d'Annunzio University of Chieti-Pescara.

Geochemical analyses on total rock using XRF and ICP-MS. Analysis of eluates in ICP-MS and quantification of extracted rare earths. SEM-WDS mineralogical analyses for the quantification of REE and any other Critic Raw Materials. In collaboration with the Geosciences Department of the University of Padua. Analysis of stable isotopes in carbonates (C and O) in collaboration with CNR, Montelibretti Unit. Radiogenic isotope analysis (Sr, Nd) in collaboration with Dip. Earth Sciences La Sapienza University (Rome).

4) DATA MANAGEMENT AND RETURN OF RESULTS

The first aim of the proposed research is to define the area development of secular fluorititici-carbonatitic deposits, estimating the thicknesses and giacimentological potential for LREE (La. EC) and V and Y. The GIS platform will be set up: the outcrop and the geological map, accompanied by georeferenced photos. All products will be produced in accordance with the standards defined by the project coordination and with the criteria described in Chapter 4.

The progress report will be the subject of a quarterly report.

In conclusion, a final report will be produced with descriptions of lithotypes, details of stratigraphies and explanatory geological sections and petrographic, mineralogical and geochemical data.

The collected campaign and laboratory data will be used to develop a petrogenetic-ore geology model of latial fluorititic-carbonatitic deposits. This model is of particularly relevant as the carbothermal process is poorly studied and potentially applicable in other similar geological contexts as well as in Italy (e.g. Vulture, Ernici?) and abroad.

Possible extension in Phase 2 and 3

Based on the results obtained, it will be possible to plan more in-depth and localised surveys (e.g. drilling surveys, seismic lines). Ore geology data will also provide an opportunity to assess the possibility of REE recovery and to test extraction and exploitation methods with a low environmental and sustainable impact.

Based on the developed model, it will be possible to extend the research and exploration to areas with similar geo-lithological and structural characteristics not covered by this project, such as the Mt district. Ernici, and Mt. Vulture.

Expected impacts

Phase 1:

Science, mining and technology:

- Significantly improved knowledge of the mining potential of fluorspar/baryte and REE mining in the Roman Comagmatic Province
- Increase in past knowledge using regional and local archives
- Revision of conceptual models with possible extension of research into excluded areas based on old models
- Training of experts and researchers in the field with human capital growth specialized in mineral exploration and related disciplines.

Social impact:

- Dialogue with the public and dissemination of scientifically correct information on the sustainability criteria for extractive activities

Phase 2-3

Science, mining and technology:

- Assessment of the possible lateral and deep evolution of deposits, based on planned surveys and insights.
- Development of innovative technologies for the exploration and extensive application of artificial intelligence
- Scientific collaborations between national and international universities/LRAs

Economic and social:

- Increased investment in the mining system resulting from the provision of base elements on deposits in the study area
- Attracting foreign investments stimulated by exploration results
- Regional economic diversification with possible restart of other sectors of activity
- Increasing interest in mining and increasing visitors to mining parks/museums
- Involvement of local mining companies for possible interest in Lazio fluorites
- Business involvement for industrial minerals and recovery action for extractive waste
- Stimulating the creation and growth of local businesses for the provision of goods and services for mineral exploration
- Training of new local professionals, graduates, and associations of professionals specialized in mining research
- Creation of new professional opportunities

Environmental impacts:

- Development and dissemination of criteria and methods to minimize environmental impact of exploration activities
- Removal/mitigation of environmental concerns related to the presence of extractive waste

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9) INDUSTRIAL MINERALS AND CRITICAL ELEMENTS IN QUATERNARY VOLCANIC ROCKS IN THE CAMPANIA REGION

The project aims to assess and expand knowledge on the mining potential for industrial minerals and critical elements (zeolites, feldspars, and their contents in terms of Rare Earth Elements and lithium) in the Campania Region. In particular, reference will be made to Quaternary volcanic deposits widely spread in central and southern Italy, consisting of volcaniclastic and pyroclastic deposits, often deeply affected by marked syn- and post-depositional minerogenetic processes, which have also led to the transformation of reactive volcanic glass into minerals of the zeolite family (De Gennaro et al., 2000; Cappelletti et al., 2003; Langella et al., 2013). These deposits have been intensively exploited over the past decades, mainly for use as building stone, owing to their low cost, low density, and favourable mechanical and thermal insulation properties (De Gennaro and Langella, 1996).

Regarding these deposits, there is a strong scientific background in the literature, both in terms of mineral petrography and volcanology, supporting the possibility of a renewed exploitation strategy. Recent assessments highlight the presence of glass, zeolitic and feldspathic phases that could include critical elements to an appreciable extent. Established and potential uses of these industrial minerals (for example, zeolites used in animal feed and agriculture in current applications, and pharmaceutical and environmental remediation for potential innovative uses) are the starting point for a future exploitation strategy, together with the assessment of critical content, which still requires systematic evaluation.

State of art

Main Raw Materials: zeolites

Critical Raw Materials: feldspars

Strategic Raw Materials: Rare earths, lithium

Location: Campania (volcanism linked to the activities of the Campi Flegrei)

Geology: Trachytic ignimbrites in zeolitised and feldspathized facies of Quaternary age (mainly Campanian Ignimbrite and Tufo Giallo Napoletano deposits, ~40,000 years ago) (Figure 29).

Ore geology: The fields potentially affected by the study are mainly those linked to the huge volcanic deposits created by Quaternary eruptions, widely distributed in the Campania Region (in all its provinces, but mainly in Caserta and Benevento, which are less affected by the intense urbanisation of the Region). These have already been exploited, as mentioned above, mainly for the extraction of building blocks. The content of the zeolitic phases of interest (mainly phillipsite, cabasite, but also analcime) and feldspar (mainly potassic) has been extensively studied in these deposits, but little attention has so far been paid to their critical content, especially in zeolites, which by their nature could be considerably enriched in some critical elements (REE and potentially lithium, given the selective exchange capacity of certain zeolites). The potential content of elements of interest in feldspar, both primary and authigenic (especially in the feldspathised facies of the Campanian Ignimbrite), should also not be overlooked.

Mining: There are currently few surviving quarries compared to the many extractive sites (more than 100) that were active from the 1950s (some of them still in operation until the 2000s; PRAE Campania Region, 2006), but there is no doubt that potential mining sites are widespread. Indeed, the lithostratigraphic structure of the Campania Region is highly influenced by the presence of volcaniclastic deposits associated with Phlegraean eruptions, which have produced large volumes over a wide area. The provinces of Caserta and Benevento, followed by Naples and Avellino and extending to Salerno, represent outcrops to be investigated both for scientific purposes and for a possible exploitation strategy. The sectors to be identified could therefore cover a very large part of the provinces of Caserta and Benevento, in which both grey (feldspathised) and yellow (zeolitised) facies are located. Currently, the only mining activities still active concern geo-environmental recovery projects of previously exploited sites (Figure 30)

Project

The reasoned assessment of the content of critical elements in the rocks of the deposits described above is certainly the primary objective, but, similarly, a study will be carried out on the use of such materials (whether zeolitised or feldspathised) as potential substitutes for melters in modern ceramic processes (De Gennaro R. et al., 2007; Pansini et al., 2010), and in all possible applications in strategic fields using these steps.

The implementation of the investigation plan provides for a systematic re-evaluation of all possible zeolitic and feldspathic raw materials linked to the Quaternary magmatism of Campania (with the exception of those currently covered by mining concessions or active research permits) in the light of current processing technologies and product criteria for the various uses. A targeted approach will be applied to the full exploitation of deposits and thus to the valorisation of by-products that may contain critical and strategic raw materials (REE-Lithium).

The activities will be structured as follows:

I. study and development of past knowledge on raw materials (zeolites, feldspars, REE, Li) with identification of the most promising deposits;

II. geological survey campaign and targeted sampling of deposits/sites identified on the basis of the previous point;

III. laboratory analysis of the samples collected for their basic characterization;

IV. technological tests with enrichment and separation of the mineralogical phases identified, in order to assess their application potential.

The planned activities will be carried out using the scientific expertise present at the Federico II University of Naples (Department of Earth, Environment and Resources Sciences), the University of Benevento (Department of Science and Technology), and the National Research Council (CNR) (Institute of Science, Technology and Sustainability for the Development of Ceramic Materials).

1) EVALUATION AND SUMMARY OF PREVIOUS STUDIES

By carrying out a thorough analysis of existing studies and mapping the deposits of interest (identified and potential), the areas for extracting minerals contained in the rocks under investigation can be delimited, by reprocessing and updating the giacimentological information (in terms of availability and content of phases and elements of interest), both on the basis of new data and by completing knowledge using new and up-to-date technologies that will make it possible to outline new scenarios for the applications of the identified resources. In particular, the focus will be on the different lithofacies in the region, taking into account the specificities resulting from the different mineral processes that affected the deposits, referring to the relevant areas of pyroclastic rocks shown in the figure below.

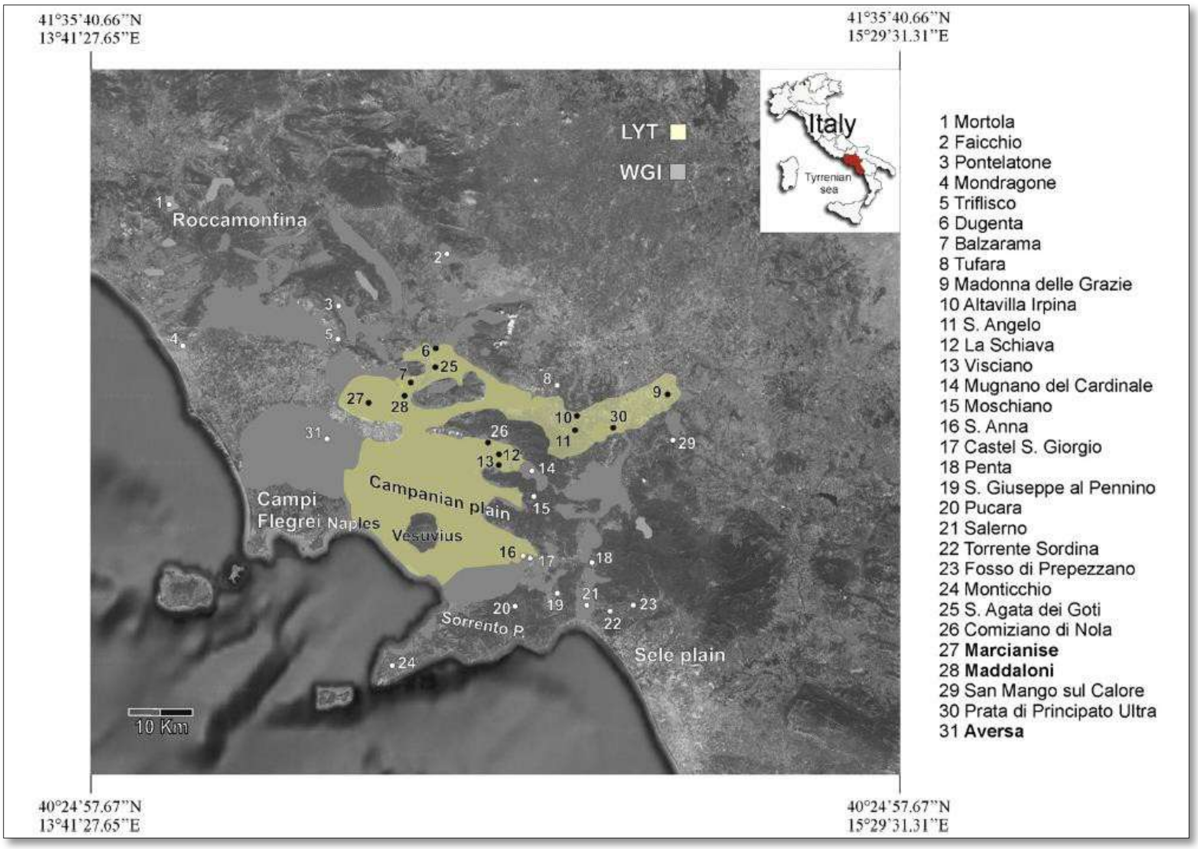

Figure 29 - Sketch of the outcrops of the Campana Ignimbrite and Yellow Tuff.

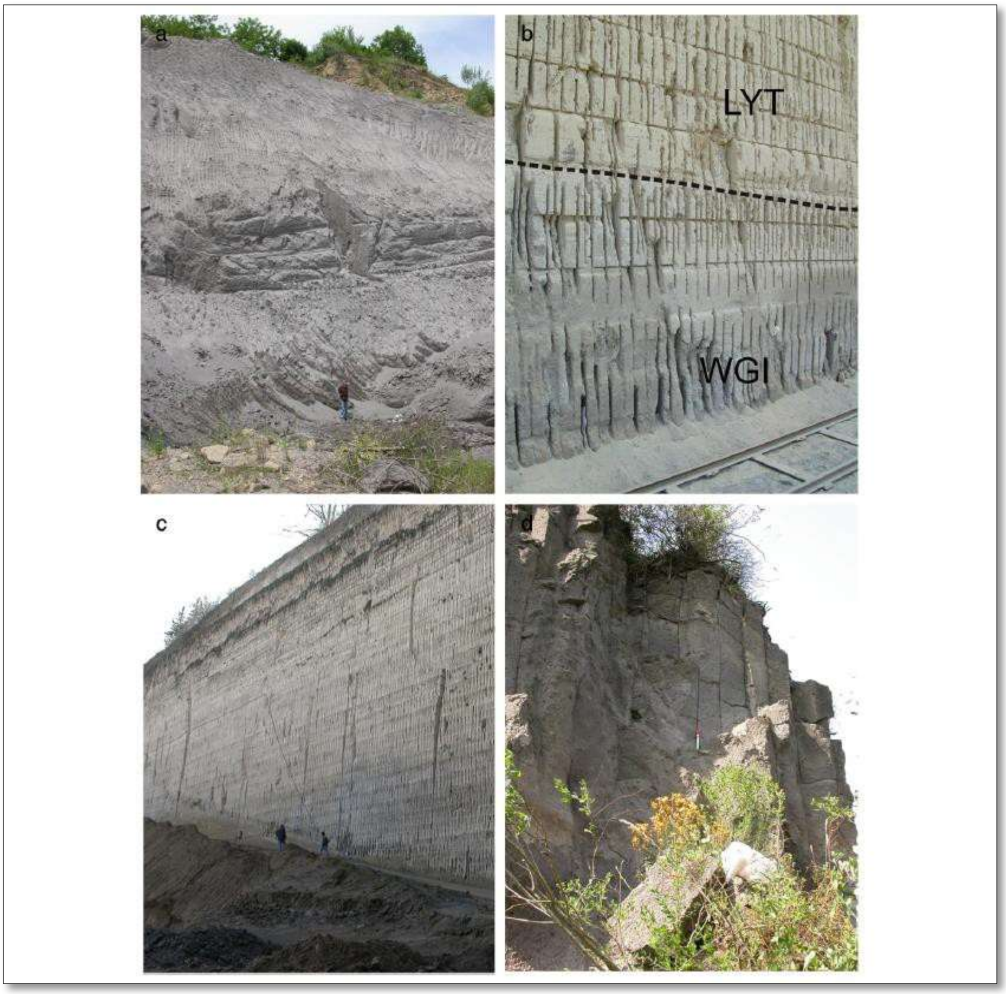

Figure 30 - Examples of quarry fronts and tuff/ignimbrite outcrops.

2) FIELD ACTIVITIES AND SAMPLING

During the survey and sampling activities, thematic maps will be drawn up, helping to define the various lithostratigraphic areas and delimiting the areas of interest. These maps will also indicate the giacimentological characteristics in terms of material availability (exposure, extension and thickness of potential deposits). Detailed sampling will then be carried out, leading to the subsequent laboratory analytical phase.

3) LABORATORY ANALYSIS

The samples will be characterized both on a mineralogical-petrographic basis, in order to verify the presence (in quantitative terms) of the phases of interest, and from the point of view of the abundance of the elements of interest, with particular reference to Rare Earth Elements and others, including Li, B, Ba and Sr, using analytical techniques such as:

- Optical microscopy and SEM electron microscopy with EDS/WDS microanalysis;

- Chemical analysis of major, minor and trace elements of interest by XRF and ICP/MS/OES;
- Qualitative and quantitative mineralogical analysis on total rock and on enriched/separated samples (QXRD);
- Thermogravimetric analysis (TG, DTG, DTA, EGA);
- Assessment of the technological performance of materials prepared for surface modification (cationic exchange capacity, anionic exchange capacity, zeta potential, surface area);
- Heating microscope fusibility tests (HSM);
- Infrared spectroscopy (FTIR);
- Hyperspectral analysis on outcrops to determine the extent of the most mineralized facies;
- Technological behaviour tests in ceramic mixtures (laboratory scale) for the production of porcelain tiles;
- Functionalisation by means of surfactants to prepare for anionic exchange (zero and reverse surface charge process).

4) DATA MANAGEMENT AND RETURN OF RESULTS

All products will be produced in accordance with the standards defined by the project coordination and with the criteria described in Chapter 4.The progress report will be delivered quarterly.The final report will contain, in addition to the results updating the potential of the resources occurring in Campania with regard to zeolites and feldspars, an overview of the availability of any critical elements present in these deposits, which has so far been investigated only to a very limited extent.

Possible extension in Phase 2 and 3

The methodological approach of this project may be replicated, in cooperation with the Research Units for Areas 8 and 10, in other areas of the national territory with large outcrops of volcaniclastic and pyroclastic rocks, in particular:

- Other Plio-Quaternary volcanics of the 'Roman Comagmatic Province' in Tuscany, Lazio and Basilicata (in particular, the volcanic complexes of Monti Vulsini, Monti Vicani, Monti Sabatini, Monte Vulture, Tolfa-Manziate-Cerite, and rhyolites from central and southern Tuscany).

Expected impacts

Phase 1

Science, mining and technology:

- Significant improvement of knowledge on mining potential related to critical (feldspar), non-critical (zeolites, bentonites) industrial minerals and critical raw materials (rare earths, lithium) of Campania.
- Enhancement of past knowledge using regional and local archives.
- Revision of conceptual models with possible extension of research into areas previously excluded based on old models.
- Training of experts and researchers in the field, with growth of human capital specialized in mineral exploration and related disciplines.

Social impact:

- Dialogue with the public and dissemination of scientifically accurate information on the sustainability criteria for extractive activities.

Phases 2–3

Science, mining and technology:

- Assessment of the possible lateral and deep evolution of deposits, based on planned surveys and insights.
- Development of innovative technologies for exploration and extensive application of artificial intelligence.
- Scientific collaborations between national and international universities and research institutions.

Economic and social:

- Increased investment in the mining system as a result of the provision of basic data on deposits in the study area.
- Attraction of foreign investment stimulated by exploration results.
- Regional economic diversification with the possible restart of other sectors of activity.
- Growing interest in mining and increased visitors to mining parks and museums.
- Involvement of local mining companies, in particular for industrial minerals and extractive waste recovery.
- Stimulation of the creation and growth of local businesses for the provision of goods and services related to mineral exploration.
- Training of new local professionals, graduates, and professional associations specializing in mining research.
- Creation of new professional opportunities.

Environmental impacts:

- Development and dissemination of criteria and methods to minimize the environmental impact of exploration activities.
- Removal/mitigation of environmental concerns related to the presence of extractive waste.

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10) FELDSPAR, REE AND INDUSTRIAL MINERALS IN ACIDIC MAGMATIC ROCKS OF SARDINIA

The project aims to improve knowledge on the mining potential for critical raw materials (feldspar, REE) and other industrial minerals (zeolites, bentonites) in Sardinia related to acidic magmatism (Ordovician, Hercynian and Cenozoic). Sardinia is already the largest national producer of sodic feldspar (albitites in the Orani-Ottana district), quartz-feldspathic sands (Florinas Formation in the Sassari area) and bentonitic clays (Oligo-Miocene pyroclastic deposits, S'Aliderru mine, Sassari). In addition, it has started to supply zeolites (Tertiary cineritic pyroclastic flows from northern Sardinia).

In recent decades, several bentonite mines have been exploited and, for short periods, also other sources of feldspathic material (Hercynian granites, rhyolites, Ordovician porphyroids). Although there is a broad geological and petrographic knowledge base on the island's Ordovician, Hercynian and Cenozoic magmatism, there is a lack of a systematic and updated approach covering all possible resources and aligned with current processing technologies and requirements for ceramic melters and other uses. A holistic approach is therefore necessary, aimed at the full exploitation of deposits and the valorisation of by-products that may contain Critical Raw Materials (e.g. REE in magnetic concentrates). The project aims to fill this gap in order to identify resources with the greatest potential for mining exploitation and the areas where operational research should be concentrated.

State of art

Main Raw Materials: fluxes for glass and ceramics_

Critical Raw Materials: feldspar

Strategic Raw Materials: REE

Other commodities: zeolites (clinoptilolites), benthic clays (smectites)

Location: Sardinia (Ordovician, Ercinic and Cenozoic magmatism districts)

Geology: Hercynian batholith (various granitoids, intrusive units and lithological facies); Oligocene-Miocene volcanic complexes (bentonites, rhyolites, zeolitised volcanics, possible epiclastites); Pliocene-Quaternary volcanic rocks (alkaline rhyolites, phonolites, bentonites); Ordovician metavolcanics in the metamorphic basement (porphyroids, metarhyolites).

Ore geology: The focus is on intrusive and effusive facies enabling mineral processing with higher efficiency and lower costs. Among the intrusive units, priority should be given to large fields (leucogranites) or alkali-enriched lithotypes (albitites, syenites, aplites, at least partially albitised; potassium-rich porphyries). In addition to feldspathic content, Rare Earth Elements (REE) should be considered, as their presence in significant concentrations has been documented both in accessory minerals of albitised lithotypes (epidotes, allanites, monazites) that constitute the magnetic fraction during enrichment, and through bulk analyses of phonolitic lithotypes. Regarding effusive units, the focus is mainly on pyroclastics (possibly epiclastic) with widespread zeolitisation and the formation of substantial bentonitic deposits, as well as high-alkali lithotypes (phonolites, alkaline rhyolites, metavolcanics, including hydrothermal alterations).

Mines: There are many active mines extracting sodium feldspar (Orani-Ottana and Buddusò albitites), quartz-feldspathic sands (Miocene sediments from the Florinas Formation) and bentonite (Sulcis, Nurra and Marmilla). In the past, about 20 sites of bentonite and bleaching earths were exploited, and for short periods feldspathic sources were extracted in Baronie and Ogliastra (for bentonites), in Arburèse and Sarrabus (granite), and in Gerrei (Ordovician metavolcanics). There are many quarries for ornamental and aggregate stones, both active and abandoned. The Hercynian magmatism units mainly involve granites and granodiorites from the extractive basins of Arzachena-Luogosanto, Tempio Pausania-Calangianus, Buddusò-Alà dei Sardi, Ovodda-Sarule and other smaller districts. Cenozoic volcanism includes pyroclastites and lava throughout north-western Sardinia; zeolitised pyroclasts form small spotted deposits, while bentonitic clays include, among others, the extensive deposit of Sa'Aliderru (Sassari).

Project

The investigation plan provides for a systematic re-evaluation of all possible feldspathic raw materials related to Ordovician, Hercynian and Cenozoic magmatism in Sardinia (excluding those currently under mining concessions or research permits) considering the current mineral processing technologies and product criteria for ceramic feedstock and other uses. A targeted approach will be applied to the full exploitation of deposits and to the valorisation of by-products that may contain Critical and Strategic Raw Materials (REE).

Activities will be carried out in four successive steps:

- study and development of past knowledge on raw materials (feldspars, bentonites, zeolites, REE);
- geological survey and sampling campaign in the most promising sectors identified;
- compositional and technological characterization of collected samples;
- laboratory-scale mineral processing tests on the most promising samples to further assess application potential.

The scientific and technological expertise to carry out these activities will be provided by the CNR (Institute of Science, Technology and Sustainability for the Development of Ceramic Materials), the Federico II University of Naples (Department of Earth, Environment and Resources Science), and the University of Cagliari (Department of Chemical and Geological Sciences).

1) EVALUATION AND SUMMARY OF PREVIOUS STUDIES

Previous studies will be collected, screened, selected, summarized and reformulated. These represent a very large volume of publications and thematic maps on acidic magmatism (Ordovician, Hercynian and Cenozoic) in Sardinia, including geological, petrographic, geochemical and technological data. The material will be reviewed and reprocessed considering the latest scientific perspectives in the field of raw materials (feldspars, bentonites, zeolites, rare earths), from both a ore deposits geology and mineral processing point of view, and in terms of applications (ceramics, glass, the wide range of bentonites, as well as concentrates containing REE).

The magmatic units assumed to be included in the general framework amount to 70–80 lithologies, covering those listed in the "Ore geology". The main areas covered by the preliminary assessment are shown in Figure 30. We will then select the most promising resources and target 3 or 4 areas of intervention, where the following activities will be carried out (Figure 31)

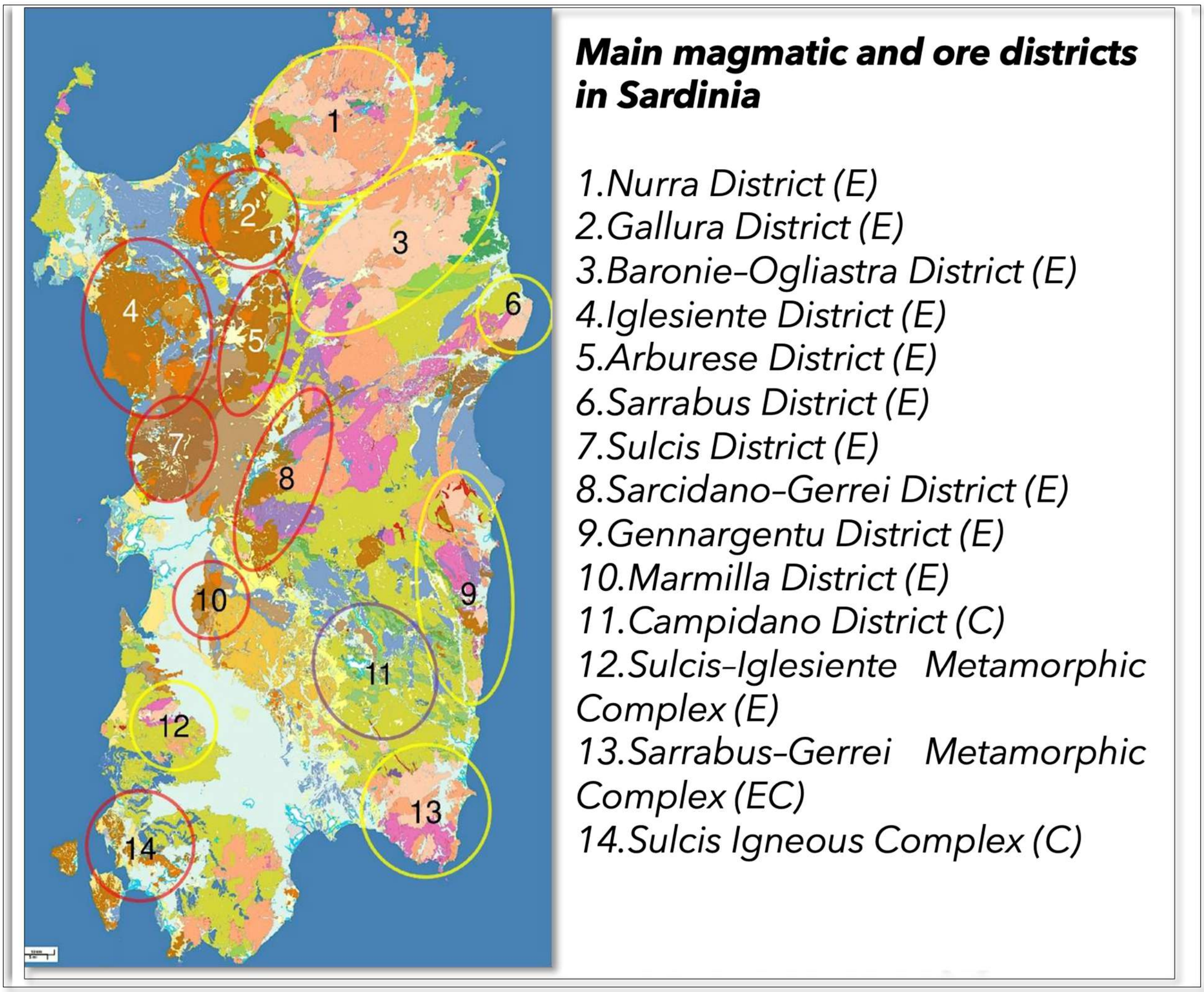

Figure 31 - Main areas, pre-assessed for feldspar, bentonites, zeolites, REE from the Ordovician, Ercinic and Cenozoic acid magmatism rocks (SardegnaMappe lithological map, https://www.sardegnageoportale.it)

2) FIELD ACTIVITIES AND SAMPLING

Resource mapping will be followed by a geological survey and sampling campaign in the areas identified as most promising. The purpose of these activities is to verify the field characteristics of the deposits (exposure, extension and thickness) and to collect representative samples for subsequent analysis and testing.

3) LABORATORY ANALYSIS

Laboratory investigations will be carried out on the samples to verify the presence and concentration of CRMs and other useful minerals of potential economic interest. The campaign may include various survey methods and use both university laboratories and external organisations and companies. Investigation methodologies may include:

- study of macroscopic samples and optical/SEM microscopy with EDS;
- chemical analysis of major, minor and trace elements (XRF, ICP-MS);
- qualitative and quantitative mineralogical analysis on total rock (XRD);
- heating microscope fusibility tests (HSM).

For the most promising samples, based on compositional analysis:

- mineral composition and grain-size analysis to define liberation targets and guide purification and concentration processes;
- technological behaviour tests in ceramic mixtures (laboratory scale) for porcelain tile production;
- technological tests (laboratory scale) on zeolitised and clay (bentonite) samples;
- mineral processing tests (laboratory scale, possibly pilot scale).

4*) DATA MANAGEMENT AND RETURN OF RESULTS*

All products will be produced in agreement with the standards defined by the project coordination and with the criteria described in Chapter 4.

Progress will be reported quarterly.

At the end of the activities, a final report will be drawn up, providing a comprehensive overview of the results for each of the resources considered (feldspars, bentonites, zeolites, REE), highlighting the mining potential of Sardinia in general and of the areas specifically investigated.

Possible extension in Phase 2 and 3

The methodological approach of this project may be replicated in other areas of Italy with extensive outcrops of acidic magmatic rocks, namely:

- Plio-Quaternary volcanics of the Roman Comagmatic Province in Tuscany, Lazio, Campania and Basilicata (in particular, the volcanic complexes of Monti Vulsini, Monti Vicani, Monti Sabatini, Campi Flegrei, Monte Vulture, Tolfa-Manziate-Cerite, and rhyolites from central and southern Tuscany);

- Granites and differentiated acidic rocks (and their metamorphic equivalents) related to Hercynian magmatism of the Calabro-Peloritano Arc (in particular, intrusive and metamorphic units of Sila, Serre, Aspromonte and Monti Peloritani);

- Products of acidic magmatism of the Alpine Arc (Ordovician, Hercynian, Triassic and Cenozoic), represented by a wide range of lithologies (intrusive, effusive and metamorphic equivalents), mainly in Liguria, Piedmont, Lombardy, Trentino-Alto Adige and Veneto.

Expected impacts

Phase 1 –

Science, mining and technology:

- Significant improvement of knowledge on the mining potential related to critical (feldspar), non-critical (zeolites, bentonites) industrial minerals and Critical Raw Materials (REE) in Sardinia.
- Enhancement of past knowledge using regional and local archives (Ente Minerario Sardo/Progemisa/IGEA, Sardinian Mining Association, Regional Archives).
- Revision of conceptual models with possible extension of research into areas previously excluded based on old models.
- Training of experts and researchers, with growth of human capital specialized in mineral exploration and related disciplines.

Social impact:

- Revitalisation and enhancement of the mining/geotechnical specialization of the Giorgio Asproni Institute of Higher Education – Enrico Fermi of Iglesias, increasing local technical and professional skills.
- Dialogue with the public and dissemination of scientifically accurate information on the sustainability criteria for extractive activities.

Phases 2–3 –

Science, mining and technology:

- Assessment of the possible lateral and deep extension of deposits, based on planned surveys and analyses.
- Development of innovative exploration technologies, with extensive application of artificial intelligence.
- Scientific collaborations between national and international universities and research institutes.

Economic and social:

- Increased investments in the mining sector as a result of the availability of fundamental data on deposits in the study area.
- Attraction of foreign investments stimulated by exploration results.
- Regional economic diversification with the possible restart of other industrial sectors.
- Increased public interest in mining and higher numbers of visitors to mining parks and museums.
- Involvement of local mining companies, particularly for industrial minerals and extractive waste recovery.
- Stimulation of the creation and growth of local businesses for the provision of mining-related goods and services.
- Training of new local professionals, graduates, and associations specializing in mining research.
- Creation of new professional opportunities.

Environmental impacts:

- Development and dissemination of criteria and methods to minimize the environmental impact of exploration activities.
- Removal and mitigation of environmental concerns related to the presence of extractive waste.

11) MIXED SULPHIDE MINERALIZATION (Cu-Pb-Zn ± Ag), W, REE AND Ti IN THE FUNTANA RAMINOSA DISTRICT (CENTRAL SARDINIA)

State of art

Main raw materials: Cu-Pb-Zn "mixed sulphides";

Critical Raw Materials: Cu, W, Rare Earths

Strategic Raw Materials: Cu, W, Rare Earths

Other possible Raw Materials: magnetite, Pb, Zn, Au, Ni, Co, In, Ga, Ge,

Geology/Ore geology: Known since the pre-Roman era, the copper–lead–zinc "mixed sulphide" ores are typical in the Funtana Raminosa district in Barbagia. The orebodies are hosted in Palaeozoic rocks south of the Gennargentu Massif: Ordovician to Devonian volcanic and sedimentary rocks (aged 450–360 million years), highly folded and deformed, and in contact with younger granitoid rocks (Permian age: ~299 million years). The genesis of the main orebodies is related to the emplacement of the granitoids, which caused intense thermal metamorphism on the host rocks and released hydrothermal fluids, forming abundant concentrations of ore minerals in skarn deposits. The main economic historically exploited ore was represented by "mixed sulphides" and magnetite. The best-known orebodies (Figure 32) are located along the Rio Saraxinus valley (Funtana Raminosa), the Flumendosa valley (San Gabriele) and the area west of the village of Gadoni (Giacurru/Perdabila and Su Nusai).

Mines: The modern mining history of this district began in the early 1900s, when, in addition to resuming historical excavations in the Saraxinus Valley, exploration was extended to surrounding areas. At Funtana Raminosa, the mine went through several phases of development alternating with periods of inactivity, each marked by technical difficulties in processing "mixed sulphides ores", which are intimately intergrown with each other and with gangue minerals. Nevertheless, innovative techniques were tested here in Italy, such as flotation of copper ores (1917).

At the end of the 1930s, the arrival of Cogne marked a phase of major investment in mineworks and ore dressing plants (Figure 32). Reserves at that time amounted to 200,000 tonnes of mixed sulphide ores (Cu content ~2%) at Funtana Raminosa, plus 175,000 tonnes at Su Nusai and San Gabriele. Early exploration of the Giacurru/Perdabila magnetite deposit identified a potential of several million tonnes of magnetite in large lenses, modestly exploited until the 2000s by a small Sardinian company, mainly for Fe hydroxides to be used in cement production.

In 1979, SAMIM launched a new mining project, installing a large 1,000-ton/day dressing plant and constructing an access ramp, but the investment proved oversized relative to the deposit's characteristics, leading to closure in 1987. In the Giacurru sector, a mining concession application from Sabbie di Parma SRL is currently pending (Figure 33).

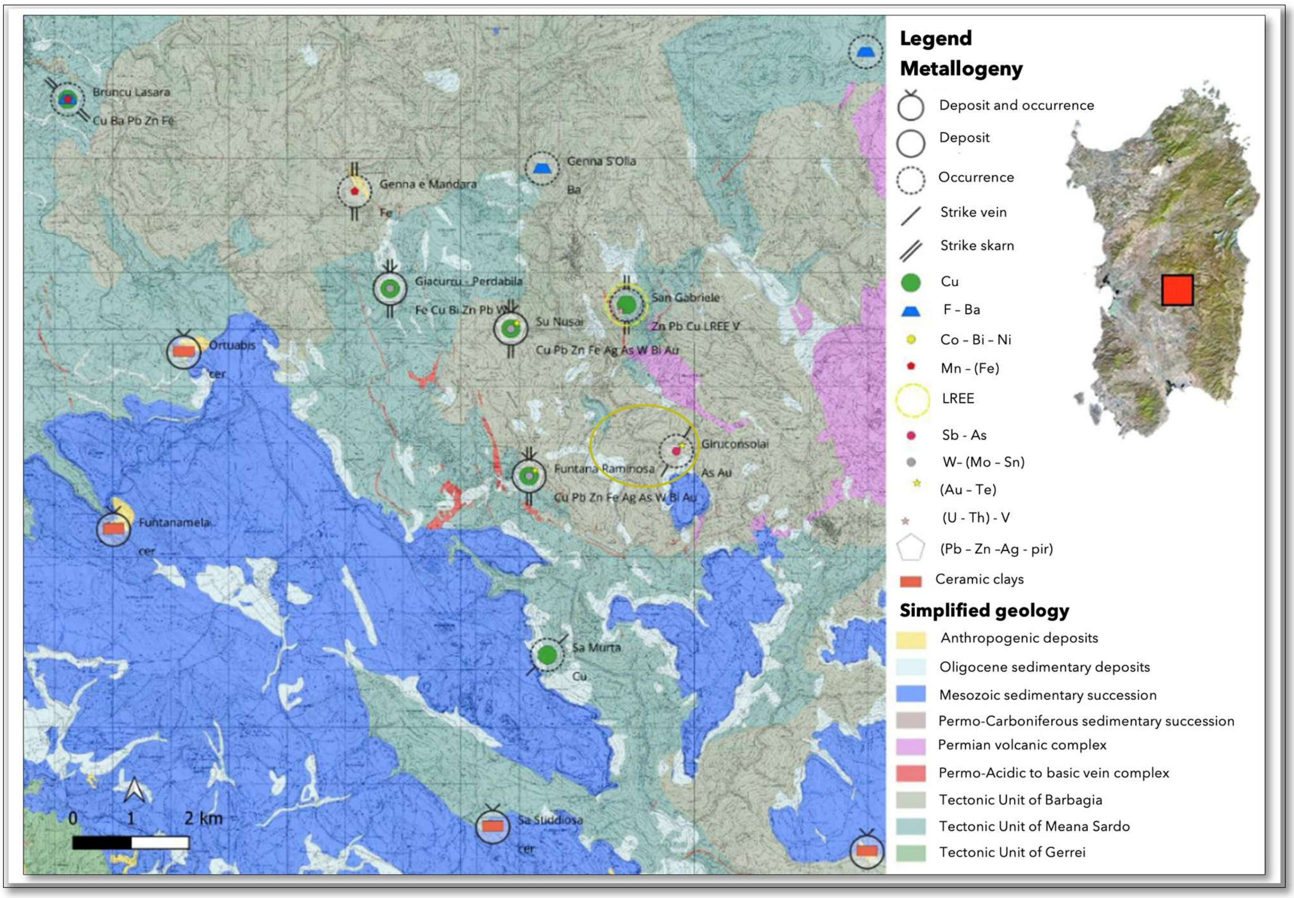

Figure 32- Location of the main orebodies of the Funtana Raminosa district

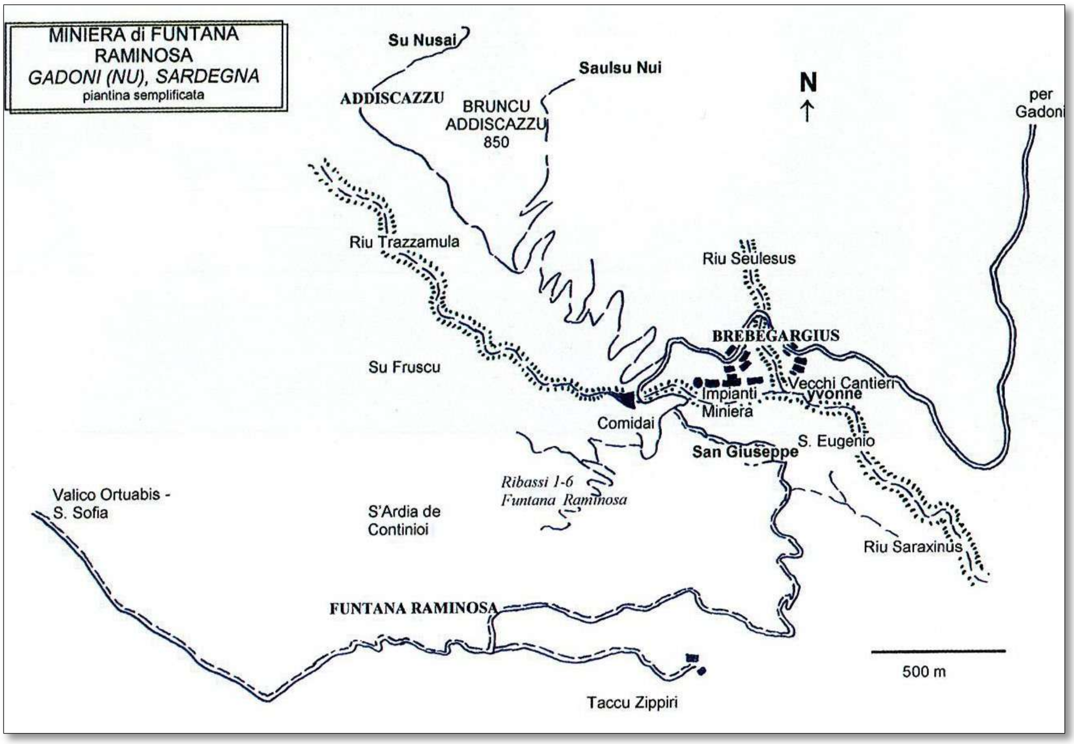

Figure 33- Main mineworks in the Funtana Raminosa sector

Potential of the area

The closure of the Funtana Raminosa mine was due more to technical and economic reasons than to the exhaustion of mineralization. The "mixed sulphide ores" generally occur as relatively small but numerous and dispersed bodies. Studies carried out during the last evaluation of the deposit (late 1970s) identified at least 55 sulphide bodies, often rich in silver and containing gold, totalling about 500,000 tonnes of ore, only partly exploited in the 1980s. Currently, data on accessory minerals associated with the sulphides are limited, but ongoing studies are highlighting significant potential for strategic raw materials: in addition to copper, tungsten and REE define this area as one of the most interesting in Sardinia. Tungsten, already reported in the Giacurru sector and at Funtana Raminosa, occurs as scheelite ($CaWO_4$). Given the difficulty of identifying this mineral—distinguishable in ore only with UV lamps of suitable frequency—it is likely that scheelite may also occur in unexploited portions of the sulphide bodies, possibly associated with magnetite as in Giacurru.

High REE contents have also been identified in some altered rocks of the area, highlighted in studies by the CNR and University of Cagliari in the 1990s: highly epidotised rocks (epidotites), a Ca-silicate capable of REE enrichment. More recently, preliminary exploration by the University of Cagliari identified significant light rare earth element contents (up to 0.5–0.6% total REE) in Ti-oxide-rich sedimentary rocks (TiO_2 content 6–8%) between Funtana Raminosa and Giacurru. Mineralogical analyses revealed fluorocarbonates (bastnäsite, synchysite) and phosphates (monazite), among the most attractive mineral species for metallurgical extraction of REE.

The area of interest should also be extended to similar occurrences already investigated in the past for mixed sulphides (by Ente Minerario Sardo in the 1970s), in the eastern Gennargentu and Ogliastra sectors, such as the Talentinu-Bau Arenas and Correboi mines, Lake Alto Flumendosa, Orgosolo–Funtana Bona, etc.

Activities

1) ACQUISITION, EVALUATION AND SUMMARY OF PREVIOUS STUDIES

In addition to scientific publications, technical mining reports and documents on past activities in the district are available from numerous sources in Sardinia (municipal archives of Gadoni; Department of Industry – former Mineral District; Ente Minerario Sardo and Progemisa SpA archives; IGEA SpA archive; documentation at the Department of Chemical and Geological Sciences, University of Cagliari, etc.). The acquisition and critical reassessment of these materials will not only be a necessary preliminary step but will also guide subsequent exploration phases.

2) FIELD ACTIVITY

Fieldwork will include:
a) detailed surveys and systematic sampling in areas historically mined for "mixed sulphide ores", including outcrops, waste dumps and accessible underground workings, with particular focus on the margins of previously exploited bodies to verify the presence of tungsten and other valuable minerals;
b) systematic surveys and sampling of the formations where enrichment in rare earths (fluorocarbonates and monazite) and titanium oxides has been reported. In addition to examining key geological features (e.g. granitoid–country rock contacts hosting mineralization), the surveys will define the spatial distribution of mixed sulphide orebodies and REE- and Ti-bearing zones, with stratigraphic and structural controls useful for exploration.
Since the area is characterized by a limited soil cover, initial work will involve simple rock chip sampling; once promising outcrops are identified, channel samples and small core samples (10–20 cm long, 2.5–5 cm diameter) using portable coring devices will be taken to better evaluate the potential of the mineralization.
Measurements will also include hyperspectral data acquisition using VNIR sensors (<1,000 nm) mounted on drones or handheld, significant for detecting REE-bearing minerals. A second SWIR sensor (1,000–2,500 nm), to be purchased with project funds, would greatly expand detection capabilities to a wider range of critical minerals (e.g. Ti ores), with applications also in other areas covered by the National Exploration Plan.
Additionally, stream-sediment sampling may be carried out along selected river sections (e.g. Rio Trazzamula, Fig. 2) upstream of the main mining areas, to detect mineralized zones not revealed by previous work. Sampling will be supported by portable instruments available at the University of Cagliari (pXRF spectrometer for semi-quantitative analysis of metal contents; portable gamma detector for radioactivity linked to monazite; UV lamps for scheelite fluorescence; portable corer). The study area initially covers ~35 km^2 but may be extended to other sites in the Gennargentu massif similar mineralization occur.

3) LABORATORY TESTS

Samples will undergo mineralogical and chemical characterization to determine the presence, abundance and distribution of Critical And Strategic Raw Materials. The analytical protocol includes:

a) petrographic studies on rocks and ores in the DSCG laboratories: thin sections and polished mounts studied in transmitted and reflected light microscopy; SEM-EDS microanalysis and compositional mapping;

b) X-ray diffraction (XRD) analyses for qualitative/quantitative mineralogy;
c) bulk chemical analyses of major, minor and trace elements in certified international laboratories (XRF, ICP-MS, etc.).

4) DATA MANAGEMENT AND RESULTS

Exploration data will be organised into:

- data sheets for each revisited/newly identified mineralized occurrence;
- a geochemical database of samples;
- GIS layers for geological maps;
- mineral distribution maps from hyperspectral data.

A final report will summarize results and interpretations in relation to the geology and deposit framework of the area and the broader regional metallogenic context, with recommendations for further work, including indirect (geophysical) and direct (trenching, drilling) investigations.

Expected impacts

Phase 1:

Science, mining and technology:

- Improved understanding of metallogenic processes in Cu-Pb-Zn mixed sulphide ores and REE systems of the Sardinian district.
- Enhanced knowledge through regional and local archives (Ente Minerario Sardo/Progemisa/IGEA, Sardinian Mining Association, Regional Archives).
- Revision of conceptual models with possible extension to previously excluded areas.
- Training of researchers and specialists, strengthening human capital in mineral exploration.

Social impact:

- Revitalisation of mining/geotechnical specialization at the Giorgio Asproni Higher Education Institute – Enrico Fermi, Iglesias, raising local technical and professional skills.
- Public dialogue and dissemination of scientifically accurate information on sustainable mining practices.

Phases 2–3

Science, mining and technology:

- Assessment of lateral and depth extensions of deposits.
- Development of innovative exploration technologies and extensive use of artificial intelligence.

- Scientific collaborations between national and international universities and research institutions.

Economic and social:

- Increased investment in the mining sector thanks to new fundamental data.
- Attraction of foreign investment stimulated by exploration results.
- Regional economic diversification and possible revival of related industries.
- Potential supply of ores to the Portovesme smelter.
- Growth of mine tourism and visits to mining parks/museums.
- Involvement of local mining companies, especially in industrial minerals and waste recovery.
- Stimulation of new local businesses providing goods and services for mineral exploration.
- Training of new professionals, graduates and associations specialized in mining research.
- Creation of new professional opportunities.

Environmental impacts:

- Development and dissemination of methods to minimize environmental impacts of exploration.
- Mitigation of environmental issues related to extractive waste.

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12) HYDROTHERMAL MINERALIZATION OF FLUORSPAR-BARITE AND RARE EARTH ELEMENTS, CENTRAL-SOUTHERN SARDINIA.

State of art

Main raw materials: fluorspar, baryte

Critical Raw Materials (CRMs): fluorspar, baryte, Rare Earth Elements

Strategic Raw Materials (SRMs): Rare Earth Elements

Other possible raw materials: Rare Earth Elements, Pb, Zn, Ag

Geology/Ore geology: The Paleozoic basement of central-southern Sardinia is characterized by the presence of numerous vein-type deposits of fluorspar and baryte in a quartz and carbonate gangue, associated with variable amounts of metallic sulfides (mainly Pb-Zn) and, in some cases, with very high silver contents. In southwestern Sardinia (Sulcis-Iglesiente), the main mineralization occur primarily within the limestones of the Gonnesa Formation or the so-called "metalliferous auct." (Lower Cambrian); other, mostly minor, occurrences are hosted within Ordovician sedimentary sequences. The mineralized bodies are represented by sub-vertical veins; within the same geological formation, important baryte mineralization of karstic type are also common (baryte filling karst cavities). In central-eastern Sardinia (Sarrabus-Gerrei and partly Marmilla and Sarcidano), the mineralization are again concentrated in sub-vertical veins hosted in low-grade metamorphic Paleozoic sequences, particularly within the San Vito Sandstone Formation (Cambrian–Lower Ordovician), in volcanic rocks ("Porphyroids" auct.) of Middle Ordovician age, and in carbonaceous argillaceous schists ("black shales") and limestones of Silurian–Devonian age. Less frequently (Sarrabus), the veins are hosted within Permian granites. The only deposit currently under development is the fluorspar deposit of Silius, consisting of two main veins hosted in "Porphyroids," which intersect and overlap, forming one of the largest fluorspar ore bodies in Europe. Several recent studies have highlighted the genetic link between granites and fluorspar mineralization. The granites of southern Sardinia are indeed rich in fluorine, and some important fluorspar occurrences clearly have a magmatic origin, including those formerly exploited at the Su Zurfuru and Perda Niedda mines (southwestern Sardinia). The vein-type mineralization are thought to derive from leaching of the granites by hydrothermal fluids, which circulated along fault systems, giving rise to fluorspar–baryte mineralization. The mineralization are only partially dated (Silius is attributed to the Permian), but based on geological relationships with the host rocks, multiple mineralizing events can be inferred, continuing from the late Paleozoic up to the Pliocene. The nature of the host rocks appears to control the type of mineralization, particularly regarding the abundance and variety of metallic minerals. In general, a marked increase in polymetallic character and in silver grades is observed when the host rock consists of carbonaceous "black shales" (e.g., the "Filone argentifero" mines of Sarrabus, Correboi mine, etc.). The discovery in recent years at Silius of significant concentrations of rare earth minerals (fluorocarbonates and phosphates) represents a new and additional element of interest for this type of critical mineral mineralization, warranting a comprehensive reassessment of these occurrences across the entire region.

Mines: In the Sardinian districts, the discovery of the main hydrothermal fluorspar and baryte mineralization (Figure 34) was closely linked to the exploration and exploitation of Pb, Zn, and Ag sulphide deposits. From the second half of the 19th century until the early decades of the 20th century, fluorspar and baryte were regarded as gangue minerals from many mines where the primary targets of exploration and extraction were metallic sulphides and silver. It was only after World War II (1950s) that baryte, and subsequently fluorspar, became the main commodities of mining activities, with extensive regional-scale exploration campaigns carried out for these minerals.During this period, major fluorspar mines entered production, including Genna Tres Montis and Muscadoxiu (Silius), Santa Lucia and Su Zurfuru (Fluminimaggiore, Iglesiente), Monreale and Perda Lai (Sardara), Mont'Ega (Narcao), and Is Crabus (Villasalto). At the same time, wide hydrothermal baryte vein fields were prospected in southeastern Sardinia (Santoru vein, Bruncu Molentinu vein) and in the southwest (Tzurufusu). Karst-type baryte deposits were intensively exploited, particularly in the Sulcis area (Barega mine and numerous minor localities). Due to the international decline in fluorspar prices, many mines ceased production in the early 1980s, while baryte extraction continued until the early 2000s. Overall, Sardinian fluorspar and baryte mineralization appear, by modern standards, underexplored. With the exception of the Silius mine and the silver-bearing mines (e.g., Monte Narba in the Sarrabus), it must be noted that in most cases exploration and exploitation of fluorspar and baryte bodies were limited mainly to the shallow parts of the deposits, with small companies quickly abandoning operations due to technical or economic difficulties. Furthermore, the geological and deposit models on which exploration was based now appear outdated, while exploration was rarely supported by geophysics or adequate drilling campaigns. As a result, reserve estimates appear rather approximate when evaluated according to modern criteria: Silius, with 2,200,000 tonnes of certified reserves grading 34% fluorspar, still stands as an exception, together with some deposits in the Sarrabus area (Bruncu Molentinu, Monte Genis) that were investigated in the 1970s and 1980s by the Ente Minerario Sardo (Sardinian Mining Authority).

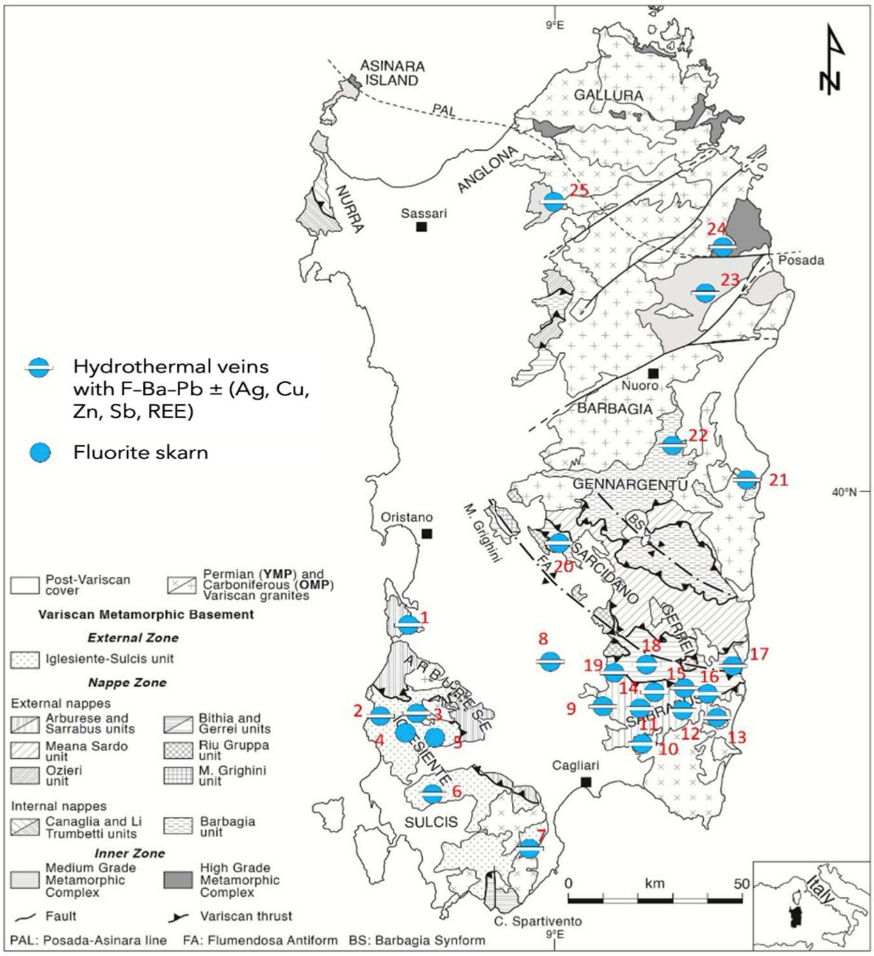

Figure 34- Regional distribution of the main fluorspar-barite mineralization in Sardinia. 1.Tzurufusu; 2. Santa Lucia; 3. Perda S'Oliu; 4. Su Zurfuru; 5. Perda Niedda; 6. Mont'Ega; 7. Sa Galanza; 8. Monreale; 9. S'Ortu Becciu; 10. Burcei; 11. Monte Genis; 12. S'Arcu Mannu; 13. Monte Narba; 14. Is Crabus; 15. Su Leonaxi; 16. Bruncu Molentinu; 17. Bruncu Vintura; 18. Silius; 19. Bruncu Mannu; 20. Castel Medusa; 21. Goene; 22. Correboi; 23. Guzzurra; 24. Posada Valley; 25. Su Laccheddu.

Potential of the area

As shown in Figure 35, the fluorspar–baryte mineralization of Sardinia are widely distributed at the regional scale and, in the framework of the objectives of the National Exploration Plan, would require a multi-year research program. Within the current program, based on a critical reassessment of the literature data and on direct field observations, it is possible to identify at least three specific areas in south-central Sardinia on which to focus new investigations. In all three cases, documentation from previous exploration activities is available: mineralization are visible both at outcrop and in former mining works (trenches and galleries).

1. Bruncu Molentinu area – (San Vito). This is a vein-type system that crops out with good continuity for about 3.5 km along a North–South direction. The veins range in thickness from 1.5 m to 4 m and at outcrop appear at the topographic surface as quartz veins with abundant baryte. The vein field has been explored several times by various mining companies (Montecatini, Sarramin, etc.) and by the Sardinian

Mining Authority (Ente Minerario Sardo), but never exploited, and a modern reserve evaluation is lacking. Available reports, based on trenches, exploration galleries and drill holes, particularly in the southern part of the system, indicate a vertically zoned mineralization with abundant baryte in the upper parts of the veins, fluorspar in the intermediate levels, and quartz prevailing in the lower parts. In the zones considered of economic interest, estimated volume fractions were baryte 10%–60%, fluorspar 30%–60%, and quartz 10%–30%. Accessory phases include Pb and Zn sulfides, particularly galena; no data are available on possible contents of Rare Earth Minerals. Based on technical reports, on old workings and the numerous assays available in the area, the high-potential surface to be investigated can be estimated at about 25 km^2. In the surrounding sectors, mineralization of the same type that could be further investigated, particularly for the presence of Rare Earth Elements and other strategic accessories, include Is Crabus, a fluorspar vein mined until the 1990s, and Monte Genis, a fluorspar vein never exploited but explored by the Sardinian Mining Authority in the 1990s. The Monte Narba silver mine, extensively exploited at the end of the 19th century, appears as a major target for its mine dumps, still rich in fluorspar and baryte.

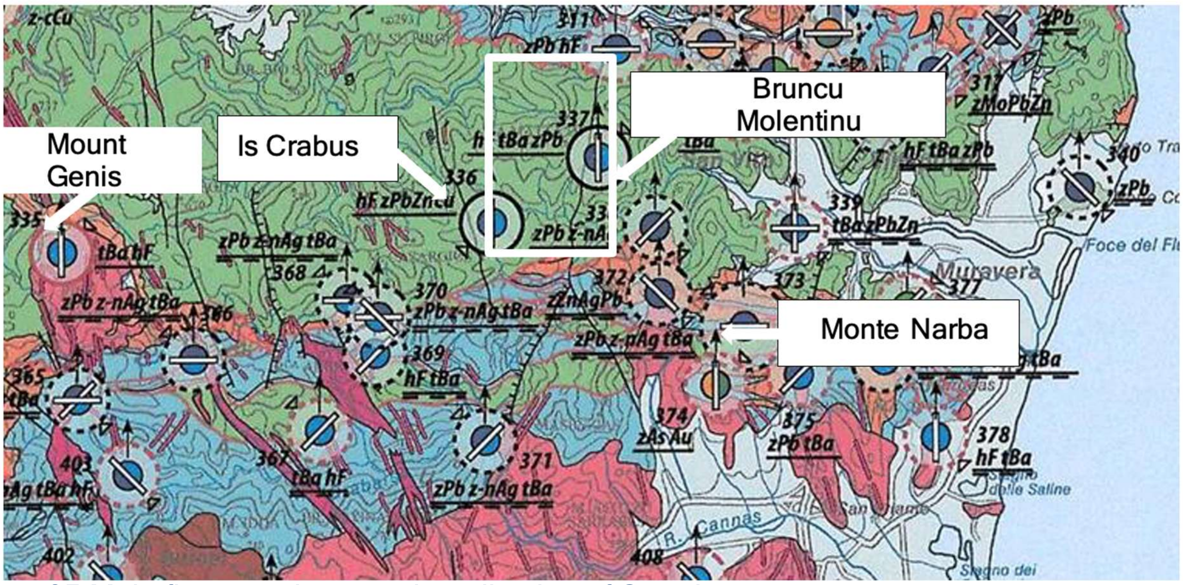

Figure 35.Main fluorspar-baryte mineralization of Sarrabus

2. **Castel Medusa area** (Asuni–Samugheo). In this area lies the "Castel Medusa vein field," characterized by a series of quartz–fluorspar and baryte veins of considerable extent and thickness (Figure 35). Due to the limited presence of sulfides, this area was less explored than other sites in southern Sardinia, with relatively recent investigations (1960s). Only four small mining operations (Forru Iscrappeddu, Costa Ualla, Riu Misturadroxiu, and Genna Oggiastru) began activity in the area, initially in search of silver, while fluorspar and baryte were regarded as gangue minerals. Several mine dumps rich in fluorspar and baryte are still present at these mining sites. Overall, as in the Sarrabus veins, those of the "Castel Medusa vein field" are sub-vertical with a "rosary-like" geometry, alternating highly mineralized zones with poorer or barren ones. The thickness of the veins at outcrop ranges from 0.30 m to 1.5 m, with surface lengths from 3 m up to 20 m; in accessible galleries, thicknesses

of up to 2.5 m have been observed for bodies traced over several tens of meters. The reported volume fractions of fluorspar and baryte vary between 20–60% and 10–40%, respectively. All available reports indicate that exploration was always limited to the near-surface portions of the veins, while very limited data exist on their depth extension. The overall area of interest covers about 85 km^2, within the municipalities of Samugheo and Asuni.

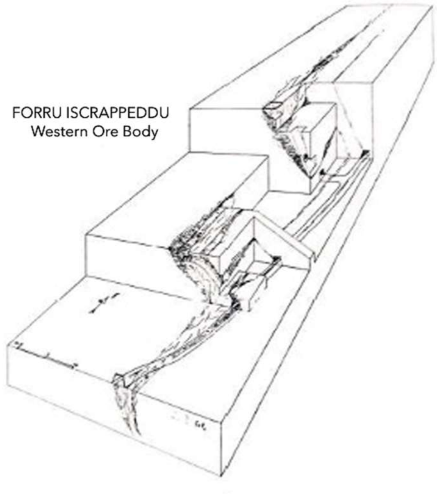

Figure 36 - Geometry of the Forru Iscrappeddu mineralization, Castel Medusa vein field

3. Santa Lucia Area (Fluminimaggiore). The Santa Lucia area is characterized by several vein systems consisting of two main parallel veins trending Northwest-Southeast, the "Filone Palazzo" and the "Sa Mena de S'Oreri" vein, along with several minor veins that intersect or connect with the main ones (Pala su Sciusciu, Perdas Albas, Niu Crobu). The mineralized belt extends northwestward into the Monte Cidrò exploration sector and southeastward into the Su Zurfuru mine sector (Figure 36). The two main veins at Santa Lucia cross a siliciclastic sedimentary sequence of the Monte Argentu Formation (Middle Ordovician) and appear as bundles of banded and brecciated veins intensely mineralized (fluorspar, baryte, and accessory Pb, Zn, and Cu sulfides in a quartz and calcite gangue), particularly where they intersect two outcrops of limestones belonging to the Gonnesa Formation ("metallifero" auct., Lower Cambrian). Both veins follow pre-existing fracture systems, partially sealed by microgranitic porphyry dykes that are themselves mineralized and responsible for evident recrystallization phenomena in the limestones, in some cases resembling true marbles. The mineralization are characterized by enrichment zones exceeding 100 m in length. The main mining works focused on these two veins, with large open pits and underground galleries, some of which remain accessible at Sa Mena de S'Oreri. Evident karst phenomena affect the Gonnesa Formation limestones throughout the area, with frequent karst cavities often filled with massive or brecciated baryte cemented by fluorspar. The cavities can often reach volumes exceeding 12 m^3, while baryte breccias are irregular, with thicknesses greater than one meter and lengths extending over several meters. Overall, the Santa Lucia area, despite past mining activities, still

appears to be of significant interest for new exploration. In particular: a) New surveys currently being carried out in the area by researchers from the Department of Chemical and Geological Sciences at the University of Cagliari are providing new interpretative keys to better frame the strong structural control of the mineralization, especially suggesting criteria to hypothesize the possible presence of non-outcropping mineralized bodies, which in fact were occasionally encountered during past mining works; b) Preliminary mineralogical investigations have confirmed the presence of rare earth element (REE) minerals (phosphates and fluorocarbonates) within the mineralization, as well as minerals of other strategic elements such as Ni, Co, and Bi. The total surface area of interest to be investigated is estimated at about 30 km^2.

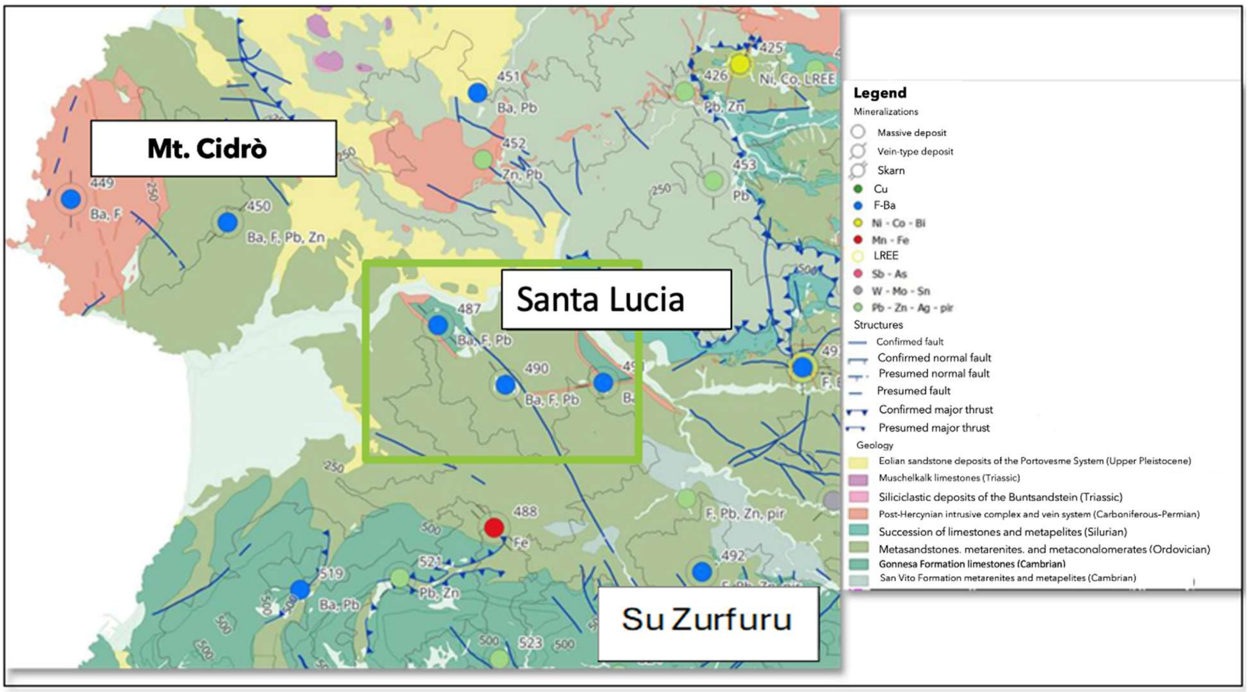

Figure 37. Santa Lucia Sector (Fluminimaggiore)

Work planning

1) STUDIES ACQUISITION, EVALUATION AND SYNTHESIS OF PREVIOUS STUDIES

For the previously described sectors, several scientific studies and more extensive technical-mining documentation on past exploration and exploitation activities are available in Sardinia from different sources, in particular at the offices of the Regional Department of Industry – former Mining District of Iglesias, as well as the exploration archives of the Ente Minerario Sardo and Progemisa SpA. Several documents are also already available at the Department of Chemical and Geological Sciences (DSCG) of the University of Cagliari. The study and critical re-evaluation of these materials will be crucial in guiding the operational phases of the exploration.

2) FIELD ACTIVITIES

Fieldwork will include detailed surveys and systematic sampling in the areas of the different proposed sectors that were previously affected by mining exploration and exploitation of fluorspar–barite mineralization. This will include sampling from mineralized outcrops, mine waste dumps, and inside currently accessible galleries. Given the strong structural control of the mineralization in all the sectors considered, detailed surveys will focus on the structural interpretation of fracture systems. In all the areas under investigation, initial sampling will consist of simple hammer sampling, while at the main mineralized outcrops chip–channel sampling will be carried out, also with a hammer. Additionally, the collection of small cores (10–20 cm in length, 2.5–5 cm in diameter) with portable core drills may be planned. All field sampling will be supported by the use of portable instruments available at the Department of Chemical and Geological Sciences (DSCG) of the University of Cagliari, including: a pXRF spectrometer for semiquantitative determination of metal contents in rocks; a portable gamma-ray detector for identifying rock levels with higher natural radioactivity; a frequency-adjustable UV lamp for the identification of fluorescent minerals such as fluorspar in underground settings; and a portable core drill.

In areas of greatest interest, under favorable conditions (e.g., northern sector of Bruncu Molentinu), geognostic investigations may be carried out using appropriate geophysical methods (seismic and geoelectric surveys, etc.), and larger-scale bulk sampling may be planned for laboratory beneficiation tests.

3) LABORATORY ANALYSIS AND DATA PROCESSING

The samples collected in the investigated sectors will be characterized from a mineralogical and chemical perspective to verify the presence and contents of critical/strategic raw materials and to define their distribution within the different mineral phases. The analytical protocol to be adopted foresees the parallel execution of the following studies and analyses:

a) Mineralogical and petrographic studies on rock and mineralization samples at DSCG laboratories: preparation of analytical mounts (thin sections, polished sections, resin-embedded mounts) examined under optical and digital microscopy in transmitted and reflected polarized light, for the preliminary identification of metallic and non-metallic minerals and their geometric–spatial relationships; scanning electron microscopy (SEM-EDS) investigations at DSCG laboratories on selected samples to refine previous analyses and obtain semi-quantitative chemical compositions of minerals, as well as compositional maps to highlight the distribution of elements of interest.
b) X-ray diffraction (XRD) studies on powders at DSCG laboratories, for a qualitative/quantitative definition of the mineralogical composition of the collected samples.

c) Bulk chemical analyses for major, minor, and trace elements to be carried out at certified international laboratories using appropriate analytical techniques (XRF, ICP-MS, etc.) on representative aliquots of the collected samples.
d) Preliminary beneficiation tests on representative samples of fluorspar and barite mineralization, to be performed in collaboration with the mineral processing laboratories of the Department of Civil, Environmental and Architectural Engineering (DICAAR), University of Cagliari. Laboratory beneficiation tests by gravity separation and flotation, supported by appropriate mineralogical and chemical characterizations, will provide preliminary data to identify the economic potential and the most suitable fields of commercial and technological application of the mineralization.

4) DATA MANAGEMENT AND PRESENTATION OF RESULTS

The data collected during the exploration will be organized on several levels:
- through survey forms related to the main revisited and/or newly identified mineralized occurrences;
- through a geochemical database including all collected samples;
- through QGIS-based digital representation of the acquired data on geological maps.

A final summary report will also be produced, outlining the results obtained and their interpretation in relation to the geology and ore deposit framework of the investigated areas, as well as within the broader regional metallogenic context. All data will be collected and managed according to the common specifications prepared by the coordination unit and described in Chapter 4. The destination of the data is the national GeMMA database, where the results of the research project will be periodically implemented, on a quarterly basis, in the dedicated section.

Possible Extension in Phases 2 and 3

Depending on the results of the first phase of investigations, it will be possible to plan the continuation of exploration aimed at identifying potential lateral and depth extensions of the mineralization, as well as applying both established and innovative prospecting and analytical methods. These operations may include indirect methods (geophysics) and direct investigations (drilling, trenches, etc.), both in accessible underground mine workings and at the surface.

Expected Impacts

Phase 1:

Scientific-Mining and Technological:

- Significant improvement in the understanding of metallogenetic processes of fluorspar-barite mineralized systems within the Sardinian mining district.

- Enhancement of existing knowledge using regional and local archives (Ente Minerario Sardo/Progemisa/IGEA, Sardinian Mining Association, Regional Archives).
- Revision of conceptual models with the potential extension of research into areas previously excluded based on outdated models.
- Training of specialists and researchers in the field, fostering the growth of human capital with expertise in mineral exploration and related disciplines.

Social:

- Revitalization and strengthening of the mining/geotechnical specialization at the Giorgio Asproni - Enrico Fermi High School in Iglesias, enhancing local technical and professional skills.
- Engagement with the local population and dissemination of scientifically sound information on the sustainability criteria of extractive activities.

Phase 2-3:

Scientific-Mining and Technological:

- Assessment of the possible lateral and depth extension of the deposits, based on drilling campaigns and planned investigations.
- Development of innovative exploration technologies and extensive application of artificial intelligence.
- Scientific collaborations between national and international universities/research institutions.

Economic and Social:

- Increase in investments in the mining sector following the provision of baseline information on the deposits present in the study area.
- Attraction of foreign investments stimulated by the results of exploration.
- Regional economic diversification with the potential revival of other industrial sectors.
- Possible involvement of Sardinian companies specialized in both fluorspar extraction and processing.
- Potential allocation of metallic minerals to the Portovesme smelter.
- Growing interest in extractive activities and increase in visitors to existing mining parks and museums.
- Engagement of local mining companies, particularly in the field of industrial minerals and waste recovery.
- Stimulation of the creation and growth of local enterprises providing goods and services to mineral exploration.
- Training of new local professionals, both graduates and technicians, as well as associations of specialists in mineral exploration.
- Creation of new jobs.

Environmental Impact:

- Development and dissemination of criteria and methodologies to minimize the environmental footprint of exploration activities.
- Removal/Mitigation of Environmental Issues Related to Extractive Waste.

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13) GRANITE-RELATED TUNGSTEN (TIN, ARSENIC, BISMUTH, MOLYBDENUM) MINERALIZATION, SOUTHWESTERN SARDINIA

State of art

Main raw materials: tungsten, arsenic, tin

Critical Raw Materials (CRMs): tungsten, arsenic, bismuth

Strategic Raw Materials (SRMs): tungsten, bismuth

Other possible raw materials: molybdenum, lead, zinc, copper, gold, tellurium

Geology/Ore geology: Tungsten mineralization represent a relatively underexplored theme in Sardinia, despite the occurrence of wolframite (iron-manganese tungstate) and scheelite (calcium tungstate) within Paleozoic rocks having been known since the early 20th century. Southwestern Sardinia hosts some of the most significant and promising occurrences for the purposes of the National Exploration Program. These occurrences were sporadically investigated in the past or found in association with mineralization exploited for other metals such as lead, zinc, copper, and molybdenum. Recent ore deposit studies have strengthened the understanding of the genesis and age of these mineralization, which in southwestern Sardinia are related to the emplacement of rare-metal granites during the Early Permian (ca. 290–285 Ma). These intrusions (Monte Linas and Sulcis massifs) are geochemically enriched in fluorine and "specialized" in rare metals such as tin, tungsten, molybdenum, bismuth, and others. Different types of mineralization are associated with granite emplacement, linked to the thermal effects of the magmas and related hydrothermal fluid circulation: skarns, greisens, and hydrothermal veins. Mineralization may occur within the granites themselves (e.g., molybdenite-bearing greisens), but more commonly in the surrounding Paleozoic host rocks, particularly in chemically reactive lithologies such as limestones, often transformed into skarns with calcium silicates. In many cases, more distinctly hydrothermal vein systems are present, emplaced along tectonic structures associated with granite intrusion.

Mines: The tungsten mineralization of southwestern Sardinia have been the subject of wolframite exploration in the Monte Linas area (Nuraghe Togoro, Gonnosfanadiga; Rio Narti, Villacidro) and of scheelite exploration in the Sulcis area (Monte Tamara sector, Nuxis). In both areas, exploration was limited to trenches and a few adits. At the same time, in several operating mines in the same districts, tungsten minerals were repeatedly reported in association with molybdenite-bearing greisens (Perd'e'Pibera mine in Monte Linas), with Pb-Zn-Cu "mixed sulfide" skarns (Sa Marchesa mine in Sulcis), or with magnetite (San Leone mine, also in Sulcis). Scheelite, in fact, was only identified relatively late in southwestern Sardinian mines (late 1960s), mainly due to the difficulty of distinguishing it from gangue minerals such as quartz. The numerous recent discoveries of this mineral in various other localities of southwestern Sardinia confirm its widespread occurrence and make it a significant subject for geological and mineral exploration. (Figure 38).

Potential of the area

When setting up a research program for tungsten and associated elements in southwestern Sardinia, it is proposed to begin from the main areas previously investigated, mainly the Monte Tamara sector (western Sulcis) and the Monte Linas area.

1) Monte Tamara Area – The area is located near the municipality of Nuxis (Province of South Sardinia) and is characterized by the widespread presence of skarn deposits with "mixed sulfides" of Pb-Zn-Cu, historically exploited in the San Pietro and Sa Marchesa mines, located respectively in the southwestern and northern parts of the limestone ridge of Monte Tamara, oriented approximately North–South. These mineralization are mainly located along the contacts between carbonate rocks of the Gonnesa Formation ("metallifero" auct.) and siliciclastic rocks of the Cambro–Ordovician Sulcis sequence, not far from the contact with the Sulcis granites, which crop out further south and east in the Pantaleo region (Monte Lattias). The mineralized bodies appear to be structurally controlled, often associated with sub-vertical faults. In addition to the two mines, the area includes several other exploration sites, both for "mixed sulfides" or magnetite (S'Ega De Is Frissas), and, more recently, for tungsten and associated elements: Sinibidraxiu, Conca Antoni Airi, and Is Lassinus. Overall, two main styles of mineralization can be distinguished: a) scheelite + arsenopyrite + Zn-Pb-Fe-Cu sulfides with a quartz-calcite-wollastonite gangue, occurring in columns within limestones (Sinibidraxiu); b) skarn bodies up to 5 meters thick, composed of pyroxene-garnet-epidote and including magnetite bands, Zn-Pb-Cu-Fe sulfides, and disseminations of scheelite-arsenopyrite-cassiterite-Bi sulfosalts-stannite-molybdenite (Sa Marchesa, San Pietro, Conca Antoni Airi, Is Lassinus). There are also reports of other iron skarn-type mineralization (magnetite) hosted in Ordovician siliciclastic units at S'Ega De Is Frissas, characterized by tungsten, arsenic, tin, and bismuth contents. Other poorly explored localities with potential interest for tungsten–arsenic, molybdenum, and tin mineralization are located further south, at Sedda Tiranna, Conca de Cerbu, and Arcu Sa Bella. In the latter area, whole-rock analyses of skarn samples revealed anomalies up to 12% tungsten and 0.4% tin. The Sinibidraxiu prospect (Figure 38b) is located in the northern portion of the Monte Tamara carbonate ridge. It was owned by the Rumianca company, which extracted arsenic, particularly abundant here, through a main gallery connected to a 60-meter-deep vertical shaft. Overall, this represents a situation of considerable interest, especially for potential geophysical applications aimed at identifying a downward continuation of the mineralized body. The old Zn-Pb-Fe San Pietro mine (Figure 38a) consists of a series of six levels, accessible from four main galleries up to 500 meters long and connected by several vertical shafts, reaching a total depth of 70 meters (303–377 m a.s.l.). The Is Lassinus and Conca Antoni Airi prospects consist of five levels located at the southeastern end of the Monte Tamara ridge (618–808 m a.s.l.).

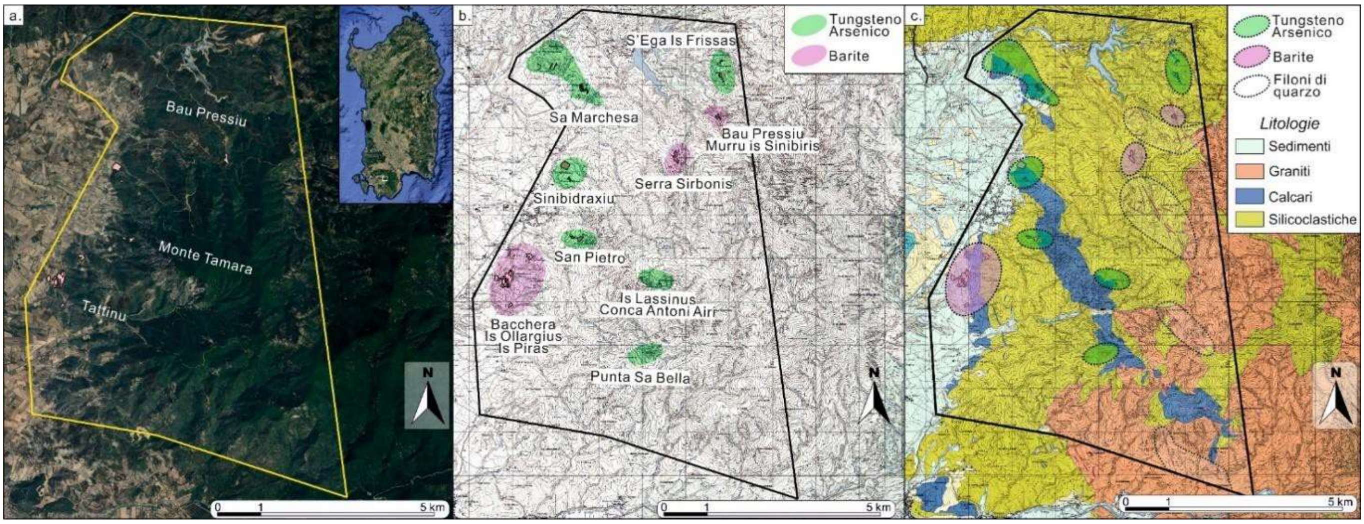

Figure 38-Nuxis-Acquacadda area, southwestern Sardinia, a)Delimitation of the investigation area; b) Main mineralized zones; c) Lithological map of the investigation area and surrounding zones, showing the relationships between granites and limestones in skarn-type tungsten-arsenic deposits. Also highlighted in the same area is the presence of barite mineralization (karst and hydrothermal).

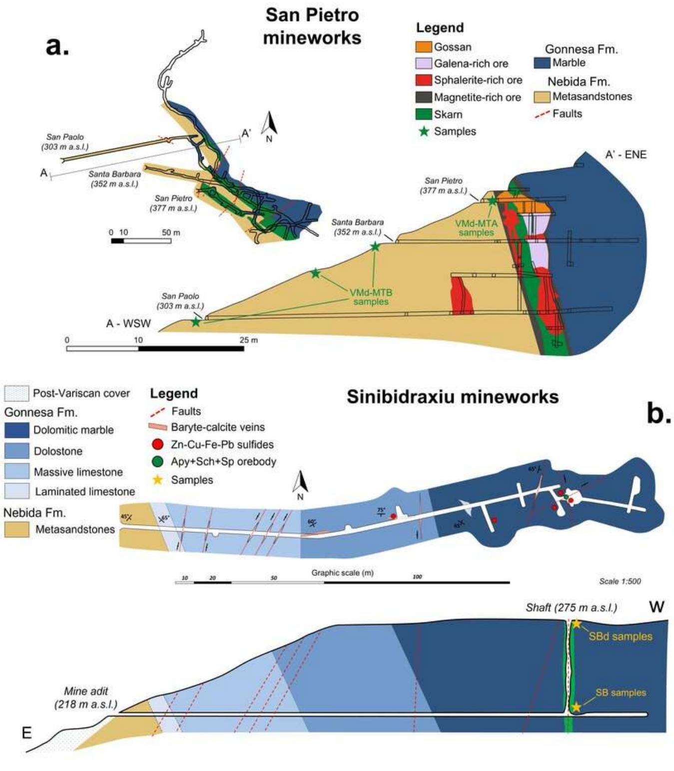

Figure 39 -Mining works at the San Pietro mine (a) and the Sinibidraxiu prospect (b).

2) Monte Linas Area. The Monte Linas sector is well known for the richness and variety of its mineralization, which include numerous occurrences of critical and strategic raw materials. The main tungsten occurrences are wolframite-scheelite veins located in the Nuraghe Togoro and Rio Narti sectors (Figure 40). At Nuraghe Togoro, north of Monte Linas, there is a set of quartz-wolframite veins with scheelite hosted in Ordovician sandstones and siltstones. The mineralized zone is about one hundred meters wide and extends for at least 2 km. The veins range in size from decimetric to metric and show zones of wolframite enrichment with crystals up to several decimeters in size. In addition to tungsten minerals, abundant bismuth and tellurium minerals are present, along with native gold (about 1 gram per ton from preliminary analyses on mineralized samples) and accessory chalcopyrite and molybdenite. The mineralization has only been subject to limited exploration works (three levels of trenches and a few small galleries) dating back to the 1930s, but given its size and spatial continuity it appears to be clearly underexplored. Similar considerations can be made for the Rio Narti mineralization, east of Monte Linas, where quartz-wolframite veins related to a molybdenite-bearing greisen have been explored through a few trenches.

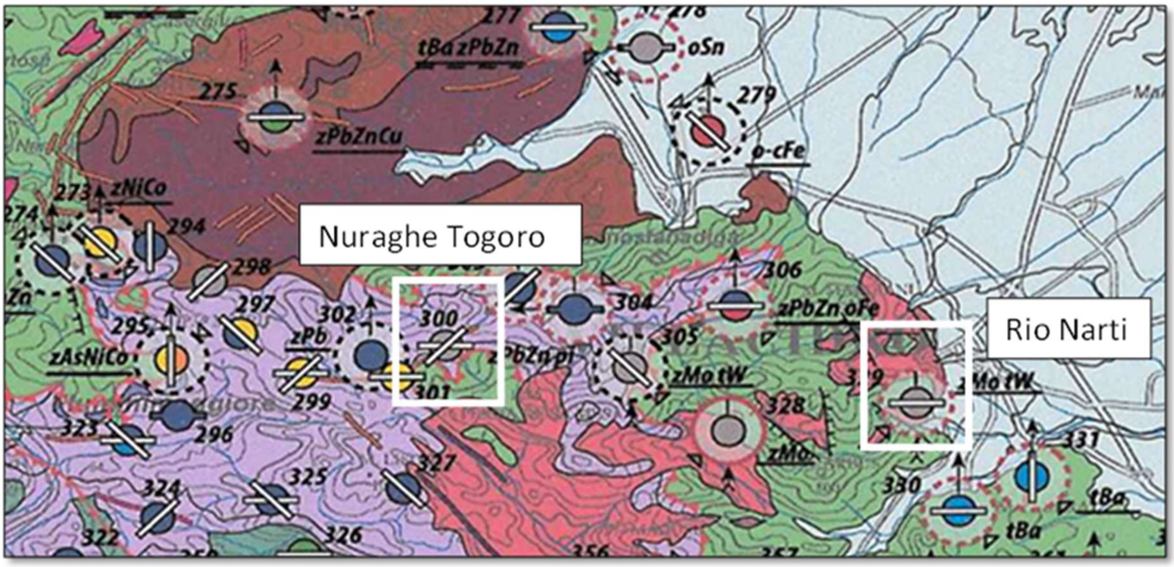

Figure 40. Tungsten Mineralization in the Monte Linas Area

Planned Activities

1) ACQUISITION, EVALUATION, AND SYNTHESIS OF PREVIOUS STUDIES

The selected areas for exploration have been the subject of some recent scientific studies, while a more extensive body of technical-mining documentation on past exploration and exploitation activities can be found at the offices of the Regional Department of Industry – former Mining District of Iglesias, at the research archives of the Ente Minerario Sardo and Progemisa SpA, and at the IGEA archives in Monteponi-Iglesias. Several documents are already available at the Department of Chemical and Geological Sciences (DSCG) of the University of Cagliari. The study and critical reassessment of these materials will be fundamental to guiding the operational phases of the prospecting.

2) FIELD ACTIVITIES

Field activities will include detailed surveys and the systematic collection of samples in the areas of the different sectors previously affected by exploration and mining works, including sampling on mineralized outcrops, in mine dumps, and inside currently accessible underground galleries. Given the strong structural control of the mineralization in all the sectors considered, detailed surveys will also focus on the structural interpretation of fracture systems. In all areas under investigation, simple hammer sampling will be initially carried out, and in the main mineralized outcrops, chip-channel sampling with a hammer will be performed; short core samples (10–20 cm in length, 2.5–5 cm in diameter) may also be taken using a portable coring drill. All field sampling will be supported by the use of portable instruments available at the Department of Chemical and Geological Sciences (DSCG) of the University of Cagliari, including a pXRF spectrometer for the semiquantitative determination of metal contents in rocks, a portable gamma-ray detector for identifying rock levels with higher natural radioactivity, a UV lamp with adjustable frequency for detecting fluorescent minerals such as scheelite and fluorspar in underground environments, and a portable coring drill. In the most promising areas, under favorable conditions (for example, the eastern sector of the Nuraghe Togoro vein system), geognostic investigations may be carried out using appropriate geophysical methods such as seismic and geoelectric surveys. Of particular interest is the Sinibidraxiu site: in addition to traditional geophysical methods, the geometry of the mining works is also favorable for the application of innovative methods such as muon radiography (muon prospecting, see below).

3) LABORATORY ANALYSIS AND DATA PROCESSING

The samples collected in the investigated sectors will be characterized from a mineralogical and chemical perspective in order to verify the presence and content of critical and strategic raw materials, and to define their distribution within the different mineral phases. The analytical protocol proposed foresees the parallel execution of the following studies and analyses.

a) Mineralogical and petrographic studies on rock and mineralization samples at the DSCG laboratories: preparation of analytical mounts (thin sections, polished slabs, mounts also embedded in resin) to be studied under optical and digital microscopy in transmitted and reflected polarized light, for the first identification of metallic and non-metallic minerals and their geometric-spatial relationships. Further studies using scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS) on selected samples will deepen the previous analyses and provide semi-quantitative chemical compositions of the minerals as well as compositional maps to visualize the distribution of the elements of interest.
b) X-ray diffraction (XRD) studies on powders at the DSCG laboratories, aimed at achieving a qualitative and quantitative definition of the mineralogical composition of the collected samples.

c) Bulk chemical analyses for major, minor and trace elements, to be performed at certified international laboratories using appropriate analytical methodologies (XRF, ICP-MS, etc.), on representative aliquots of the collected samples.

4) DATA MANAGEMENT AND DISSEMINATION OF RESULTS

The data acquired during the exploration will be organized on several levels:

- Survey sheets related to the main revisited and/or newly identified mineralized occurrences
- A geochemical database including the collected samples
- Digital rendering in QGIS on geological maps of the acquired data
- Processing and presentation of geophysical survey data

All outputs will be produced in compliance with the standards defined by the project coordination and according to the criteria described in Chapter 4.

The progress of the work will be reported in quarterly updates. In addition, a final report will be prepared, summarizing the results obtained, with interpretation in relation to the geology and ore deposit framework of the investigated areas, as well as within the broader regional metallogenic context. The report will also highlight the verified potential and perspectives for the investigated area, and provide guidance for possible extensions and follow-up exploration programs involving direct methods (e.g. drilling, trenches, etc.), both in accessible underground workings and at surface.

Muon Radiography

Muon radiography, or muography, is a non-invasive imaging technique that allows radiographic investigations of large-scale structures. It is like traditional X-ray radiography but, instead of artificially generated X-rays, it exploits the natural flux of particles constantly produced in the Earth’s atmosphere, the so-called atmospheric muons. Muographic investigation is today a rapidly expanding field. The research could be carried out by an innovative startup currently being established as a joint spin-off of INFN (National Institute for Nuclear Physics) and the University of Florence that gathers the expertise of a consolidated research team with over fifteen years of experience. The team has conducted numerous muographic studies in multidisciplinary fields such as volcanology, industry, mining, archaeology, and civil engineering, as evidenced by several high-level scientific publications. During these activities, the group has developed state-of-the-art muographic instruments: robust, compact, and low-consumption measuring devices that can be easily transported and installed in different environments. A significant study concerning the application of muon radiography in the mining sector was carried out in Tuscany, using a relatively small detector. This study made it possible to develop and refine a methodology capable of providing, in just a few weeks of data collection, reliable indications on the presence of cavities and bodies of “anomalous” density within rock layers several tens of meters thick. The use of larger-scale instruments or the possibility of longer measuring times allows the same methodology to be extended to the investigation of greater thicknesses, up to several hundreds of meters, by fixing the pointing angles. Below is the scheme of applicability in the selected mine (Figure 41).

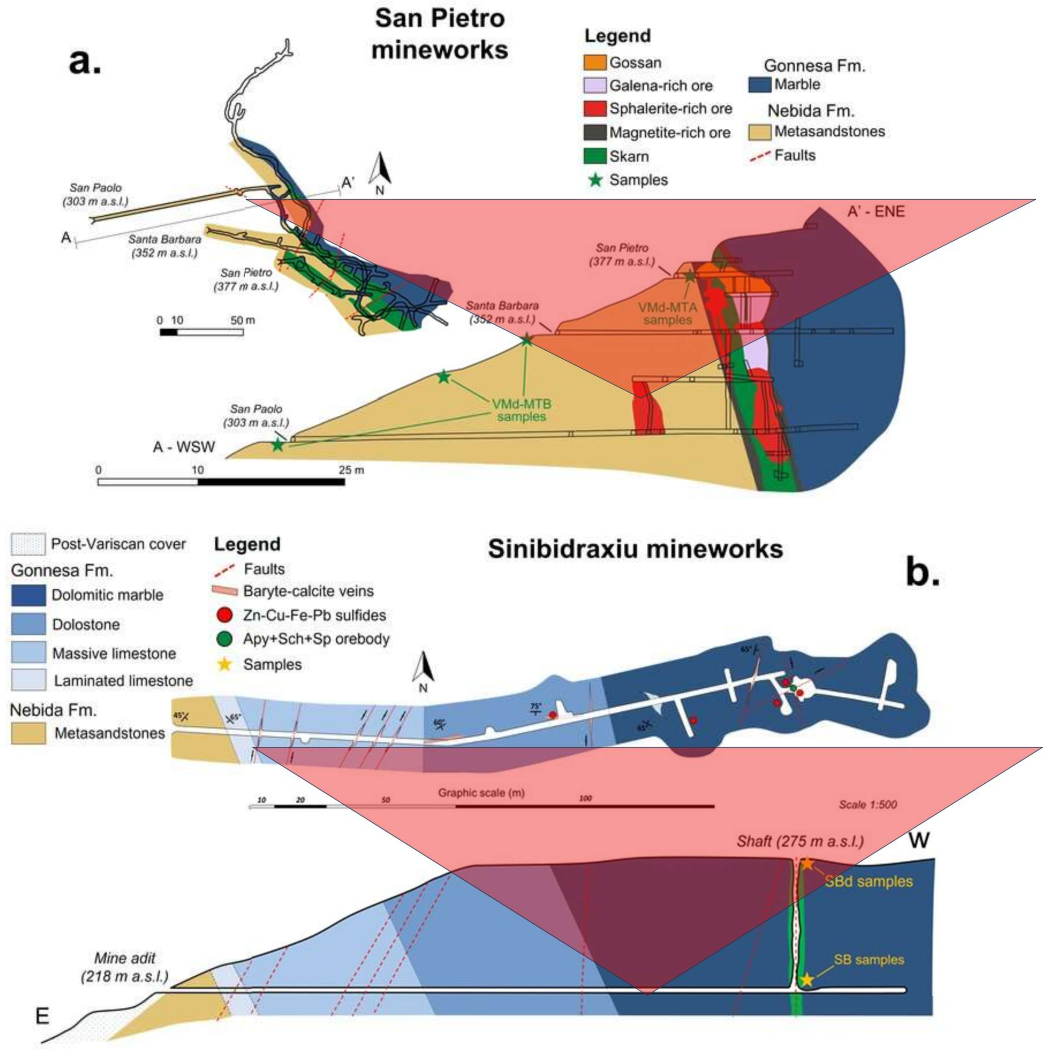

Figure 41 - Sketches of the San Pietro (a) and Sinibidraxiu (b) mines in Sardinia. On the two mine cross-sections, two red-colored triangles with a lower angle of 120° have been superimposed to represent the portion of the hill that can be inspected with a single measurement using a muographic apparatus installed at the lower vertex of the triangle.

Expected impacts

Phase 1:

Science, mining and technology

- Significant improvement in the understanding of metallogenetic processes of tungsten-bearing mineralized systems in the Sardinian mining district;
- Enhancement of existing knowledge through consultation of regional and local archives (Ente Minerario Sardo/Progemisa/IGEA, Sardinian Mining Association, Regional Archives);
- Revision of conceptual models with the potential extension of exploration into areas previously excluded based on outdated models;
- Training of experts and researchers in the field, fostering the growth of human capital specialized in mineral exploration and related disciplines;
- Testing of muon radiography for better definition of the mineralized system and potential application in other contexts.

Social impact

- Revitalization and strengthening of the mining/geotechnical specialization of the "Giorgio Asproni – Enrico Fermi" Technical Institute of Iglesias, enhancing local technical and professional skills;
- Dialogue with local communities and dissemination of scientifically sound information on the sustainability criteria of extractive activities.

Phases 2–3

Science, mining and technology

- Assessment of possible lateral and vertical extensions of deposits, based on planned surveys and analyses;
- Development of innovative exploration technologies, including the extensive application of artificial intelligence;
- Strengthening of scientific collaborations between national and international universities and research organisations.

Economic and social

- Increase in investments in the mining sector as a result of the provision of baseline information on deposits in the study area;
- Attraction of foreign investments stimulated by exploration results;
- Regional economic diversification with the potential restart of other sectors of activity;
- Increased interest in extractive activity and growth in visitors to existing mining parks/museums;
- Involvement of local mining companies, particularly for industrial minerals and extractive waste recovery initiatives;

- Stimulation of the creation and growth of local enterprises supplying goods and services to mineral exploration;
- Training of new local professionals (graduates and technicians) and establishment of professional associations specialized in mineral exploration;
- Creation of new jobs.

Environmental impact

- Development and dissemination of criteria and methodologies to minimize the environmental impact of exploration activities;
- Removal/mitigation of environmental issues related to the presence of mining waste.

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14) *COPPER, MOLYBDENUM, AND GOLD MINERALIZATION OF THE "SOGLIA DI SILIQUA" AND THE CIXERRI VALLEY, SOUTHWESTERN SARDINIA*

State of art

Main raw materials: copper, molybdenum, gold

Critical Raw Materials: copper

Strategic Raw Materials: copper

Other possible Raw Materials: molybdenum, gold

Geological and mineralization context: The area proposed for exploration is located in the Cixerri Valley, in southwestern Sardinia. The area, situated on the western margins of the Campidano "half-graben," is geologically characterized by the interaction between Oligo-Miocene volcanic activity and the Paleozoic basement. Volcanic products include sub-intrusive and intrusive andesitic and tonalitic bodies (26–29 Ma, Oligocene) that intrude Paleozoic rocks, as well as younger pyroclastic flow deposits and epiclastic sediments (possibly Miocene) that overlie both the basement and volcanic units. The intrusion of andesitic and tonalitic magmas at different depths was accompanied by significant hydrothermal activity, as evidenced by distinctive rock alteration types (propylitic and potassic alterations). These features are fully consistent with global case studies used to define mineralized systems of copper, molybdenum, gold, and base metals (Pb, Zn) of the porphyry copper type, typically associated with this style of volcanism. Outcropping mineralization appear as disseminations or as veins of Fe, Cu, and Mo sulfides, suggesting the presence of larger mineralized bodies at depth, later confirmed by geognostic investigations (see following section). The study of outcropping mineralization and alterations has shown that disseminated copper, molybdenum, and gold occurrences are linked to potassic alterations, within the framework of a possible quartz-diorite porphyry-type mineralizing system.

Mining Context: From a mining perspective, the area was the subject of tactical- and detailed-scale exploration by Progemisa S.p.A. (1988–1990). The company carried out a geostructural survey, a tactical-scale geochemical prospecting campaign (on rocks and soils), a series of diamond drill holes (1988–1989 and later in 1990), and a geophysical survey (magnetometry and induced polarization), with the objective of defining the characteristics and economic potential of the sulfide occurrences known at that time (Figure 42). The investigations particularly focused on the area between Monte Silixianu, Monte Idda, and Monte Perdosu (Figures 43 and 44), within the so-called "Soglia di Siliqua" a morphological high that forms the access to the Cixerri Valley. The prospecting results essentially revealed low-grade disseminated mineralization (around 0.4% copper, approximately 1 gram per ton gold).

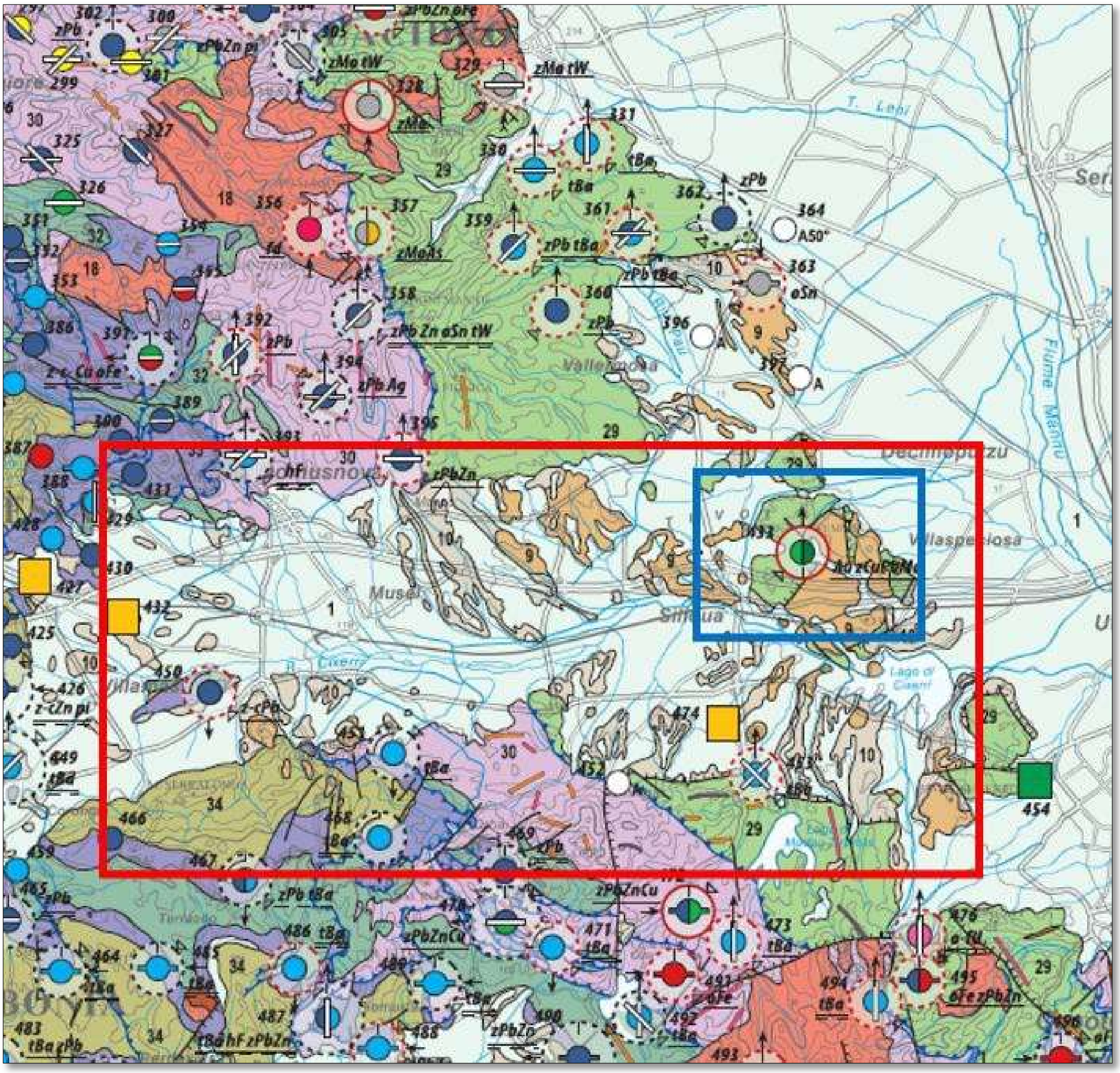

Figure 42 - Exploration target area. Light blue box: Vallermosa-Siliqua sector previously investigated by Progemisa S.p.A.; red box: area proposed for an airborne survey within the framework of the National Exploration Program. Geological formations within the proposed area: 1. Recent and modern continental deposits, Quaternary. 9. Volcanics: quartz-andesite-tonalite-dacite lavas in hypabyssal bodies with widespread alteration and copper, molybdenum, and gold mineralization; rhyolitic-rhyodacitic pyroclastics, Oligocene-Early Miocene. 10. Continental sandstone-conglomerate deposits. 29. Allochthonous terrigenous succession predating the Sardic unconformity (Arburese tectonic unit), with metasandstones, quartzites, and metapelites, Cambrian-Early Ordovician. 30. Autochthonous terrigenous and carbonate succession postdating the Sardic unconformity (External Zone): metasandstones, metaconglomerates, metapelites, carbonaceous black shales, and metacarbonates, Middle Ordovician-Early Devonian. 32-33-34. Terrigenous and carbonate succession predating the Sardic unconformity: metasandstones and limestones (34), limestones and dolostones (33), metapelites (32), Early Cambrian-Early Ordovician.

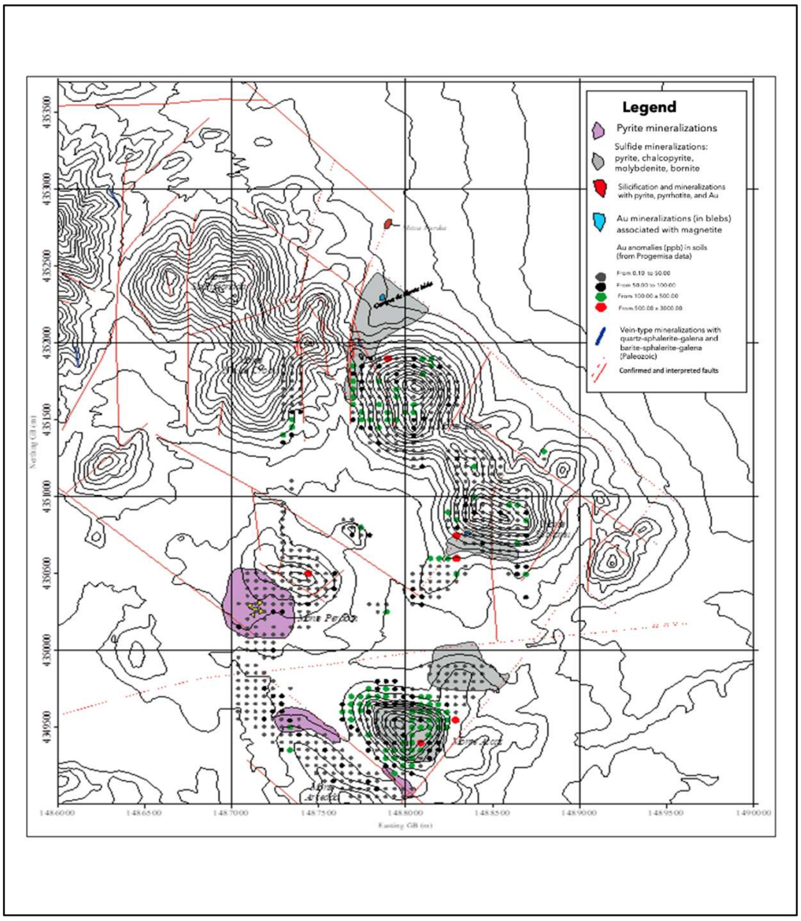

Figure 43 -Progemisa S.p.A. (1989-1990) soil geochemical map.

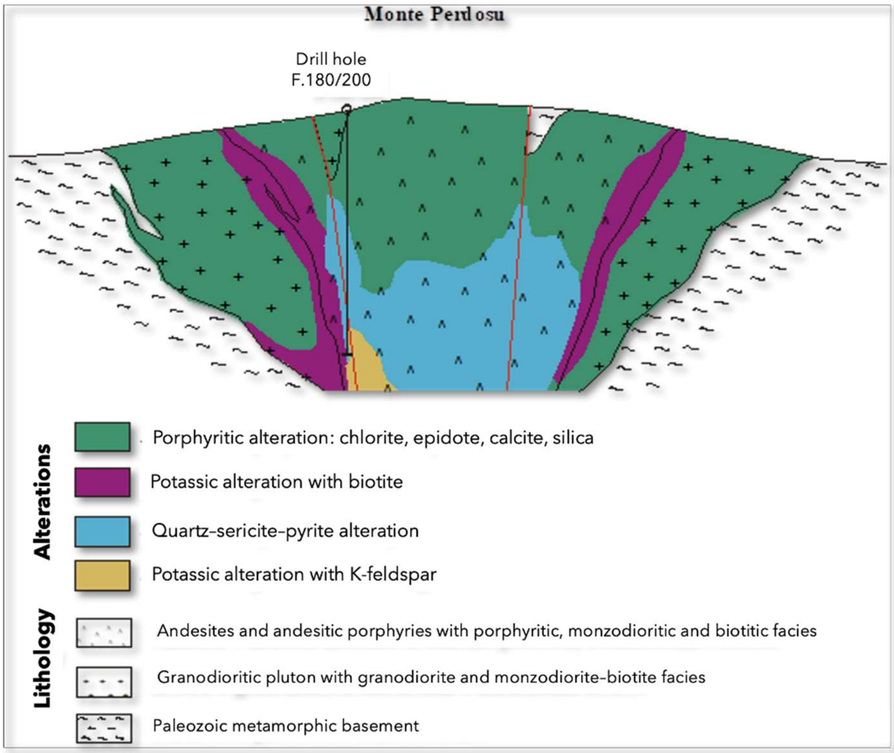

Figure 44- Conceptual alteration model interpreted at depth, based on drill data from the Monte Perdosu intrusion sector.

Potential of the area

The studies and prospecting carried out by Progemisa SpA highlighted the overall good potential of the entire area, although they were mainly focused on the restricted sector of the "Soglia di Siliqua". The directly identified mineralization proved to be of low grade, yet they remain of considerable interest in light of the current challenges concerning critical and strategic raw materials. Additional geophysical surveys using the induced polarization method were conducted in 2000 by Sardinia Gold Mining in a restricted sector north of Monte Idda, identifying mineralized bodies at shallow depth. Overall, the results of these campaigns suggest: a) the possible presence of additional, previously unidentified bodies at shallow depth and with higher grades; b) the probable occurrence of similar sub-intrusive magmatic stocks beneath the pyroclastic cover and recent sediments of the Cixerri valley, supported by geological data and alteration mapping. It therefore appears particularly relevant to extend exploration over a wider area, both to enlarge investigations around the "Soglia di Siliqua" and to acquire new data to better focus on the previously explored sectors, employing AEM geophysical prospecting methods to generate 3D subsurface models.

Planned Activities

1) ACQUISITION, EVALUATION, AND SYNTHESIS OF PREVIOUS STUDIES

   Previous data on studies and exploration within the investigation area, particularly those related to the Progemisa SpA and Sardinia Gold Mining surveys, will be preliminarily collected and critically assessed in order to guide the various operational phases.

2) AEM GEOPHYSICAL PROSPECTION

   Geophysical data will be acquired through helicopter-borne electromagnetic (AEM) surveying, using instrumentation available at the Department of Chemical and Geological Sciences, University of Cagliari. As an initial illustrative hypothesis, the Cixerri area could be divided into three sectors with decreasing levels of priority (Figure 44). Survey flights would begin over Area 1 (marked in red in Figure 45), with a flight-line spacing of 100 m (equivalent to approximately 500 linear km), oriented to intersect the main geological lineaments orthogonally and to follow the alignments of the 2000 ground-based electrical tomographies. From the helicopter data, information will be extracted on the resistivity volume of the investigated zone down to a depth of about 80–100 m, with a lateral surface resolution of approximately 30 m. In principle, it may also be possible to extract chargeability volumes. Once the highest-priority survey area has been completed, the campaign would proceed to Area 2 (marked in green in Figure 45) with a 200 m spacing, considered more suitable for a less documented brownfield-type area, and subsequently to Area 3 (marked in yellow in Figure 45), flown with a 250 m spacing. The data acquisition requires the helicopter to be available for at least five days: 2

days for mounting the instrumentation, 2 days for actual data collection, and 1 day for dismantling the equipment.

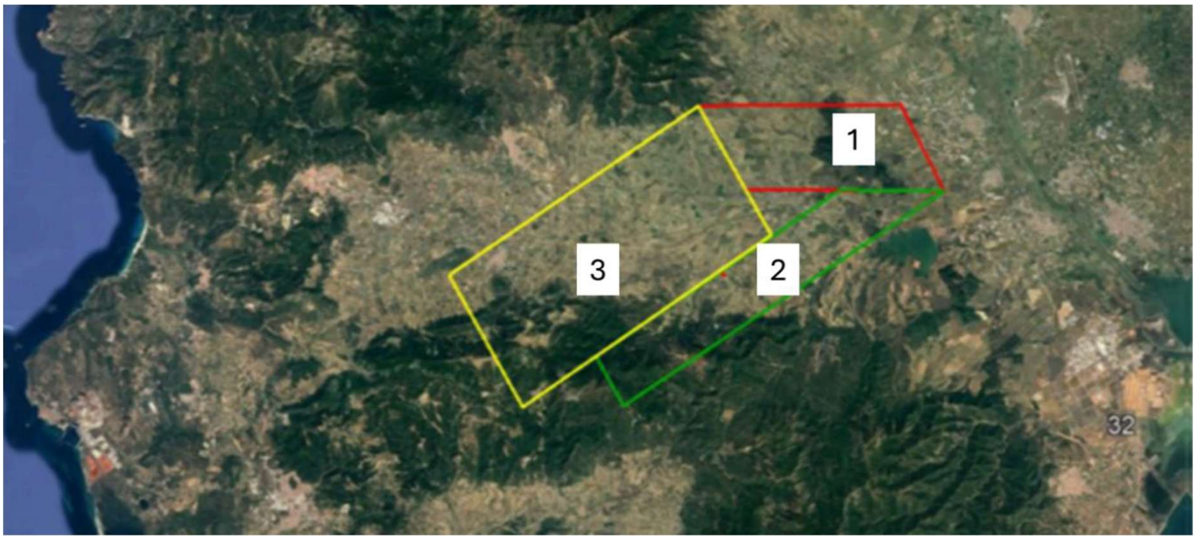

Figure 45-Possible sectors covered by the AEM survey: 1 indicates the area of the "Soglia di Siliqua".

3) DATA MANAGEMENT AND PRESENTATION OF RESULTS

The processing of the data will lead to 3D reconstructions of resistivity and chargeability, which can be compared with the data acquired during previous campaigns, in particular with the results (possibly reprocessed) of the ground electrical tomography measurements collected in 2000 in the area of the "Soglia di Siliqua". Overall, data processing and presentation would require approximately 4–6 weeks to obtain the first interpretable results. All products will be produced in accordance with the standards defined by the project coordination team and with the criteria described in Chapter 4. The progress of the work will be reported on a quarterly basis. The results of the data processing will be included in a final report, with interpretation in relation to the potential and prospects identified for the investigated area, as well as recommendations for possible extensions and further investigations through future prospecting activities that may include additional indirect methods and direct assessments (drillings, trenches, etc.).

The data acquired during the prospecting campaign will be organized at different levels:
• survey sheets related to the main mineralized occurrences revisited and/or newly identified;
• a geochemical database including all collected samples;
• digital QGIS-based representation on geological maps of the acquired data;
• presentation of the results of the geophysical surveys.

A final summary report of the results obtained will also be prepared, including their interpretation in relation to the geology and ore deposit characteristics of the investigated areas and within the broader regional metallogenic framework. The report will also highlight the potential and prospects identified for the investigated area, as well as recommendations for possible extensions and further investigations through future prospecting activities, including direct methods (drilling, trenching, etc.), both in accessible underground mining works and at the surface.

Expected impacts

Phase 1:

Science, mining and technology:

- Significant improvement in the understanding of metallogenic processes of porphyry copper-type mineralized systems involving copper, molybdenum, gold, and base metals (Pb, Zn).
- Enhancement of existing knowledge through the use of regional and local archives (Ente Minerario Sardo/Progemisa/IGEA, Sardinian Mining Association, Regional Archives).
- Revision of conceptual models with the potential extension of exploration into areas previously excluded on the basis of outdated models.
- Training of experts and researchers in the field, with the growth of specialized human capital in mineral exploration and related disciplines.
- Testing the effectiveness of airborne geophysics.

Social impact

- Revitalisation and strengthening of the mining/geotechnical specialization at the Giorgio Asproni Higher Education Institute – Enrico Fermi, Iglesias, enhancing local technical and professional skills.
- Dialogue with the public and dissemination of scientifically accurate information on sustainability criteria for extractive activities.

Phases 2–3

Science, mining and technology

- Assessment of the possible lateral and depth extension of the deposits, based on the planned drilling campaigns and further investigations.
- Development of innovative exploration technologies and extensive application of artificial intelligence.
- Scientific collaborations between national and international universities/research institutions.

Economic and social

- Increase in investments in the mining sector as a result of the provision of baseline information on the deposits located in the study area.

- Attraction of foreign investments stimulated by the exploration results.
- Regional economic diversification with the potential restart of other industrial sectors.
- Increased interest in mining activities and growth in visitor numbers to mining parks/museums.
- Involvement of local mining companies, particularly for industrial minerals and in the recovery of extractive waste.
- Stimulation of the creation and growth of local enterprises supplying goods and services to mineral exploration.
- Training of new local professionals, both graduates and technicians, and of professional associations specialized in mineral exploration.
- Creation of new jobs.

Environmental impacts

- Development and dissemination of criteria and methods to minimize the environmental impact of exploration activities.
- Removal or mitigation of environmental concerns related to the presence of extractive waste.

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7– NATIONAL EXPLORATION PROGRAMME – MONITORING PLAN

Monitoring and evaluation of the results achieved are crucial to ensure that the NEP remains relevant, effective, and aligned with national priorities, as well as adaptable to possible changes in the international availability of Critical Raw Materials (CRMs) and, consequently, in their level of criticality. Constant monitoring through appropriate indicators makes it possible to adjust the Programme to the volatility of international geopolitical conditions.

In addition to performance indicators relating to exploration activities, it will also be necessary to develop indicators concerning the overall development of raw materials and the needs of domestic industry. A proper monitoring plan therefore requires a clear division of roles, responsibilities, and tasks among the various actors involved.

Stakeholders

MINISTRIES

The relevant ministerial directorates will be responsible for defining and monitoring indicators relating to the national and international economic context, and for steering mining research accordingly.

ISPRA

As the implementing entity of the NEP, ISPRA will provide, on a quarterly basis, indicators to the Ministries regarding the state of exploration including:

1. *Indicators of Advancement and Exploration Productivity:*

- Extent of the areas investigated
- Extent of geological and mining areas
- Number of carried out geochemical sampling
- Sampling density by type and unit of area (soil/he; sediment/stream)
- Number of samples collected for mineralogical and petrographic analysis
- Extension of areas investigated using geophysical methods
- Number of new discoveries of mineralization: detection of new occurrences or orebodies.

2. *Data and interpretation quality indicators:*

- Completeness and consistency of geospatial databases: Degree of integration and reliability of geological, geochemical and geophysical data.
- Accuracy of the Geological and Thematic Maps: Assessment of the accuracy and detail of cartographic representations.

- Reliability of Geophysical and Geophysical Analysis: Results of quality checks (e.g. analysis of standards, duplicates, inter-laboratory comparisons).
- Number of scientific publications and technical reports produced: Dissemination of results and acquired know-how.
- Use of Innovative Technologies: Adoption and integration of new methodologies and tools to improve the efficiency and accuracy of investigations.

In Phase 2 and 3, based on the further possible investigations approved, the following will also be considered:

- Quality of geological models and fields: Degree of detail and accuracy of the three-dimensional reconstructions of the subsoil and mineralization.
- Level of Uncertainty in Resource Estimates: An indication of the reliability of the preliminary estimates.

3. *Environmental and social impact indicators:*

In Phase 1, there are no invasive activities that are representative of:

- Involvement of local communities: Number and type of interactions with affected communities (consultations, briefings).

In Phase 2 and 3, if the survey campaign has begun, they will be provided for:

- Total area disturbed by Exploration Activities: Measurement of areas affected by sampling, trenches, surveys, etc.
- Management of Exploration Waste: Quantity and method of disposal of waste production (e.g. drilling muds, sampling waste).
- Quality of Water and Soil in Exploration Areas: Monitoring of any contamination due to activities.
- Management of Cultural Heritage: Respect for and protection of any archaeological or historical sites in exploration areas.
- Socio-economic benefits for local communities (Potential): Preliminary assessment of possible positive impacts (e.g. creation of future jobs).
- Impact on Biodiversity: Monitoring of effects on plant and animal species in exploration areas.

4. *Governance and Programme Management Indicators:*

- Compliance with the planned Budget: Control of costs in relation to the resources allocated.
- Compliance with the programme: Assessment of the progress of the activities compared to the planned timescales.

- Effectiveness of the Organisational Structure and Exploration Team: Assessment of staff skills and collaboration.
- Transparency and Accessibility of Data (in compliance with regulations): Arrangements for sharing information with relevant stakeholders.
- Quality control and internal audit mechanisms: Procedures to ensure the reliability and integrity of the programme.
- Active National and International Collaborations: Number and type of partnerships with scientific institutions, universities, industry.
- Development of staff capacity and training: Investment in the professional growth of the exploration team.

8– TRAINING PLAN

The mine shutdowns and closures led to a fast decline in interest in university education in ore geology disciplines, resulting in the progressive closure of degree courses in mining engineering and geology of mineral resources. Scientific research has continued in many universities, though often discontinuously, with limited resources and frequently confined to basic academic or geological studies within the Earth sciences. Mining technical institutes in Italy have also undergone a reorganisation of curricula related to mining, with the training of specialized technical staff for the extractive industry—historically highly valued both in Italy and abroad replaced by more general topics in earth sciences.

The revival of mining culture at both university and professional contexts, oriented toward sustainability and responsible resource management practices, is essential if the sector has to be revitalised and again in order to support the national economy. It should also be highlighted that a generation of Italian mining professionals, who emigrated in recent decades, are now active in leading extractive industries in Australia, Canada, the USA, and South America. These professionals, together with the expertise of the residual national workforce, represent an international knowledge base that can be harnessed to relaunch the mining culture in Italy.

In this context, the establishment of a national mining register is also considered necessary, recording the institutions, universities, companies, and professionals operating in the sector, both domestically and abroad.

The current training gap is evident in the shortage of specialized staff within central, regional, and local public administrations, where the management of mining-related administrative procedures is often difficult due to a lack of adequate expertise. Bridging this gap has therefore become an urgent priority.

The NEP addresses this issue through a dedicated Activity Line (LA4) on **training, communication, and retraining of human resources**, supported by masters, summer schools, e-learning modules (such as those already available on the GeoSciences IR platform: https://geosciences-ir.it/video-webinar/), and knowledge-sharing with other Geological Services worldwide (USGS, GSC Canada, Geosciences AUS). Unlike many European countries, Italy is currently excluded, due to the lack of expertise, from major international mining research projects, including those exploring new frontiers such as seabed exploitation and extraterrestrial mining.

Objective

The plan aims to reinforce the technical and scientific skills of staff involved in implementing the NEP and, more broadly, to support the development of a new generation of professionals capable of working within the mining system—primarily, for the Italian Geological Service, in the fields of scientific research and exploration. The NEP can act as a driver for restarting the national metals sector, with the expectation that mining engineering teaching will be reactivated in universities and vocational schools. Training activities within the NEP also represent an important opportunity to enforce the technical expertise available in the public administration.

Training Audience

The training plan targets several groups, requiring different levels of depth and focus:

- Professionals already operating, or potentially involved, in the mining sector (geologists, engineers, mining experts).
- Public Administration officers, at State, Regional, and local level.
- Recent graduates and students in geology, mining engineering, and related disciplines.
- Graduates and students from Mining Technical Institutes.
- Journalists and science communicators.

Training Tools

Training will be performed through multiple instruments and formats:

- E-learning modules: hosted on the GeoSciences IR platform integrated with GeMMA.
- Master's degrees: agreements with universities to provide patronage, scientific and training support, and potential financial contributions. ISPRA will also consider launching a specific Master's in mineral exploration.
- Summer schools: field-based training for graduates, doctoral students, and freelance professionals.
- On-the-job training: at operational mining sites.
- Territorial workshops: in areas with high mining potential, organised with universities and local mining schools.
- Workshops for journalists and media professionals: to improve public communication on mining-related issues.
- Public outreach workshops: to provide citizens with scientifically accurate information.

Currently available distance learning courses, developed under the GeoSciences IR NRRP, include:

- National and European legislation on mining activities.
- Mining history of Italy.
- Mineral deposits.
- Italian mining districts: geological characteristics, historical and current resources.

- Mineral exploration techniques.
- Extractive waste: characterization, cultivation methods, legislation, industrial reuse.
- Industrial minerals: Italian classification and districts.
- Sustainability of quarrying activities and ornamental stone exploitation.
- Life Cycle Assessment and Carbon Footprint evaluation.
- Critical raw materials in the circular economy.
- Classification of primary and recycled resources under the UNFC scheme.
- Optimisation of surface and underground mining techniques, including environmental recovery and monitoring.
- Hydrogeology of mining and quarrying.
- Marine mining at national and international level (Deep Sea Mining).
- Geothermal energy.

These courses (16–22 hours each) are available after registration on the GeoSciences IR platform and award training credits. Further courses, specifically on mineral exploration methods, will be delivered during NEP activities. Courses on safety in confined and elevated workplaces are also planned.

Planned Training Activities

The first Summer School on mining fields will take place from 22 to 26 September 2025 at the Archeominerario Park in San Silvestro (LI), in the heart of the Colline Metallifere. Organised by ISPRA with the Italian Geological Society, the Italian Society of Mineralogy and Petrology, the CNR, and the Universities of Florence, Pisa, and Bari, it will provide ground-based training for at least 30 students per session. The 2026 edition will be held in Sardinia, followed by Piedmont in 2027.

In October 2024, ISPRA organised an on-the-job training day on sustainable fluorspar mining at the Genna Tres Montis mine (CA), with 20 officials from ISPRA and the Regions, accompanied by engineers and geologists from Mineraria Gerrei, and staff from the University of Cagliari. A training excursion is also planned in July 2025 to the former Allumiere mines (RM). Future field training activities will be extended to the extraction of industrial minerals, with the involvement of other operational entities.

For communicators, the first training day for journalists is scheduled for September 2025, followed by annual events agreed with the National Order of Journalists.

9– THE IMPORTANCE OF DISSEMINATION: THE COMMUNICATION PLAN

Mining, by its very nature, is an activity with potentially high environmental and social impacts. As it involves the extraction of non-renewable resources, the concept of "zero impact" is unrealistic: the transformation of geological natural capital into assets essential for human development inevitably produces effects. Mitigating the conflict between the need for resource extraction and the protection of the environment and local communities is therefore an absolute imperative and one of the guiding principles of the Critical Raw Materials Act. Ensuring sustainability and the active involvement of local communities are thus unavoidable objectives, achievable only through clear, transparent, and scientifically sound communication.

Objectives and Users of Communication

The Communication Plan aims to guarantee the correct and transparent dissemination of the purposes and methods of the NEP to all stakeholders. Its final goal is to foster public acceptance of the National Exploration Programme, by underlining Italy's role in the broader European effort to reduce dependence on foreign supply chains of raw materials that are crucial for the decarbonised development model pursued by the EU. The NEP and the identification of areas with the highest mining potential are strategic not only for the energy transition, but also for national security, industrial development, defence, and the possible creation of a European supply chain in consumer electronics. The Programme will highlight the substantial difference between general mining research, which is the specific mandate of the NEP, and operational mining research, which is the responsibility of mining companies and subject to monitoring by ISPRA and the Regions. ISPRA's dual role–as Geological Service and national environmental authority–makes it the guarantor of the environmental compatibility of all research activities.

The scientific and technical quality of the communication is also supported by the involvement of universities, local research institutions, regional environmental protection agencies, and regional/provincial offices responsible for extractive activities.

Target Audiences

The communication strategy addresses multiple groups, including:

- central, regional, and local institutions,
- the scientific and technical community,
- environmental associations,
- local communities,
- businesses,
- journalists and media professionals.

Stakeholder mapping at national level is already well advanced, but will be completed through systematic identification of local-level actors. Communication will always be evidence-based and scientifically rigorous, but adapted to the needs of each audience, making complex issues understandable without oversimplification.

Instruments and Channels

The dissemination of information will be carried out through both traditional and digital media, as well as through participatory events. National press conferences will be organised at central institutional headquarters in Rome, while regional and local press conferences will take place in the territories concerned. Constant dialogue with local communities will also be ensured, with methods and timeframes to be defined in collaboration with the municipalities involved in the research and with the research units in charge of the investigations. Information will be shared through the official social media channels of ISPRA and the participating partners, as well as through the creation of specific channels dedicated to NEP activities. The NEP will also be presented to the scientific community in the framework of conferences already scheduled or to be planned.

Regular webinars and online meetings will be organised with institutional representatives, businesses, trade associations, environmental and social organisations. On the National Mineral Resources Portal (GeMMA), each research area will have a dedicated public page, regularly updated with research results and supported by FAQs.

Scientific findings will be presented at conferences and published in specialized journals. At the same time, interviews, press releases, and informative articles will be prepared, along with any other material deemed useful for communicating to non-specialist audiences.

Given the potential interest of foreign investors, all information materials will be produced in multiple languages and disseminated internationally, including at major events such as the Riyadh Future Minerals Forum (KSA) and the Toronto PDAC (CAN), in addition to initiatives organised by the European Commission.

Planned Events (proposals subject to agreement with competent ministries)

- June 2025 – National press conference launching the NEP.
- June 2025 – Launch and update of the national database.
- July–September 2025 – Local presentations of activities to communities.
- September 2025 – Presentation of the NEP at the Congress of the Italian Geological Society and the Italian Society of Mineralogy and Petrology.
- September 2025 – Training Day for journalists on mineral resources, with a session dedicated to the NEP.
- 13–15 January 2026 – Presentation at the Future Minerals Forum (Riyadh, KSA).
- 28 February–4 March 2026 – Presentation at PDAC 2026 (Toronto, CAN).
- May 2026 – Local events presenting the first-year results.
- End of May 2026 – National event presenting the first-year results and planning the next two years.

- May 2027 – National event presenting the second-year results.
- May 2028 – National event presenting the third-year results and future planning.
- May 2029 – National event presenting the fourth-year results.
- May 2030 – National event presenting the fifth-year results.
- June 2030 – Presentation of the new NEP.

Performance Indicators (KPIs)

The effectiveness of the Communication Plan will be monitored through:

- Participation levels in public events, consultations, and webinars.
- Feedback collected during meetings.
- Media coverage and dissemination on traditional and digital platforms.
- Website traffic metrics (visits, sources, average session duration, most visited pages).
- Public engagement indicators on social media (likes, shares, sentiment).
- Assessment of knowledge improvement regarding the NEP and reduction of social opposition.

Budget and Resources

ISPRA will appoint a Communication Officer to coordinate a dedicated working group composed of ISPRA staff and representatives of research units active in the field. Resources for events and planned activities will be covered under Activity Line 4 (Training, Communication, and Human Resources). Where necessary, ISPRA may also rely on external professional support.

10-STAKEHOLDER INVOLVEMENT PLAN (PCS)

Introduction

To effectively conduct an activity such as general mining research—an endeavour with significant economic potential, high scientific and professional value, and important geopolitical implications, but also potentially divisive from a social and territorial perspective—it is essential to design and implement a comprehensive stakeholder involvement strategy.

It must be emphasised that the activities of the NEP are limited to general research and the provision of information for investors, as well as for state and regional planning and permitting authorities. The NEP does not envisage any direct operational mining activities. Within this framework, stakeholders can be grouped into four main macro-categories.

1) Central, local and Community institutions
2) Industry and entrepreneurship
3) Scientific, technical and communication users
- academies and research institutes
- scientific societies
- professional associations and associations (geologists, geophysics, engineers, mining experts, etc.),
- environmental agencies
- mass media
- freelancers
4) Citizens
- central and local cultural and environmental associations
- civic representations
- citizens

This plan for stakeholder involvement is conceived as a general framework. It must be adapted and specified according to the specific context of the National General Mineral Exploration Programme (NEP), the characteristics of the areas concerned, and the specificities of the various stakeholder groups. A flexible and adaptable approach is therefore crucial to ensure effective and meaningful engagement.

Objectives of the Engagement Plan:

The purpose of the SCP is to:

- Identify possible stakeholders for the National Exploration Programme taking into account the evolution of research over a five-year period and the possible economic, territorial, environmental and social impacts that mineral exploration may have over time.

- Build constructive relations with all relevant stakeholders and ensure that their concerns and perspectives are understood and considered in the course of investigations, also for the purpose of improving the social acceptability of the operations.
- Provide clear, accurate and timely information on the programme and its progress through the Communication Plan described in the dedicated chapter
- Identify opportunities for collaboration and partnerships.

Who may be involved

1) Institutions

The programme operates at two complementary levels:

- Centralised planning, funding and data management, also for transmission to the European Commission.
- Operational implementation of general mineral exploration and data acquisition in the identified areas.

Relevant ministries directly responsible for the NEP (MASE and MIMIT) are considered beneficiaries of the Programme, like the European Commission, and are therefore not classified as stakeholders, unless specific Directorates not directly involved in the NEP are designated as such. In the first analysis, it is considered possible and useful to involve:

Central institutions:

- Ministry of Foreign Affairs, due to the clear geopolitical connotation linked to the search for First Critic Materials and the management of meetings, through embassies, with the Geological Services and with non-European entrepreneurs
- Ministry of Civil Protection and Sea Policy, for possible/safe interest in potential underwater mineral resources
- Ministry of the Interior and Ministry of Defence, for aspects related to national security of mineral supply and for the possible use of MPCs in national defence
- National park authorities in case the study areas are close to the boundaries of the parks.
-

Supranational bodies:

- JRC, both on the dialogue to build the Italian RMIS analogue and on the interest in implementing the new metal ore BREFs
- UNECE, for the application of the UNFC Code in Italy
- OECD
- EIT Raw Materials.

Regional institutions

- Regional junctions and Ministries for the Environment, Industry and Cultural Heritage
- Regional Mining Offices
- Regional Environmental Protection Agencies (SNPA)
- Regional Park Authorities
- Mountain Communities;

They will be invited to be informed of the NEP and the URBES project on extractive waste, the regional offices for extractive activities collected by ISPRA in the RISG network (Italian Geological Services Network).

2) Industry and entrepreneurship

The programme aims to provide essential information to facilitate investments in the national territory. With regard to business and industry, the main reference stakeholders are companies active in the mining sector.

In the industrial minerals sector, several important national companies are already operating. By contrast, in the metallic sector there is a significant scarcity of Italian companies specialized in underground mining. Although one of the objectives of the NEP is to stimulate the creation and/or growth of companies, including in the metallic sector, it is currently considered strategic to involve foreign mining companies, some of which are already active in Italy.

It may be easier, also due to lower investment requirements, to attract companies interested in the exploitation of extractive waste. This activity does not require the substantial know-how needed for underground mining, especially in deep deposits.

Another relevant branch of business concerns mineral exploration services, particularly geophysical prospecting—whether terrestrial or carried out with airborne or UAV sensors. Some of these companies have already been contacted to provide quotations as part of NEP activities. Their participation, especially in the coming years, could directly support research activities and lead to expressions of interest for future cooperation.

In a preliminary analysis, the following stakeholders could be involved:

- Assorisorse, the trade association within Confindustria, representing around 100 Italian and foreign companies.
- IOCME, the Italian Observatory for Critical Raw Materials and Energy.
- National industrial minerals companies and foreign companies operating in Italy (e.g. Industrial Minerals, Polar, Soricom, Sibelco, Maffei Sarda Silicati, Mineraria di Boca, Clariant, Imerys, Holcim).
- Italian underground mining companies (Italkali, Mineraria Gerrei).

- Foreign companies holding research permits on the national territory (AltaMin, Energy Minerals, Cresta Minerals, Vulcan).
- Geophysical prospecting companies (Excalibur, Emergo).
- Other domestic SMEs specialized in geophysical and geochemical services.
- Recycling companies potentially interested in products derived from extractive waste (e.g. Erion, FAAM, Iren)

3) Scientific, Technical and Communication Stakeholders

- Universities, research centres and institutes (CNR, ENEA, INGV, Mining Schools).
- Scientific societies (SGI, SIMP, GABEC).
- Professional associations (ANIM, CNG, AIPIM, regional associations of geologists and engineers).
- Mass media (press, radio, TV, digital media).
- Independent professionals (geologists, engineers, mining experts).

4) Citizens

- Central and local cultural and environmental associations.
- Civic organisations and community groups.
- Residents of areas involved in the NEP.

Stakeholder selection and management criteria

Among these groups, the position of each candidate stakeholder (institution, organisation, group) will be assessed on the basis of the following criteria:

  - Relevance and involvement of the candidate concerned in the fields covered by the NEP (e.g. the significant impact that other Ministries may have, in addition to MASE and MIMIT, in the definition of national mining policies and the prioritisation of intervention fields, or the role of national mining companies).
  - Interest and affinity with the fields of action of the NEP from a scientific and technical point of view, including environmental protection issues
  - Influence of the candidate stakeholders on the NEP, in so far as the project incorporates comments and feedback from stakeholders, based on their technical/scientific authority, their institutional position and their relevance to environmental and spatial planning

On the basis of these criteria, two levels of interaction with stakeholders were identified:

• Key stakeholders: the project keeps stakeholders informed and expected feedback to provide advice and suggestions on the implementation of the project. While we are committed to complementing this feedback to meet stakeholders' expectations, there is no obligation to accept all suggestions.

• Ordinary stakeholders: the project keeps stakeholders informed on an ongoing basis. Dissemination actions will be undertaken, but no feedback is foreseen

To effectively manage stakeholder involvement, the NEP will use the Communication Plan and the strategies identified above to communicate project information to key stakeholders in a proactive and timely manner. Using the information provided in the Communication Plan (such as stakeholder groups, communication elements, purpose, method of communication and frequency), the project will be able to increase stakeholder support and visibility for its entire duration. Managing stakeholder involvement helps to increase the chances of success of the NIP by ensuring that stakeholders have a clear understanding of the project's objectives, aims, benefits and risks.

Managing stakeholder involvement involves two different levels of action:

- two-way interaction with *priority stakeholders*, establishing constant communication and interaction between the project and stakeholders (information feedback). This interaction allows the implementation of recommendations and suggestions in the NEP.
- one-way interaction with *ordinary stakeholders*, which mainly involves dissemination and updates, as detailed in the Communication Plan (Deliverable 1.4). Multiple communication channels will be deployed at different levels, providing both specialized resources and less specialized content.