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Research Paper

New insight on a geo-heritage sulphur itineraries in Central Sicily (Italy): Challenges and perspectives

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ABSTRACT

This article is focused on the valorization of the cultural heritage represented by sulphur mines in Sicily, Italy. In particular, it represents a first approach finalized to create geo-touristic routes and improve the knowledge of the cultural and industrial Sicilian sulphur heritage. For this purpose, a geographic information system (GIS) was used to create a specific database of the study area. At the same time, a careful territorial analysis was carried out to design a possible sulphur cultural tourist itinerary, following the regional Sicilian laws of the 1990s. In order to achieve the final goal, different actions were performed, including collection of bibliographic data and reports, sites surveys to define the actual state of the sites, and collaboration with public and private bodies such as universities, Institute for Environmental Protection and Research (ISPRA), local governments and associations. The results achieved could represent a good growth opportunity for an economic and touristic growth. In particular, the creation of the Sulphur Cultural Itinerary represented a good way to increase the Sicilian tourist attraction. The itinerary was focused on the data available on the Touring Club's guidebook, but there were differences and improvements. The main differences concerned both the starting point, for its notable landscape, naturalistic and scientific values, and the itinerary roads, some of which were no longer accessible. The outcome reached was a starting point for all stakeholders of geoheritage, such as municipalities, tourism agencies and academics.

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1. Introduction

Geoconservation strategies follow a structured process encompassing inventory, quantitative assessment, conservation, interpretation, promotion, and monitoring of sites. These steps are strategically designed to facilitate the effective development of geotourism (Hose, 2005; Sharples, 2002), a contemporary form of tourism experiencing rapid expansion globally, manifesting in landscapes across diverse ecological and altitudinal zones.

Alongside geoheritage, industrial and mining heritage encompasses all the remnants of the industrial history that enhance our understanding of the historical productive activities of a nation or a community, there is a growing interest in conserving and valorizing it by applying geoconservation strategies (Carcasio, 2017; Marescotti et al., 2018; Velikić et al., 2022; Vlachopoulos & Voudouris, 2022). Treating a monument or an object utilized in industrial processes as a repository of information is crucial

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and indispensable because it encapsulates the diverse influences of culture and the surrounding environment (Carcasio, 2017; Vlachopoulos & Voudouris, 2022).

Italy has a vast and original industrial heritage related to mining and processing minerals, as well as a diverse geo-mineral heritage. At the same time, Italy has a long documented mining history, which allows us to understand why it is one of the places where culture and art related to ore extraction have developed the most (Patanè, Sisti, & Lasco, 2020). The remains and evidence of over 2 millennia of mining activity along Italy are a huge amount of scientific, anthropological and historical-cultural data. These data represent both a significant didactic tool and a tourism potential that has not yet been fully appreciated. Mining sites are an important focus point between industrial, archaeological, cultural, historical and landscape heritage, through which societies and communities have developed over the time, determining important conditions for economic and social growth of the country (De Corso et al., 2023). According to the Code of Cultural Heritage and Landscape of Italy, pursuant to Article 10 (Legislative Decree of January 22, 2004, No. 42; De Corso et al., 2023), the mining sites having historical or ethno-anthropological interest are considered cultural heritage (Brocx & Semeniuk, 2007). In 2015, the National Network of Parks and Mining Museums (Re.Mi) was established, promoted and coordinated by Institute for Environmental Protection and Research (ISPRA) with the aim of enhancing the activities at a national level and raising awareness of the historical and cultural heritage (Patanè et al., 2020). ISPRA operates throughout the territory to promote the recovery and enhancement of decommissioned mining sites and to promote the development of mining tourism in Italy.

In this framework, the post-mining regions of Sicily exhibit elevated socio-ethno-cultural and aesthetic attributes, showcasing significant geotouristic prospects that have largely remained untapped until now.

In this way, the main goal of this paper is to study and valorize an area located in Sicily, Italy, precisely between the provinces of Agrigento, Caltanissetta, Enna and Palermo, where various sulphur, rock and potassium salts mining activities take place. These activities could be enhanced to serve as economic and tourism development attractors. The recovery of the mining facilities and their transformation into industrial archaeology and ethno-anthropology museum centers can represent a good tool for the development of cultural and tourism activities in this area. In particular, Sicilian sulphur has been used since ancient times up to the modern era for different purposes such as agricultural, religious, war, chemical, domestic, medical and in other different fields (Carcasio, 2017). As scientific research progressed, resulting in new discoveries between the 15th and 18th centuries that found immediate application in technology and industry, especially in France and England, the sulphur mining industry in Sicily reached its peak in the 19th and 20th centuries (Carcasio, 2017; Dacquino, 2024). Such was the strategic importance of this activity that the Kingdom of the Two Sicilies and the United Kingdom came to the brink of war over a sulphur trade dispute involving not only the two European powers, but also France, this crisis which took place in 1840 is known as the “Sulphur War” (VV. AA. 1840). The study published by ISPRA in 2006, titled *Italian Mining Sites (1870–2006)* by Dacquino (2024), surveyed 763 mining sites in Sicily between 1870 and 2019. Of these, 661 were mining sites for sulphur and the paragenetically associated minerals such as rock salts (52) and mixed alkali salts (Touring Club, 1981).

The decommissioned mines from the 1980s to the 1990s have left their marks on the landscape of the island, with some being partially protected and turned into museums, while the majority have been abandoned. On the base of the historical importance of industrial sulphur production, Sicily took a legislative approach in the 1990s to lay the groundwork for the enhancement of the great socio-cultural heritage of historic sulphur mines, which operated from the 1800s until the 1960s.

The definition of this legislative approach has determined different actions in order to establish a mining network and a tourist-cultural thematic itinerary to preserve, valorize and manage the sulphur mining sites scattered across Sicily.

The creation of a geo-tourism itinerary could thus finally enhance a cultural and archaeological-industrial heritage of great landscape-environmental and historical-anthropological relevance (partially already subject to regional protection), promoting the knowledge of a large part of the Sicilian territory, including the provinces of Agrigento, Palermo, Caltanissetta, and Enna, which offers a geological, geomorphological and mining variety of great interest.

This activity would have a positive impact on the tourist offer of the Sicily, since it can improve geotourism, especially in areas where tourism is generally less developed (i.e., Central Sicily). For this reason, we propose an integrated approach to preserve and valorize the Sicilian mining landscape in the present research. Specifically, the initiative began by incorporating sites identified in the Italian Touring Club Guide of 1981, supplemented by additional mining sites designated as regional museums according to respective laws. A comprehensive database was then constructed, drawing from the ReMi-ISPRA database, literature, and newly acquired data, all suitably integrated with photographic and cartographic documentation. Field surveys have been conducted to assess the current conditions of the sites, providing valuable insight into their present state.

In order to reach this goal, we create a geo-database in a GIS environment for the subsequent design and implementation of a geo-archaeological-socio-tourist itinerary in Central Sicily. In particular, we have used an open source software QGIS 3.28 through the geoprocessing tools.

2. Material and methods

2.1. Study area

The study area is located in Sicily of Italy, precisely between the provinces of Agrigento, Caltanissetta, Enna and Palermo, where various sulphur, rock and potassium salts mining activities take place.

Table 1
Selected pilot sites with their position.

Mining site	City	Geographic coordinates [WGS 84]
Floristella-Grottacalda Mining Park	Enna, Aidone, Piazza Armerina, Valguarnera	(37° 29'19.5216"N, 14° 21'5.6268"E)
Mining Museum of Gessolungo	Caltanissetta	(37° 30'37.4868"N, 14° 05'15.1548"E)
Mining Museum of Cozzo Disi	Casteltermini	(37° 30'48.0672"N, 13° 40'56.6364"E)
Museum and Archaeological-Industrial Park of the Zolfara of Lercara Friddi	Lercara Friddi	All municipal area of Lercara Friddi
Ciavolotta Mine	Agrigento	(37° 16'2.1972"N, 13° 39'11.1384"E)
La Grasta Mine	Delia	(37° 22' 0.1092"N, 13° 58' 20.3916"E)
Trabia-Tallarita	Riesi, Sommatino	(37° 17'57.588"N, 14° 02'7.6596"E)

In particular, the principal selected sites are the followings:

- Floristella-Grottacalda Mining Park, located in the municipalities of Aidone, Enna, Piazza Armerina and Valguarnera;
- Mining Museum of Gessolungo, located in the municipality of Caltanissetta;
- La Grasta Mine, located in municipality of Sommatino;
- Mining Museum of Trabia-Tallarita, which falls within the municipalities of Riesi and Sommatino and is divided by the Salso River;
- Mining Museum of Cozzo Disi Mine, located in the territory of the municipality of Casteltermini, in the province of Agrigento;
- Ciavolotta Mine, located in the municipality of Favara;
- Museum and Archaeological-Industrial Park of the Zolfara of Lercara Friddi (Palermo). This is the only mining centre in the province of Palermo. The first sulphur mines arose between 1833 and 1836, although the first unsuccessful searches date back to 1788.

The choice of these sites is related to the historical, cultural, environmental, legal, and photographic data which are useful to define the Sulphur Cultural Itinerary. The full description of each site's features is reported in the Results section.

2.2. Methodology

The methodology used in this work focused on the collection of bibliographical data, report, and surveys to understand the actual conditions of the selected places and to promote collaboration among various public and private entities such as universities, ISPRA, public administrations, and local associations. The methodology developed could be summarized in five main steps.

- (1) Data acquisition: This phase was devoted to a systematic collection of all available data within a geographic information system (GIS) project by checking the correctness and consistency of the information in the datasets, homogenization and correction of errors. This phase was crucial in order to create a suitable database for subsequent processing.
- (2) Survey: In this stage, campaign checks were carried out to verify, confirm or possibly improve the assessments made in the previous stages.
- (3) Data processing: In this phase, some of the previously acquired data were processed in order to obtain a specific dataset for the study area and the generation of derived cartography such as digital terrain model (DTM).
- (4) Data homogenization: Once the data processing phase was completed, the data were imported into a single cartographic reference system so that they could be overlaid, compared and integrated.
- (5) Discussion and conclusion: All data were first discussed and then conclusions were elaborated by conducting a critical analysis.

To define the sulphur itinerary, various data types were utilized, including geographic, historical, cultural, environmental, legal, and photographic data. These data were essential for itinerary planning and a comprehensive understanding of sulphur mining history and culture. The integration of these diverse data sources was pivotal in developing a thorough itinerary while ensuring compliance with existing regulations.

This methodological approach was applied to the following selected pilot sites (Table 1).

The itinerary proposed by the Touring Club in its 1981 guidebook was certainly a good starting point for planning the "Sulphur Cultural Route." This route is still under evaluation and modification, being implemented by ISPRA-ReMi in collaboration with the University of Calabria and the Municipality of Caltanissetta within the context of "First Mediterranean Lifestyle World Park."

In particular, the itinerary proposed by the Touring Club's guidebook offered a detailed route through various sulphur mines in Sicily, some of which were still operational at that time. The guide pays particular attention to the history, economy, and environmental impact associated with the mining industry of that period. Specifically, at the time of its writing, it already foreshadowed

Table 2
Databases converging on GeMMA.

Databases (DB)	Contents	Period	Type	Overlay
DB CARG	Quarries and mines from ST013- Resources and Surveying.	1988–2017	GEO DB	40% of national territory
DB mines and quarries	Active quarries and mines	2014 (mining production), 2017 (state of activity)	GEO DB	National territory
DB mining sites	Abandoned mines	1870–2006, 2017 update	GEO DB	National territory
National inventory of mining waste	National inventory of type A mining waste storage facilities	2012–2022	Excel	National territory
DB PRAE	Regional Mining Plans	Several years	Maps and report	Regional territory
DB ReMi	Census schedules	2023	Excel	National territory

what would happen shortly thereafter, namely, the complete decommissioning of the mines throughout Sicily and, consequently, the conclusion of the already initiated decline of a historical period for the economy and society in the so-called “Sulphur Area.”

The first approach to define the main itinerary features was focused on the definition of the state of art, considering all mining historical documentation available. In particular, during this step, detailed reports were analysed regarding the condition of the locations where the abandoned mining sites were situated. These reports included information on the presence of any legal constraints, site ownership, as well as the potential existence of redevelopment and reclamation projects for the surrounding areas.

A search was conducted for basic data on the current status of disused mining sites in the provinces involved (Agrigento, Caltanissetta, Enna, Palermo) as literature data, with the help and involvement of the various public bodies (Department of Energy and Public Utilities and Energy Department of Sicily; Caltanissetta Mining District; Caltanissetta Municipality; territorial associations). These data were derived from the portal of the Geological Survey of Italy (georesources) and ISPRA's Geological Mineral-Environmental (GeMMA) Database under construction.¹

ISPRA's GeMMA Database was born out of the need for policy development oriented toward the sustainability of the solid minerals industry, and this cannot be separated from an adequate level of knowledge. In Italy, a variety of data and information are available, but they are often dispersed among various managing bodies, both current and past. ISPRA's GeMMA Database is therefore based on the retrieval, revision, validation and harmonization of the information in the archives of the Geological Survey of Italy, which is supplemented by the new national geological cartography at the scale 1: 50,000 (CARG Project), as well as the data derived from other databases, notably the one related to the aforementioned census of disused mining sites (Carta et al., 2017) (Table 1).

The ISPRA's GeMMA Database was built with the INSPIRE principles and criteria (2007/2/EC, Legislative Decree 32/2010) with the aim, therefore, to ensure that the spatial data infrastructures of all European Union Member States are compatible and usable in an European Union context.

The following was a summary regarding the state of disused mining areas with the data collected to date, which could be a fundamental starting point for the future work of planning, reclamation, recovery and enhancement of the sites concerned. Initially, the study focused on the sites identified by regional laws (Table 2). However, as the analysis progressed, it was decided to also highlight disused sites not identified by regional laws but deemed noteworthy and worthy of visitation. Additionally, all emergencies significant from environmental, historical, archaeological, and tourist perspectives were considered along the itinerary. These included protected areas, villages, walkways, disused railways with potential for conversion, important museums, and more (Table 3).

3. Results

The Sulphur Cultural Itinerary in Sicily inters with other historical and/or naturalistic routes such as Via Francigena, Mount Capodarso and Southern Imera Valley between Caltanissetta and Enna, which has been included in the list of Sites of Community Importance under Directive 92/43/EEC and the European Geoparks Network, within the Rocca di Cerere Geopark (Italy).

A good valorization of these sites requires a holistic approach, including land protection, promotion of sustainable tourism, environmental education and raising awareness within the local community. In this way, the itinerary can become a model of sustainable development and enhancement of Sicily's cultural, natural and anthropological heritage.

In particular, the creation of the Sulphur Cultural Itinerary can represent a good way to increase the Sicilian tourist attraction. The last published data about the tourist flows related to the years 2021 and 2022 underline a 50% in tourist presence in Sicily.

¹ The national database on mineral resources under the portal of Geological Survey of Italy (isprambiente.it): <http://portalesgi.isprambiente.it/it/news/news/la-banca-data-nazionale-sulle-risorse-minerarie>.

Table 3
Sites identified by regional laws.

Mining site	City	Regional law
Mining Museum of Gessolungo	Caltanissetta	17/91
La Grasta Mine	Delia	17/91
Mining Museum of Trabia-Tallarita	Riese, Sommatino	17/91
Ciavolotta Mine	Agrigento	17/91
Mining Museum of Cozzo Disi	Casteltermini	17/91
Floristella-Grottacalda Mining Park	Enna, Aidone, Piazza Armerina, Valguarnera	17/91
Museum and Archaeological-Industrial Park of the Zolfara of Lercara Friddi	Lercara Friddi	15/93

Unfortunately, this increase is not homogeneous throughout the island, for example, the Caltanissetta area shows a decrease. This itinerary could be a means to uniformly encourage all tourist activities in the Sicilian territory.²

The Sulphur Cultural itinerary (Fig. 1) is described below starting with the Floristella-Grottacalda site, which entered the Re.Mi Network in April 2022. For the sake of brevity, the mining sites representing the main stages of the above itinerary are described, established as regional museums by the relevant regional laws.

3.1. Floristella-Grottacalda Mining Park

Floristella-Grottacalda Mining Park is located in the municipalities of Aidone, Enna, Piazza Armerina and Valguarnera. It is managed by the Sicily, the Regional Province of Enna, and the municipalities involving and the Floristella-Grottacalda Mining Park Authority. The park was established to protect and preserve the sulphur mining complex in the area, with particular attention to the landscape and environmental aspects. In addition, it promotes socio-cultural and recreational activities and ethno-anthropological research to study “mining society” and technology related to “mining culture.”

The park includes the Floristella and Grottacalda mines, as well as the Gallizzi sulfara. It covers an area of 400 ha and represents one of the largest and most important sulphur mining areas in Sicily, as well as one of the main sites of industrial archaeology in Southern Italy. The Floristella Mine was exploited from 1825 and closed in 1986, although there is evidence of mining as early as Roman times.

From a logistic point of view, the park can be reached by car following the road signs from the Dittaino highway exit. The visit to the park begins with a welcome in the parking lot near the former Palmento Pennisi, where vats for crushing grapes and a canal made of Sicilian tile that transport the must to the cellars of Palazzo Pennisi, are still visible.

Through an evocative flight of steps called “Via del mosto,” one arrives at Palazzo Pennisi, currently under restoration, where there are two exhibitions: one is on the Sicilian Fasci and the other is an educational exhibition in the former chapel. Along the pathways are some miniatures of tower of a well extraction “Pozzo nuovo,” the calcheroni and the Gill furnaces, as well as educational panels and a reconstruction of a gallery with wooden armor.

In the Palazzo Pennisi hypogeum, there is an exhibition consisting of about 90 educational panels curated by Italian Association of Industrial Archaeology (AIPAI, acronym in Italian), illustrating the paths of industrial archaeology in Italy. After visiting the underground exhibition, visitors can proceed outside to the area of Well 3 (Fig. 2), which is the most recent and was built between 1970 and 1971 (Cirrione, Fiannacca, & Punturo, 2022). The well has a depth of 222 m and a diameter of 3.5 m. Here it is possible to observe the steel casing and all the transport and loading elements, such as the carts and tracks used to move and unload the mined material.

During the visit, along the routes there are some shaft mining towers surrounded by buildings such as an infirmary, miners' quarters and workshops. Next, it is possible to reach the limestones, equipped with an inclined plane and a battery of gill furnaces unearthed in 2008. Along the way, limestones are visible, representing an ancient smelting method to separate sulphur from limestone.

The park also has notable scenic and natural features, such as a sulphur source that feeds the Floristella stream and the waterfalls of the same name. In addition, continuous methane and ferruginous salt water emissions can be observed from some mouths called “Maccalube” or mud volcanoes, they are visible in the northern part of the park. Finally, there are numerous mouths of drainages (about 180) in the Gallizzi district, which testify to mining activity from the 18th century until the end of the 19th century. The remains of the “old well” or “St. Joseph well,” which dates back to the period when the site belonged to the religious order of the Society of Jesus, can also be seen (ARR, 2023).

3.2. Mining Museum of Gessolungo

The Mining Museum of Gessolungo, is located in the municipality of Caltanissetta. Although it is one of the sites of the Regional Mining Museum in Caltanissetta, established by Regional Law No. 17 of 1991, it has not yet begun any renovation and reconversion work as a museum.

The mine was exploited starting in 1839 and was closed in 1986 after eight years of inactivity. It is known to be one of the deepest mines in Sicily, about 300 m deep. According to GeMMA Database of ISPRA, the area includes several mines (Fig. 3).

² <https://ufficioturistico.eu/informazioni-e-consigli/itinerari/>.

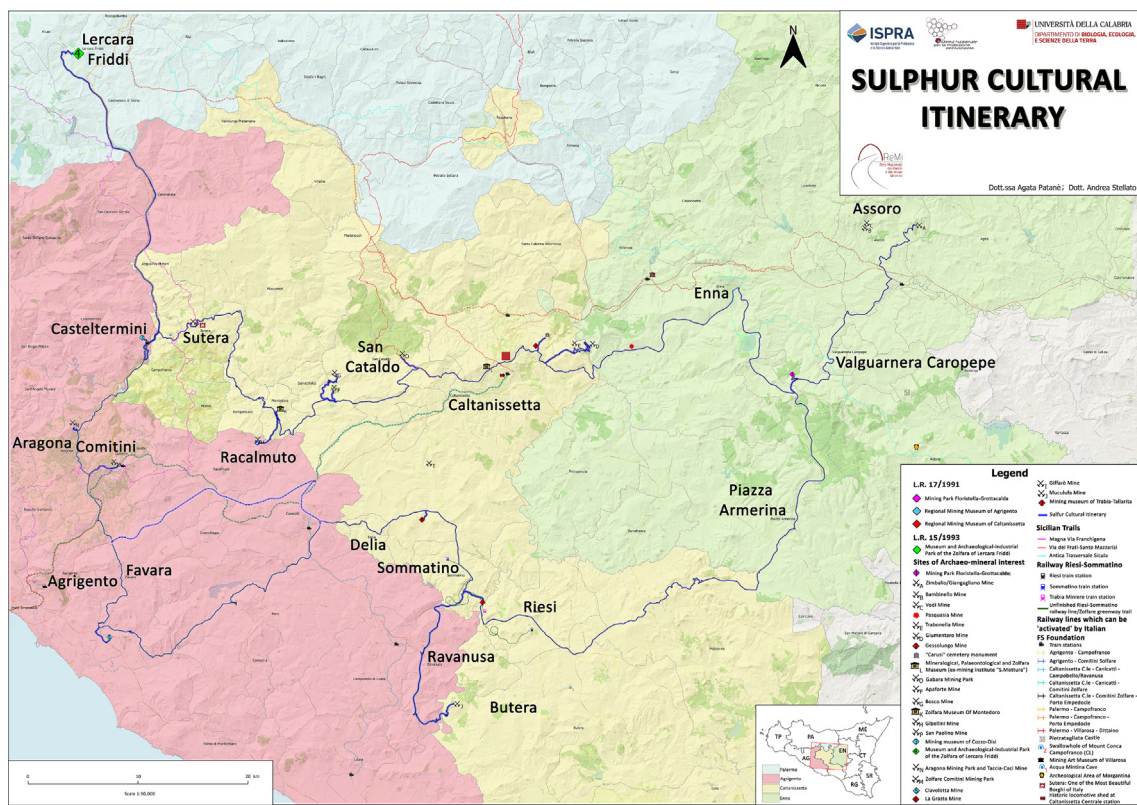


Fig. 1. The Sulphur Cultural Itinerary.

3.3. La Grasta Mine

La Grasta Mine is located in municipality of Sommatino. It was a small sulphur mine, which was opened in 1967 and finally closed in 1988. The access routes to the underground were closed at the end of 1990. The exploited sulphur layer was contained between the bed limestones and roof marls. The underground caverns in which cultivation took place by means of explosives, were formed by a succession of large geodes or cavities (called “garbere”), inside of which thousands of bright white celestine crystals were found. These crystals were immersed in a sulphur matrix that completely covered the walls and roof of the cavities (Calabrò, 2015).

At present, although the mine is identified as a regional mine-museum, it is privately owned and therefore not available for use by third parties.



Fig. 2. “New Well” or Well 3, the most recent well of the three.



Fig. 3. Location of disused mining sites belonging to the Mining Museum of Gessolungo area (yellow points) and other ex-mining sites in the surrounding area (red points). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.4. Mining Museum of Trabia-Tallarita

Trabia-Tallarita Mine, at the centre of the chalky-sulphurous plateau of central Southern Sicily, falls within the municipalities of Riesi and Sommatino and is divided by the Salso River. The mining activities started in 1823 thanks to the first owner who was the Prince of Trabia and Butera, while in the years from 1913 to 1921, it was owned by the Florio family. It remained active until 1975.

The mine was purchased by the Regional Department of Cultural Heritage between 2000 and 2003. On March 8, 2010, the first phase of restoration work was inaugurated, involving the Palladio Power Plant and the adjoining buildings that were once used as workshops and offices. In 2022, the Mining Museum of Trabia-Tallarita joined ISPRA's Re.Mi Network. The museum, built on the premises of the former Palladio Power Plant, houses an interactive and educational exhibition comprising five main parts:

- the discenderia, a simulation of access to the shafts with stops at the galleries, which allows visitors to virtually enter the mine (Fig. 4);
- the mine pavilion consisting of a multimedia space;
- the Tosi engines (Fig. 5), restored, animated and accompanied by stories;
- the scientific exhibits, workshops dedicated to electricity;
- a timeline tracing the most significant moments in the history of sulphur in Sicily.



Fig. 4. Simulator of access through mine wells, which is located in the building of Mining Museum of Trabia-Tallarita.



Fig. 5. Tosi motors which are restored and displayed in their original position inside the former Palladio Power Station of the Trabia-Tallarita Mine.

The adjacent buildings house the permanent photographic exhibition “Sulfaro e Sulfarari” on life in the mines (Fig. 6), a projection room, a conference room, a didactic room, a collection of minerals and crystals from the chalky-sulphur series, a collection of miners' equipment and a space for temporary exhibitions.

At the same time, outside to the museum, it is possible to visit a part of the imposing flotation plant (Fig. 7) and the remains of the pylons of the cableway that connected the entire mining complex with the Campobello station, along the Canicattì-Licata line, to transport sulphur to the ports on the coast, along a 10 km route.

On the Sommatino side, it is possible to visit the miners' village with the buildings used for accommodation and offices, although they are not open to the public. Visitors can follow the dirt road leading to the gill furnaces and the winch halls situated above the wells (Fig. 8).

3.5. Mining Museum of Cozzo Disi

Cozzo Disi Mine was one of the most important mines in Europe, which is located in the territory of the municipality of Casteltermini, in the province of Agrigento. The entrance to the site (Fig. 9), currently protected by a gate, is located on SS 22 highway, a short distance from SS 189 highway.



Fig. 6. Entrance to the “Sulfaro e Sulfarari” photo exhibition.



Fig. 7. Flotation system of Trabia-Tallarita Mine.



Fig. 8. Miners' village on the Sommatino side of the Trabia-Tallarita Mine.

The mine was exploited from 1839 to 1988, and was subject to a direct ethno-anthropological constraint of considerable size (over 60 ha) under Law 1089/1939. In addition, the site was designated as a regional museum by Regional Law No. 17 of 15 May 1991.

The importance of the mining site, underscored by the wealth of evidence and memories that it still offers visitors, is strongly linked to the fundamental role that the sulphur industry played in the Sicilian economy in the past time, especially in terms of employment.

The temporal extension of the ore's cultivation is clearly reflected in the artefacts found on the site, which testify to the succession of various technologies for sulphur purification, some of which are still partly visible.

The process of sulphur purification has undergone continuous improvements over time due to the emergence of new technologies. At the Cozzo Disi site, four different artefacts representing various techniques are arranged in chronological order: the calcheroni, the Gill furnaces, the steam melting plant and the flotation plant. The commissioning of the flotation plant marks the beginning of a new era for the mine, which would undergo significant changes in appearance and activities until its closure.

Access tunnels, flotation tunnels, ventilation wells, winch room, flotation plant, conveyor belts, storage buildings, workshops and dwellings, steam ovens with feed trolleys and other vestiges can be observed on the site. The site can be divided into two



Fig. 9. Entrance of the Mining Museum of Cozzo-Disi Mine.

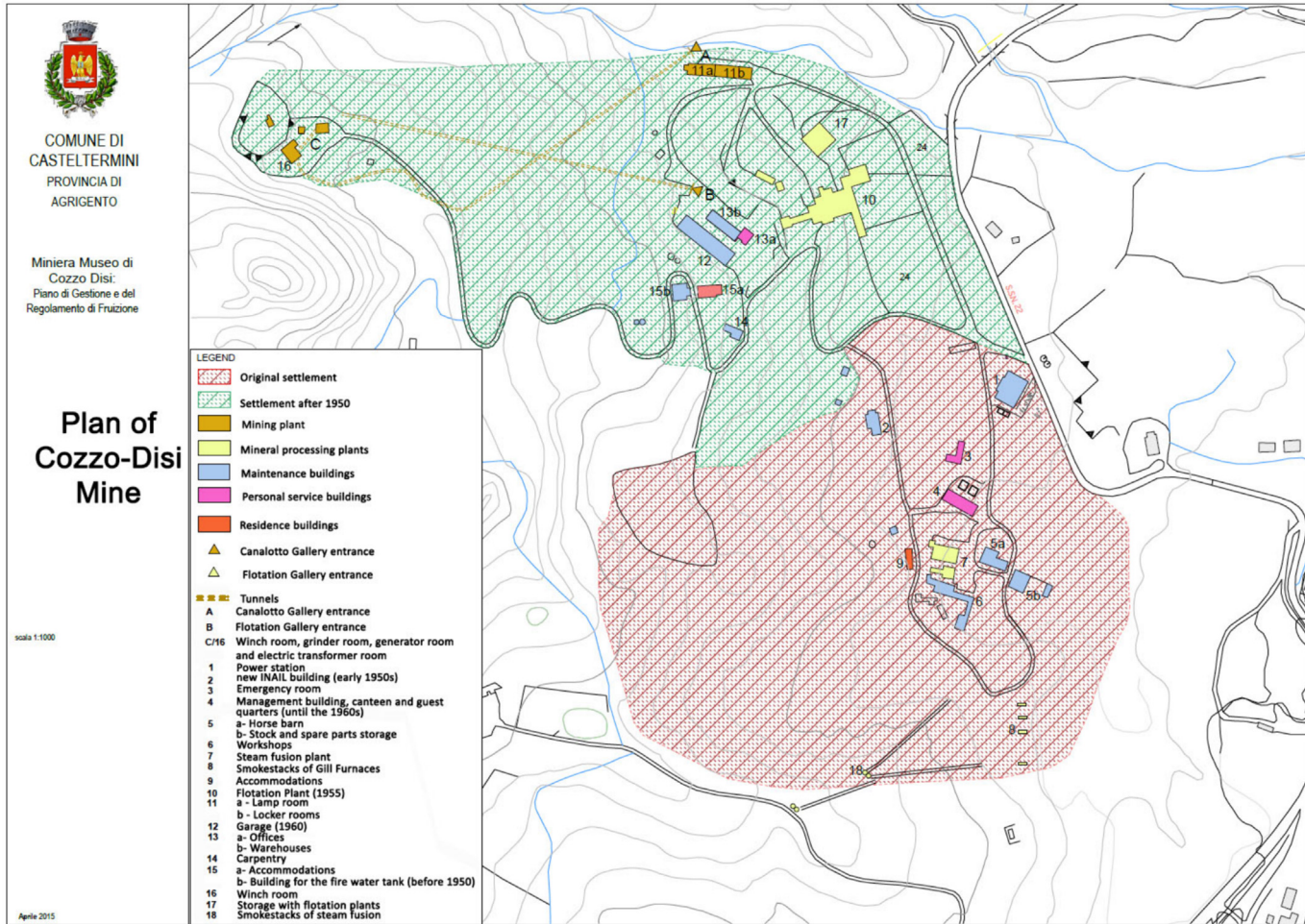


Fig. 10. Planimetry of the Cozzo-Disi Mine from which it is possible to identify the two macro areas. The original settlement is in red while the settlement after 1955 is in green. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Fig. 11. Outdoor theatre with the converted building of the former power station.

macro-zones, the first containing the original settlement (before 1950), the second comprising the buildings constructed after 1955 (Fig. 10). This distinction is due to the installation of the flotation plant that moved the centre of activity to the highest part of the settlement, near the mouth of the current tunnels.

The original centre of the mine can be reached by proceeding along the path to the left of the current entrance. The buildings are in a state of degradation but still visible and under preservation, although not in optimal condition, which include the main artefacts that housed the mine's production and ancillary activities. The modern core, located further northward and at a higher elevation than the original settlement, exhibits different artefacts associated with the later phase of mine activity, notably the presence of the flotation plant.

As far as the underground is concerned, the Cozzo Disi Mine has a considerable and complex extension. The mine was subdivided by height into 12 levels, which was excavated progressively as the levels above were exhausted. Today, due to the lack of water education, they are flooded. The main well, named "D'Ippolito" in honour of the first director of the mine, crosses the various levels until it almost reaches the surface, under the plateau where the winch room and the transformation cabin are located. Around it, there is a "workers' way," a narrow passageway with steps connecting the various underground levels.

An open-air theatre has been built at the entrance to the mining area (Fig. 11), and the old power station, which still houses diesel engines, has undergone restoration (Fig. 12). Additionally, a reception room providing access to the Canalotto gallery has been established.

Although the site was undertaken to different valorization actions over the years, currently it is not open to visitors, due to a lack of constant management and maintenance.

Since 1992, the Mining Museum of Cozzo Disi, thanks to different founded projects, has carried out several improvement actions, such as restoration of some of its surface artefacts (e.g., the power plant, the lamp room, the winch room, and partly the steam melting plant), and the installation of video surveillance, anti-intrusion and fire-fighting systems.

In 2012, under Law No. 17/1991 and by special agreement, the management of the mine was entrusted to the Municipality of Casteltermini. The municipality established a Technical-Scientific Council, which remained in office until 2016. In 2015, the site

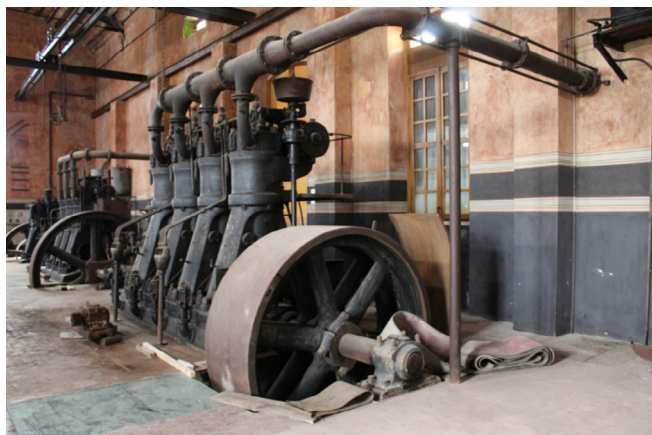


Fig. 12. Diesel motors inside the converted Cozzo-Disi Power Plant.



Fig. 13. Processing plants and heaps.

became part of ISPRA's Re.Mi Network. The municipality drafted a *Management Plan and Regulations of Use*, which was submitted to the relevant Regional Directorate of Cultural Heritage and Sicilian Identity (IS) for approval, which remains unapproved.

In 2017, the site received additional funds for the partial musealization of the area (entrance area, reception area and outdoor amphitheater, parking area) with resources also derived from Territorial Pacts referred to by the Ministry of Economic Development.

Today, the mine remains in a state of neglect and degradation, even with the new works carried out; it has been subject to repeated theft, which has led to its current degradation, due to the absence of surveillance.

It would involve continuously identifying buildings and structures on maps that require restricted access. This would be achieved by installing suitable fencing along with an efficient video surveillance system, as indicated by data from the Sicily Region—Department of Energy and Public Utilities and Energy Department, Caltanissetta Mining District.

3.6. Ciavolotta Mine

Ciavolotta Mine is located in the municipality of Favara. It was established as a regional museum by Regional Law No. 17/1991. In this area which is currently abandoned, one can still see piles of residues, smelting chimneys, the remains of ancient Gill furnaces, sulphur processing plants and administrative buildings (Figs. 13, 14). The mine was one of the largest in the province of Agrigento, going into operation in 1839 (Antinoro, 2012). To date, there are enhancement projects that have not been possible to acquire from the Entities.

3.7. Museum and Archaeological-Industrial Park of the Zolfara of Lercara Friddi

In Lercara Friddi, the only mining centre in the province of Palermo, the first sulphur mines arose between 1833 and 1836, although the first unsuccessful searches date back to 1788. Mining activities ended after a series of ups and downs between 1963 and 1968.



Fig. 14. Ex-administrative building.

In 1843, the Swiss Consul Hirzel in Palermo noticed outcrops of “briscali” (a white granular substance found on the surface of sulphurous strata) and sulphurous water sources on the slopes of the four hills around Lercara Friddi: Colle Croce, Colle Madore, Colle Friddi and Colle Serio.

According to the ISPRA’s GeMMA Database, there are 46 former mining sites within the municipality of Lercara Friddi. The structures are currently in a state of abandonment, but the zolfare (sulphur fields) around Lercara and the mining installations for the extraction and processing of sulphur are still clearly recognizable as the remains of smelting furnaces of the most archaic type (calcheroni) and later ones (Gill furnaces).

Museum and Archaeological-Industrial Park of the Zolfara of Lercara Friddi (Stop 4), established by Regional Law No. 15/93, is managed by the municipality of Lercara Friddi. The park intends to preserve, revitalize and transmit the historical memory through a series of initiatives and projects related to the tangible remains of the sulphur culture ([Ministero Della Cultura, 2024](#)). Finally, The Lercara Friddi Civic Museum has a section dedicated to the mining world.

3.8. Other cultural and environmental heritage in the area

As mentioned above, in addition to the established regional museums, the area is rich in other historical mining sites, such as the following sites:

- Zimbaliò/Giangagliano Mine (Enna)
- Bambinello Mine (Enna)
- Giumentaro Mine (Enna)
- Trabonella Mine (Caltanissetta)
- Mineralogical, Palaeontological and Zolfara Museum (ex-mining institute “S.Mottura”) (Caltanissetta)
- Gabara Mining Park (Caltanissetta) (it joined the Re.Mi Network in June 2023)
- Bosco Mine (Caltanissetta)
- Apaforte Mine (Caltanissetta)
- Zolfara Museum Of Montedoro (Caltanissetta)
- Gibellini Mine (Agrigento)
- San Paolino Mine (Caltanissetta)
- Muculufa Mine (Caltanissetta)
- Giffarò Mine (Caltanissetta)
- Aragona Mining Park and Taccia-Caci Mine (Agrigento)
- Zolfare Comitini Mining Park (Agrigento) (which joined the Re.Mi Network since 2015)

In order to make the most of the entire Sicilian mining heritage, several key areas are highlighted that could enhance the Sulphur Cultural Itinerary, which is currently being planned. These include naturalistic-cultural paths, as well as disused railways that can be reconverted into gentle mobility routes.

As is evident from the itinerary map ([Fig. 1](#)), these slow mobility routes fall within and lap the area, and the combination of the pathways and the mines present in the sulphur basin of central Sicily can be valorized in an economic-cultural key related to heritage enhancement.

3.8.1. Antica Trasversale Sicula

Antica Trasversale Sicula is one of the oldest historical routes in the region, which has been identified according to the theories of archaeologist Biagio Pace ([1927](#)). He identified a road dating back to the Greek period that cuts the island into two parts. This path was retraced in 2016. It is over 650 km long and comprises 38 stages and 2 different variants, passing through the most important Greek, Sicilian, Elymian and Carthaginian settlements ([Pace, 1927](#)). The mine is developed along the disused railway tracks and covers 55 municipalities, 6 archaeological parks, 47 sites of historical-archaeological-monumental interest, 1 nature park and 7 nature reserves. The aspect that arouses further interest is its intertwining with the sulphur triangle, thus becoming a link between the mining sites that intercept it, the archaeological sites and the various emergencies ([Pirrerà & Gristina, 2022](#)).

3.8.2. Magna Via Francigena

The Magna Via Francigena is another ancient road route located between Palermo and Agrigento. It was traced around the year 1000 in Norman time and gradually was abandoned, but was recovered in recent years thanks to topographical research. The total length of Magna Via Francigena is approximately 185 km and divided into 9 stages ([Comunale, 2017](#)).

3.8.3. Via dei Frati

Via dei Frati is a proposed route located along provincial roads, footpath, dirt tracks and mountain paths for 173.2 km from Caltanissetta to Cefalù. This route was created to walk through the Sicilian hinterland, just as what the questing friars did for centuries, travelling from the largest monasteries to the most remote countryside to collect alms to take to their brothers, in a spirit of humility and sharing how little they had with the neediest people ([Frati, 2021](#)).



Fig. 15. Panoramic view of some of the viaducts that are still viable.

3.8.4. Railway lines which can be “activated” by Italian FS foundation

In order to increase tourist attractiveness, it should be noted that some Sicilian railway lines are already used for touristic purpose, such as the following ones:

- Agrigento Bassa–Porto Empedocle (complete);
- Noto–Pachino (work in progress);
- Alcantara–Randazzo (work in progress up to Francavilla di Sicilia).

At the same time (from the information provided by the FS Foundation), there are other railway lines in the Sicily that could be used for touristic aims, such as the following ones:

- Caltanissetta–Canicattì–Campobello/Ravanusa (Trabia Tallarita, Miniere Passarello);
- Caltanissetta–Canicattì–Comitini Zolfare (Comitini Mining Park);
- Caltanissetta–Comitini–Porto Empedocle (Sulphur Cultural Itinerary);
- Palermo–Campofranco (Cozzo Disi Mining Park);
- Palermo–Campofranco–Porto Empedocle (Sulphur Cultural Itinerary);
- Agrigento–Comitini Zolfare (Comitini Mining Park);
- Agrigento–Campofranco (Cozzo Disi Mining Park);
- Palermo–Dittaino–Villarosa (Floristella Grottacalda Mining Park or Villarosa).

3.8.5. Unfinished Riesi–Sommatino railway line

The railway was planned to connect the most important mines in the area to the main railway network and to make the municipalities crossing accessible. The work began in 1914 but was interrupted due to the First World War. The work resumed under the Fascist regime until a Royal Decree in 1935 imposed a definitive halt to construction work after it was almost completed.

As of today, the Zolfare Greenway Association, which has conducted several inspections and aims to promote a walk along the intended railway route between Sommatino and Riesi, reports that this route features numerous traversable viaducts (Fig. 15) and a helical tunnel.



Fig. 16. Downstream entrance to the helicoidal tunnel. It is flooded due to an earthen barrage to store water from a source inside the tunnel.



Fig. 17. Entrance upstream of the helicoidal tunnel. The entrance is partially occluded but accessible.

The latter can only be reached from Riesi. The two entrances are located on the western slope of Mount Stornello. The downstream entrance (Fig. 16) is obstructed by an artificial earth wall, which was created to accumulate water for irrigation purposes and has caused partial flooding of a section of the tunnel.

On the other hand, from the upstream entrance (Fig. 17), several hundred meters (Fig. 18) can be travelled (the tunnel being 1,091 m long and sloping), with a sufficiently powerful torch. Significant change is the “fascio littorio” beam on the upstream entrance with the inscription A XI EF (eleventh year of the fascist era), a true birth certificate of this extraordinary testimony of industrial archaeology. Once past the helicoidal track, the route arrives at Riesi without interruption, where the final station, in good condition and inhabited by private individuals, is located.

To date, a technical table is active among municipalities and entities interested in converting the decommissioned line into a tourist cycleway, in collaboration with the ReMi Network.

4. Discussion and conclusions

The cultural valorization of mining areas extends beyond the tangible material heritage, encompassing elements such as wells, buildings, industrial installations, waste repositories, and basins. Equally important is the preservation of the intangible heritage, which holds significant evocative power. This intangible heritage is characterized by the production methods, the lives of miners, and the historical labor struggles, among other aspects. Cultural heritage, in this context, transcends the confines of a conventional museum setting. It encompasses a multifaceted realm of historical, cultural, environmental, identity, and symbolic values that are inherently ingrained in the objects themselves. Furthermore, it extends to the social and territorial contexts within which these values are defined (Patanè, 2010).

In this work, an investigation of several sites to be included into the Sulphur Cultural Itinerary in Central Sicily has been carried out. Such investigation includes geographic framing, historic information and evaluation of the current accessibility. The



Fig. 18. Inside the helicoidal tunnel, which can be followed for a few hundred meters.

information has been collected in a GIS database. The itinerary includes several existing active and functioning realities: the tour of the sulphur mines allows to discover a world that, although largely reduced to an archaeological landscape, still lives in people's memories, representing one of the many elements of the island's culture.

The itinerary is focused on the data available on the Touring Club's guidebook, but there are differences and improvements. The first stop on the itinerary is the Touring Club, located in the Caltanissetta province, specifically at the Solfara Museum. In this new route, the starting point shifts to the Floristella-Grottacalda Mining Park, situated in the province of Enna. The choice fell on this mining park as it is the largest in the area and preserves all the mining structures in excellent condition, including various types of extraction shafts and buildings. The different historical phases of sulphur smelting technologies and techniques are well represented. In addition to this, the park offers notable landscape, naturalistic and scientific values, enriched by a long and significant history linked to mining activity. Furthermore, some differences between the itinerary proposed by the authors and that of the Touring Club's guidebook are related to roads that are no longer in existence or accessible in the guidebook's itinerary. Additionally, the authors primarily focus their attention on mining sites designated as regional museums; however, despite this designation, some of these sites are effectively abandoned and in a state of general degradation. In particular, the analysis has focused on seven sites (Mining Museum of Gessolungo, La Grasta Mine, Mining Museum of Trabia-Tallarita, Ciavolotta Mine, Mining Museum of Cozzo Disi, Floristella-Grottacalda Mining Park, Museum and Archaeological-Industrial Park of the Solfara of Lercara Friddi), three historical routes (Antica Trasversale Sicula, Magna Via Francigena, Via dei Frati), and old railways, which are included in the itinerary for a better harmonization among the sites and integration with the territory.

The outcome of the research is a starting point for all stakeholders of geoheritage, such as municipalities, tourism agencies and academics. The attractiveness and receptivity of the area undoubtedly depend on the availability of sufficient resources, but also on the cooperation of public and private entities, each with its own objectives, but all committed and co-responsible for the quality of the territorial offer. The area should be evaluated based on its environmental, landscape, and natural attributes, as well as its cultural and traditional significance. Additionally, its ability to offer high-quality services including hospitality, tourist experiences, amenities for residents, and infrastructure for both citizens and businesses should be considered.

A more effective tourism promotion policy in the region will undoubtedly have positive results. Regional public institutions must necessarily play a decisive role in attracting the attention of all potential adherents as well as in securing the appropriate financial resources, tools and expertise necessary for their implementation.

The future research will focus on strategies to collaborate with the regional tourism office for promoting the Sulphur Cultural Itinerary. In particular, the management actions also should be planned in terms of communication using regional social media to reach national and international tourists, and we will also try to insert the itinerary on the official web portal of the Sicily region,² precisely in the cultural itineraries section. At the same time, a part this itinerary is available on the official website of ISPRA³, making it accessible not only to national visitors but also to international ones.

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Not applicable, because this article does not contain any studies with human or animal subjects. The authors certify that there is not ethical issue in this paper.

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Declaration of competing interest

The authors declare no conflict of interest.

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³ <https://www.isprambiente.gov.it>.

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