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ORIGINAL ARTICLE

Quantitative Assessment of Geosites and Mine Heritage as a Resource: The Case Study of Lungro Salt Mine (Calabria, Italy)

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Abstract

In this work, the old Lungro mining site was studied by applying two classification methods (Brilha and IELIG Method), considering the site-specific scientific, educational, touristic, and degradation aspects, to promote it as a geosite. The results were compared with those from other worldwide areas, and a potential re-evaluation in the tourism sector was suggested, considering historical data and geological issues. The methods used evaluate the Lungro site an average score from a scientific perspective, and from high to very high for the tourist-educational aspects. On the contrary, lower scores were found regarding the degradation of the site due to natural phenomena, led to a lower total score. The obtained results are comparable with other similar restored mining areas, located in various parts of the world which today represent important geotourists sites recognized internationally.

Based on these results, the safest, most cost-effective, and straightforward way to preserve and restore the site is by creating a *"Geotourism Route."*. This choice would increase awareness of the area, providing the general public, including the curious and "non-experts", with an understanding of various geological processes and the extensive history of the mine. A campaign to promote and preserve the Lungro site as a *geoheritage* will be encouraged, with significant implications for tourism at the local, national, and international levels.

Keywords Geoheritage · Geotourism · Geosite · Lungro salt mine · Messinian salinity crisis

Introduction

Geosites and the organizations responsible for them can play a crucial role in safeguarding and improving geological features like fossils, landscapes, and rocks, collectively referred to as "geoheritage".For many authors, (Lazzarri et al. 2014; Henriques et al. 2011; Marescotti et al. 2018; Vukoicic et al. 2020) "geoheritage" is a broad but precise term used to describe sites and areas with significant scientific, educational, cultural, and/or aesthetic value from a geological perspective.

Although Italy boasts an incredible geological heritage, no national legislation is currently in place to protect these sites (Giovagnoli 2023). There is currently only formal legal protection for fossils that are classified as part of the historical or cultural heritage. However, not all geosites warrant the same level of protection. It is essential to classify the site based on its significance, considering objective criteria. Various quantitative assessment methods are used in the literature to evaluate geosites and their potential for tourism and economic benefits. Some of these methods use several all-encompassing parameters (Fancello et al. 2022) focus on a single parameter, such as geodiversity value, aesthetic value, or geotourism potential (János et al. 2018; Carrión-Mero et al. 2020; Herrera-Franco et al. 2020; Cavalcanti et al. 2021; Weis 2022; Fancello et al. 2022; Carrión Mero et al. 2018).

As highlighted by several authors (Carrión-Mero et al. 2020, 2024; Maia et al. 2022; Cavalcanti et al. 2021; Weis 2022; Mehdioui et al. 2022; János et al. 2018), abandoned

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mine sites are the most common type of geosite with a high social, cultural, and scientific importance. These sites offer valuable insights into past activities and provide opportunities for underground exploration, making them deserving of inclusion in geoconservation programs (Lopez-Garcia et al. 2011). The term “geoconservation” gained popularity following the 1991 International Conference on the Protection of Geological Heritage (Martini 1994).

The mining activity dates back to ancient times, and minerals are used by human society for a variety of purposes. For example, salt extraction was one of the most significant mining activities throughout history and played a crucial role in the development of towns during the Middle Ages, leading to their economic and social autonomy (Langer et al. 2013). Today, some of these mines are no longer used for extraction, but have been transformed into popular tourist attractions. For example, several have been turned into museums that draw in hundreds of thousands of visitors annually. One notable example is the World Heritage salt mine of Wieliczka in Poland, which is visited by one million tourists every year (Bralsewska et al. 2022). Another example is the Tusa salt mines in Romania, which were visited by 35,000 people in 2019 (Sorcaru et al. 2021). These two mines are considered paradigms of abandoned salt mine reuse (Kimic et al. 2021). Additionally, Italy has well-developed salt extraction activities, such as in Piombino/Follonic (Sevink et al. 2021), Volterra (Solari et al. 2020), and others. In the Italian context, the Lungro salt mine, mentioned in “Naturalis Historia” by Pliny the Elder, is located in the northern sector of the Calabria Region in Southern Italy. It represents one of the main sites for salt extraction and was one of the most important mining sites in the region from an economic standpoint until its closure in 1976. In 2018, the Historical Museum of the Salt Mine of Lungro (MUSMSA) and the mine site were added to the Italian national network of mining parks and museums (ReMi) by ISPRA (Italian Institute for Environmental Protection and Research). The aim of this network is to protect and promote Italy’s extraordinary mining heritage. Unfortunately, today the site is in a state of extreme degradation, despite its high potential from both scientific and tourist perspectives. The main aim of this work was to explore the potential of the old Lungro mining site. This was done by utilizing two quantitative analysis methods, Brilha (Brilha 2016) and IELIG (García-Cortés et al. 2013). Additionally, the findings were compared to those of other global sites, and a potential reassessment for tourism purposes was recommended, taking into account the mine’s significant historical importance and its current state of criticality.

Geological Settings

The Lungro salt mine is situated in the northern sector of the “Peloritan-Calabrian Orogen” (PCO - Cirrincione et al. 2015; Amodio-Morelli et al. 1976; Bonardi et al. 1982) in the proximity of the western boundary of the Crati Valley, a Plio-Pleistocenic tectonic valley. The northern boundary of the Crati valley is represented by the Pollino chain while the southern one is associated with the Falconara - Carpanzano Fault (Van Dijk et al. 2000; Tansi et al. 2007). The formation of the Crati Valley is a consequence of the opening of the Tyrrhenian Sea. The tectonic setting, that occurred during the Pliocene, affects the type of sedimentation and the development of horst and graben structures in different sectors of the area. The evidence of the tectonics events is represented by the N-S fault system that hides the previous strike-slip phase (Tansi et al. 2016). In proximity to the study area, another system is represented by the NE-SW fault, one of the most important related to the Sangineto Line. This fault system puts in contact the Apennine terrain with the crystalline basement of the Calabria region. According to Lanzafame and Tortorici 1981; the stratigraphic sequence of the Crati Valley is composed of (i) Miocene deposits made up of polygenic conglomerate overlayed by clay, and evaporitic Messinian successions (Halite and Gypsum - Vespasiano et al. 2021; 2023) showing, in localized areas, thickness up to 250 m; (ii) Lower Pliocene deposits, that outcrop on the western side of the Crati Valley. This succession is made by Conglomerates and turbiditic sandstones and silty clay which, in some cases is in concordance with some Messinian deposits; (iii) Upper Pliocene and Pleistocene deposits, made by conglomerates, clay, sand, and sandstone.

From a morphological point of view, the area of the Lungro salt mine is strongly affected by gravitational phenomena (Antronico et al. 2015; Gullà et al. 2017; Cianflone et al. 2018; Guerricchio et al. 2005). The entrance of the old mine is located in a depressed area limited by a hill known as “San Leonardo”. In particular, the mine’s buildings are threatened by many landslides (Figs. 1 and 2). As pointed out by Guerricchio et al. 2005 the area is also affected by subsidence phenomena, with a rate of 10 cm every 10–15 years. The effects of this vertical movement, in part related to the dissolving salt (Cianflone et al. 2018), are clearly visible in the landscape causing deep damage of infrastructures like roads and houses (Fig. 1d). For these reasons, it is necessary to create safe conditions before using the area for various purposes.

History of the Lungro Mine Site

The Lungro mine site has been popular for many years. According to several authors (e.g., Martell et al. 1981),

Fig. 1 (**a**) Panoramic view of the main building of the mine, (**b**, **c**) some details of the degradation and (**d**) a tilted house on top of San Leonardo Hill

the salt mined in Lungro played a significant role in the development of prehistoric communities in the area. Some authors (Patanè et al. 2023) believe that the Lungro salt was a key factor in the wealth and prosperity of the ancient town of Sibari. Archaeological evidence suggests that salt mining in the area dates back to the Neolithic period. The peak of the mine's success was in the late 19th century (De Neef et al. 2019). During that time, the miners reached the lowest point (-225 m from the entrance, as reported by Sole 1981). The mine consisted of five levels where salt was extracted. Some sources indicate that salt production in the late 19th century reached 70,000 tons (Cortese & Domestico, 2010). Today, the mine area is easily accessible via the now paved and well-maintained old road. Several buildings within this area are remnants of the old mine, with the central one being the most significant, characterized by its iconic circular entrance. Recently, this building has undergone renovations. The area is incredibly picturesque, enhanced by the beautiful landscape that surrounds it. The main entrance of the mine offers a stunning view of Cozzo del Pellegrino (1987 m above sea level) and Mula (1935 m above sea level), two mountains that are part of the Pollino Unesco Geopark. The salt extracted from the mine originates from evaporitic deposits that were formed during the Messinian Salinity Crisis (MSC), a geological event that took place 5.98 million years ago. Due to geodynamic evolution and climate variations, the Mediterranean Basin experienced high evaporation rates, resulting in the formation of closed basins with high salinity and limited water circulation. It was under these conditions that the evaporitic successions were formed. These rocks can be found throughout the entire Mediterranean region and are considered as evidence of the basin's evolution during that period (Lofi et al. 2011; Roveri et al. 2016). As reported in (Padula 1977), the latter part of the late 19th century, four types of salt were extracted from this mine: "cervino salt" (gray), "formico salt", "white lamellous salt", and "white and pure salt with perfect crystallization". The salt was used for various purposes including human consumption, industrial uses, and refrigeration (Lefond 1969). Preliminary analysis by Cianflone et al. 2018 suggests that the halite crystals do not exhibit a cubic habit, but instead have an elongated shape with some signs of dissolution. All primary structures, including fluid inclusions, appear to be obliterated.

Materials and Methods

This study required analyzing data gathered from previous literature as well as from new on-site activities carried out in June 2021 to thoroughly reconstruct the site's history and present condition. To implement the proposed evaluation methods, it was crucial to collect as much information as possible. As reported by Brilha 2016; one of the first steps in defining and conserving a geosite consists in evaluating its potential scientific, tourist, educational, and social value. A major challenge in geosite assessment is the inherent subjectivity of the evaluation process. Previously, evaluation of this site relied solely on direct observations and rapid assessments by a single expert. More recently, systematic methods based on specific parameter measurements have been developed. Two of these methods were

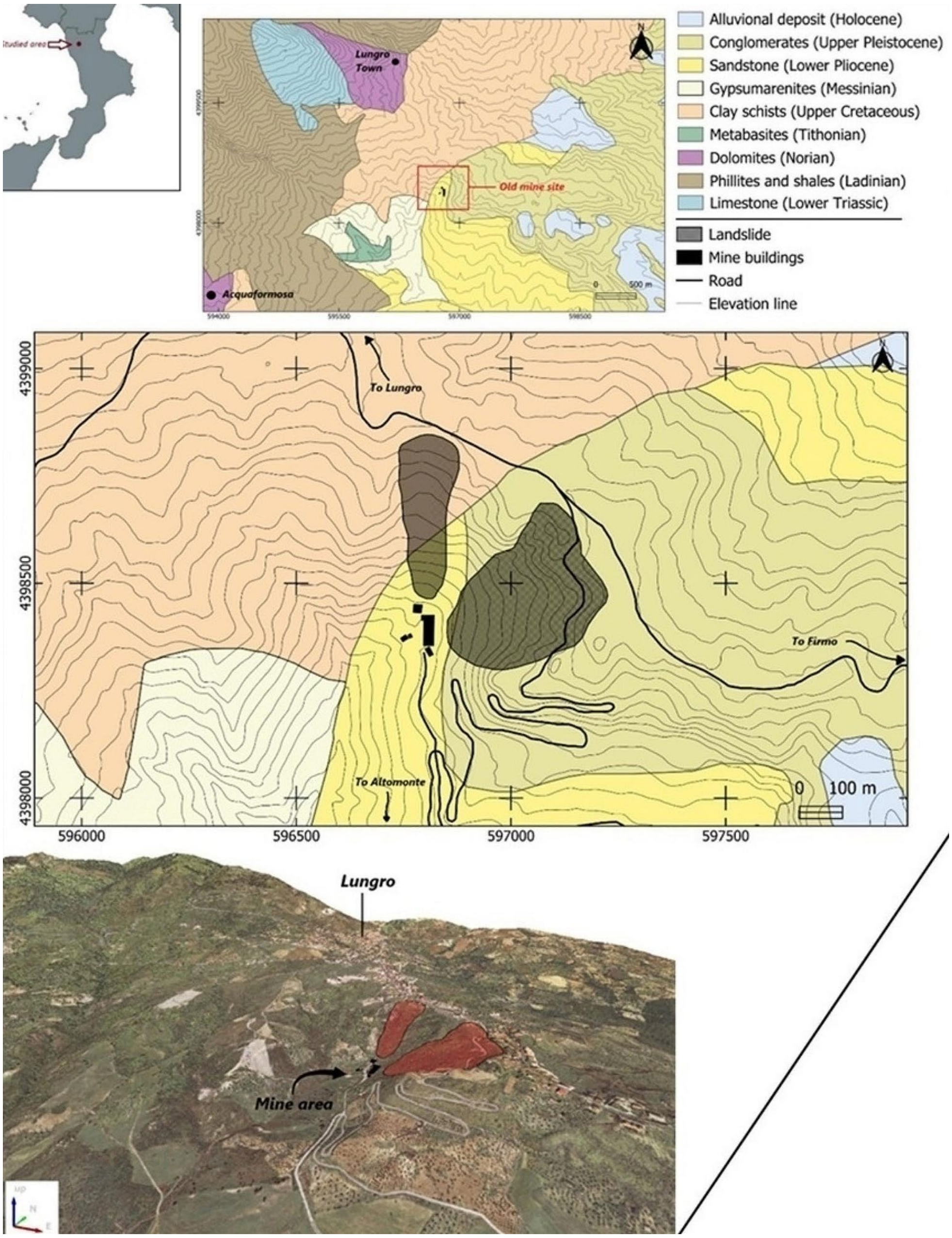

Fig. 2 Lithological map (from Ietto and Ietto 2011) and the possible occurrence of landslides in the studied area

used in this study: (a) the Brilha method (Brilha 2016), an evaluation method widely used in the literature, and (b) the IELIG Method (García-Cortés et al. 2013), which places a strong emphasis on evaluating degradation risks, an important aspect to consider when assessing the site. This research allowed a comparison between the two proposed methods and the identification of potential critical issues.

Brilha Assessment Method

Brilha 2016 proposed a method based on assigning a value, within a rank, to some parameters with specific weight. Potentials of the method include (i) low subjectivity in assessment and (ii) the possibility of comparing different sites. This makes it a valuable tool for spatial planning as it can help in selecting sites that deserve greater "geo-conservation" efforts. Despite its many applications, in this work it was only used for the evaluation of the site's potential. Specifically, the method is divided into four macro-indexes:

- The determination of the scientific value of the site (SV);
- The determination of the educational potential (PEU);
- The determination of the tourism potential (PTU);
- The assessment of the risk of site degradation (DR);

Each of these indices is composed of specific parameters. For instance, SV includes: (i) Representativeness: the capacity of a geosite to illustrate geological elements or processes; (ii) Key locality: the importance of a geosite as a reference or model for stratigraphy, palaeontology, mineralogy, and others; (iii) Scientific knowledge: the existence of published scientific studies related to the geosite (related to the geological framework under consideration when applicable) reflecting the recognition from the geoscientific community; (iv) Integrity: the conservation status of the main geological elements (related to the geological framework under consideration when applicable); (v) Geological diversity: a high number of different geological elements with a scientific interest in a geosite implies a higher SV; (vi) Rarity: a small number of similar geosites in the area of interest increases the SV; (vii) Use limitations: the existence of obstacles that may be problematic for the regular scientific use of the geosite has an impact.

Each parameter can be assigned a value of 0, 1, 2, or 4. Educational potential (PEU), on the other hand, is calculated based on 12 parameters, 10 of which are also included within the calculation of tourism potential (PTU). The parameters are: (i) Vulnerability: the existence of geological elements that can be destroyed by visitors; (ii) Accessibility: how is easy to access the site; (iii) Use limitation: the existence of limitations for educational or tourist use of the site; (iv) Safety: the existence of low-risk condition; (v) Logistics: the existence of facilities to receive students and tourists like toilets or food; (vi) Density of population: how many people live near the site; (vii) Association with other value: the existence of other natural or cultural elements associated with the site that can justify interdisciplinary field trip; (viii) Scenery: represent the beauty of geological elements of the area; (ix) Uniqueness: how much rare are the geological features of the area; (x) Observation condition: how it's easy to observe the geological elements; (xi) Didactic potential: is it possible to use the site for students of every grade? (xii) Geological diversity: how many geological features are found in the area; (xiii) Interpretative potential: related to the capacity of geological features to be easily understood by people with no geological background; (xiv) Economic level; (xv) Proximity of recreational areas: the presence of some touristic attractions in the surrounding area (Table 1).

The last parameter concerns the site's degradation potential (Degradation risk) composed of five parameters scored from 0 to 4: (i) Degradation of geological elements: the measure of the possibility of a loss of geological elements (due to tourists or students or vandals); (ii) Proximity to areas/activities with the potential to cause degradation, such as urban areas or mining and industry facilities; (iii) Legal protection: related to the fact that an area can be part of a national park for example; (iv) Accessibility: related to the condition of access for the general public; (v) Density of population: related with the number of people that live near the site and can cause deterioration of the site due to inappropriate use.

IELIG Method

The IELIG method was originally introduced by García-Cortés et al. 2013 in Spain to create a geological heritage inventory. IELIG, which stands for the Spanish Inventory of Places of Geological Interest, was developed by the Geological and Mining Institute of Spain. This approach encompasses three categories of interest: scientific, academic, and touristic. Each category consists of various criteria, each assigned a specific weight (Table 2). Some of the criteria in the IELIG classification are similar to those found in the *Brilha* classification. Both methodologies assess the susceptibility of a site to degradation using the "degradation susceptibility (DS)" index.

Table 1 Parameters contributing to the definition of scientific value (SV), potential Educational Use (PEU) and potential touristic use (PTU) (modified from Brilha 2016)

Scientific Value (SV)	Potential Educational Use (PEU)	Potential Touristic Use (PTU)	Degradation Risk (DR)
Representativeness	Vulnerability	Vulnerability	Degradation of geological elements;
Key locality	Accessibility	Accessibility	Proximity of activities to a potential cause of degradation
Scientific Knowledge	Use Limitations	Use Limitations	Legal protection
Integrity	Safety	Safety	Accessibility
Geological diversity	Logistics	Logistics	Density of population
Rarity	Density of population	Density of population	
Use limitations	Association with other values	Association with other values	
	Scenery	Scenery	
	Uniqueness	Uniqueness	
	Observation condition	Observation condition	
	Didactic potential	Interpretative potential	
	Geological diversity	Economic level	
		Proximity of recreational areas	

Table 2 The “interest classes” provided in the IELIG method (García-Cortés et al. 2013)

	Value (Weight)			
Parameter	Value	Scientific (S)	Accademic (A)	Touristic (T)
Representativeness	0 to 4	30	5	-
Standard of reference sites		10	5	-
Knowledge of the site		15	-	-
State of conservation		10	5	-
Conditions of observation		10	5	5
Scarcity rarity		15	5	-
Geological diversity		10	10	-
Educational values		-	20	-
Logistic infrastructure		-	15	5
Population density		-	5	5
Accessibility		-	15	10
Size of site		-	-	15
Association with other natural elements		-	5	5
Beauty		-	5	20
Informative value		-	-	15
Possibility of recreational/leisure activities		-	-	5
Proximity to other places		-	-	5
Socio-economic situation		-	-	10
Total (weight)		100	100	100

Table 3 Computing of the fragility and vulnerability values in the IELIG method (García-Cortés et al. 2013)

	Fragility (F)		Vulnerability (V)	
Parameter	Value	Weight	Value	Weight
Geosite size	0 to 4	40	0 to 4	-
Vulnerability to looting		30		-
Natural hazards		30		-
Proximity of infrastructure		-		20
Mining exploitation interest		-		15
Protected area designation		-		15
Indirect protection		-		15
Accessibility		-		15
Ownership status		-		10
Population density		-		5
Proximity of recreational areas		-		5

Table 4 The Protection priority equations as proposed in the IELIG method (Navarrete et al. 2022)

Protection Priority	Equation
Scientific Priority (S-Pp)	$(IS)^2$ x DS x $(1/400^2)$ (2)
Academic Priority (A-Pp)	$(IA)^2$ x DS x $(1/400^2)$ (3)
Tourist/ recreational (T-Pp)	$(IT)^2$ x DS x $(1/400^2)$ (4)
Protection Priority (Pp)	$(\frac{IS+IA+IT}{3})^2$ x DS x $(1/400^2)$ (5)

Whereas in Brilha’s method, only a generic index is considered, in the IELIG method there are two separate indexes (Table 3): (F) Fragility of the site (the risk of degradation related to the natural causes) and (V) Vulnerability of the site (the risk of degradation related to the man’s activities). V and F indexes are combined to calculate the DS index, a global degradation index that considers either natural or human causes (Table 4). The DS index is calculated with the Eq. (1):

DS = (F x V)/400 (1).

The last part of this method consists of calculating some “priority index” (García-Cortés et al., 2013) that facilitates the choices about the site’s potential use.

Results and Discussion

Brilha Assessment Method

Table 5 reports the results of the *Brilha* method. As said before, this method can indicate the best use of the geosite, by comparing the different indexes (Scientific, Educational, or Touristic). Once the value is calculated for each category, there is a rank that provides an interpretation of this number. Following Navarrete et al. 2022; the value can be 0-100 ◊ very low, 101–200 ◊ low, 201–300 ◊ moderate, and 301–400 ◊ high (where 400 is the maximum score). The *Brilha* assessment method returns for the site under consideration a low Scientific value (115/400), but moderate Educational and Touristic values (240/400 and 205/400 respectively). These results suggest the best use of the site for Educational and Tourist purposes. The Degradation risk, on the other hand, is high (355/400) and this is even related to the numerous active landslides in the area (Antronico et al. 2015; Gullà et al. 2017). The landslides are in part caused by the past extraction activities.

IELIG Method

As mentioned for the *Brilha* method, the IELIG interpretation can be obtained by comparing the results to a specific scale: < 50 ◊ low value, 50–134 ◊ medium value, 134–266 ◊ high value, 267–400 very high value. The results (Table 6) agree with those of the *Brilha* method. The second approach provides a medium score (90/400) for the scientific index, a high score for the touristic index (135/400), and a very high score for the educational index (235/400). The primary distinction between the two methods lies in the potential degradation of the area. Table 7 illustrates that natural hazards are the primary factors contributing to the degradation of the area, while Table 8 displays the value of each “Priority index” and compares it to the specific scale. Specifically, the

Table 5 The results obtained by the Brilha method

	Value (Weight)							
Parameters	Scientific (S)		Educational Potential Use (PEU)		Potential Tourism Use (PTU)		Degradation Risk (DR)	
	Value	Weight	Value	Weight	Value	Weight	Value	Weight
Representativeness	2	30	-	0	-	0	-	0
Key locality	0	10	-	0	-	0	-	0
Scientific Knowledge	0	15	-	0	-	0	-	0
Integrity	1	10	-	0	-	0	-	0
Geological diversity	0	10	2	10	-	0	-	0
Rarity	2	15	-	0	-	0	-	0
Use limitations	1	10	2	5	2	5	-	0
Vulnerability	-	-	2	10	2	10	-	0
Accessibility	-	-	3	10	3	10	3	15
Safety	-	-	2	10	2	10	-	0
Logistics	-	-	4	5	4	5	-	0
Density of populations	-	-	1	5	1	5	1	10
Association with other value	-	-	2	5	2	5	-	0
Scenery	-	-	0	5	0	15	-	0
Uniqueness	-	-	3	5	3	10	-	0
Observation conditions	-	-	1	10	1	5	-	0
Didactic potential	-	-	4	20	-	0	-	0
Interpretative potential	-	-	-	0	3	10	-	0
Economic level	-		-	0	1	5	-	0
The proximity of recreational areas	-		-	0	4	5	-	0
Deterioration of geological elements	-		-	0	-	0	4	35
Proximity to areas/activities with the potential to cause degradation	-		-	0	-	0	4	20
Legal protection	-		-	0	-	0	4	20
Total	115		240		205		355	

Table 6 Details of the score assigned to the Scientific, Academic, and touristic parameters for the IELIG method

		Weight		
Parameters	Value	Scientific (S)	Academic (A)	Touristic (T)
Representativeness	1	30	5	-
Standard of reference site	1	10	5	-
Knowledge of the site	0	15	-	-
State of conservation	0	10	5	-
Conditions of observation	0	10	5	5
Scarcity, rarity	2	15	5	-
Geological diversity	2	10	10	-
Educational values	4	-	20	-
Logistic infrastructure	4	-	15	5
Population density	1	-	5	5
Accessibility	2	-	15	10
Size of site	1	-	-	15
Association with other natural elements	4	-	5	5
Beauty	0	-	5	20
Informative Value	2	-	-	15
Possibility of recreational/leisure activities	1	-	-	5
Proximity to other places	0	-	-	5
Socio-economic situation	2	-	-	10
Total		90	235	135

approach assigns a moderate value to the Sc-Pp (Scientific Priority), To-Pp (Tourist/Recreational), and Pp (Protection Priority) indexes (5-11-14) and a high value for the Ac-Pp (Academic Priority) index (Maia et al. 2022).

Comparison with Similar Sites

For a more accurate classification of the Lungro mining site, the results obtained through the proposed methods were compared with those obtained in similar and comparable areas. These methods are typically used for all type of geosites, and in certain instances for assessing abandoned mine sites ("El sexmo" from Carrión-Mero et al. 2020; "Noguerina mine", "Serrinha mine", "Vale de Arca mine" and "Monges mine complex" from Maia et al. 2022; "Chico Rei mine" from Cavalcanti et al. 2021; "Hesselsbierg", " Hutblerg", "Giele Botter", "Mine Walert", " Lalléngerbier", "Crosnière" and "Waisskaul" from Weis 2022; "El karit Mine" from Mehdioui et al. 2022; "Gant bauxitbànya" from János et al. 2018; "Quarry" from Carrión-Mero et al. 2024). The methods indicate that the Lungro salt mine has the lowest Scientific Value (SV), the highest Degradation Risk (DR), and PEU and PTU (*Brilha's method*) values comparable to

Table 7 Values of Fragility (F) and vulnerability (V) paremeters computing based on the IELIG Method

Parameter	Fragility (F)		Vulnerability (V)	
	Value	Weight	Value	Weight
Geosite size	2	40		-
Vulnerability to looting	1	30		-
Natural hazards	4	30		-
Proximity of infrastructure		-	1	20
Mining exploitation interest		-	1	15
Protected area designation		-	4	15
Indirect protection		-	2	15
Accessibility		-	2	15
Ownership status		-	1	10
Population density		-	2	5
Proximity of recreational areas		-	0	5
Total	230		170	
DS value	(F x V)/400 = **97.75**			

Table 8 Value of each protection priority (IELIG method) calculated with the expression (1)

Protection Priority	Value
Scientific Priority (Sc-Pp)	5
Academic Priority (Ac-Pp)	34
Tourist/ recreational (To-Pp)	11
Protection Priority (Pp)	14

the other sites considered (see Fig. 3). Despite the significant critical issues faced, the Lungro mine has the potential to be enhanced for both touristic and scientific purposes, similar to other sites that have undergone successful valorization. Despite the challenges that many mining sites around the world face, various authors have suggested different plans for their valorization, focusing on both scientific research and tourism opportunities. For instance, the Serrinha and Vale de Arca mines (Portugal) and El karit Mine (Morocco), which presents several degradation issues, were inserted in site-specific "*geoturistical route*" (Mehdioui et al. 2022; Maia et al. 2022). Furthermore, Chico Rei mine (Brasil), affects by flooding phenomena, were already opened in the '80 for visitors and nowadays is part of a geoturistics trail.

Proposed Enhancement of the Lungro Mine Site

Considering the geological asset of the area, it is proposed a requalification plan that considers the risk linked to the landslides. The proposed plan is aimed at professionals and local authorities (landowners, tourist agency, regional authority, etc.) in order to benefit the local economy. One of the best solutions is to create a "geoturistic route", similar to the ones proposed by various authors (e.g., Carrión-Mero et al. 2020; Mehdioui et al. 2022) in different sites worldwide. This route would be accessible to students and tourists, connecting the mine with the related museum which is located approximately 2 km away. The primary benefit of this type of solution is that visitors can avoid the dangerous area. The implementation of the route should also involve improving the surrounding area of the mine, by installing equipment and setting up panels that offer historical, technical, and geological information about the salt mine. The suggested route follows the path that miners historically took to reach the area known as "dopolavoro", where they would relax after work. The proposed "geotouristic route" (Fig. 4) extends for approximately 2.3 km with an altitude difference of 150 m and includes several points of interest (the mine site, the museum of the salt mine, and the building where miners rest). Along the route, there are plans to

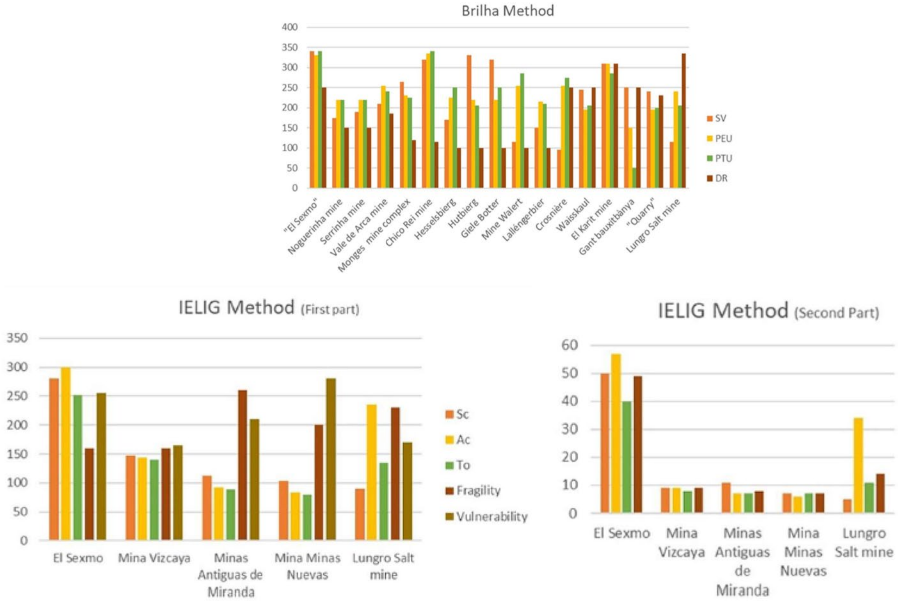

Fig. 3 Comparison between another mine site and the Lungro mine. The value of other sites derived from: "El sexmo" from Carrión-Mero et al. 2020; "Noguerina mine"," Serrinha mine", "Vale de Arca mine" and "Monges mine complex" from Maia et al. 2022; "Chico Rei mine" from Cavalcanti et al. 2021; "Hesselsbierg", "Hutblerg", "Giele Botter", "Mine Walert", "Lalléngerbier", "Crosnière" and "Waisskaul" from Weis 2022; "El karit Mine" from Mehdioui et al. 2022; "Gant bauxitbànya" from János et al. 2018; "Quarry" from Carrión-Mero et al. 2024

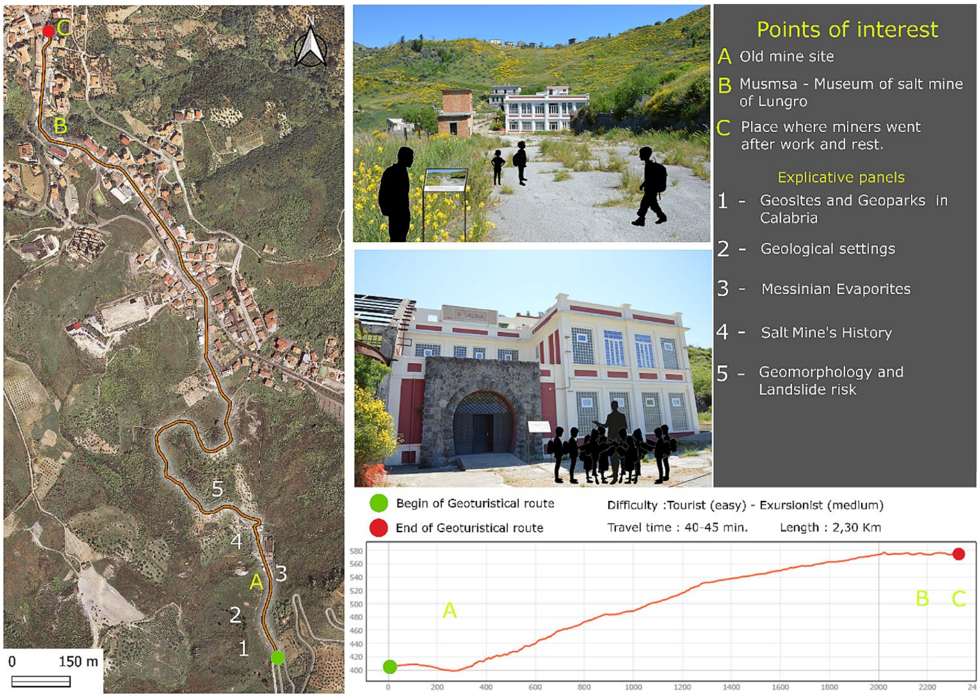

Fig. 4 The proposed "geotouristic route" with the location of each point of interest and description of the explicative panels

install five explanatory panels: Panel 1 - A detailed description of Geosites and Geopark in Calabria and the role of the Lungro mine on a regional scale; Panel 2 - The geological setting of the area and description of the main landscape forms observable from the route; Panel 3 - Insight into the processes that favoured the accumulation of quarried halite. Near the third panel, a glass box with salt samples can be placed, this can be useful to explain how the salt looks like in the different levels of the mine; Panel 4 - Salt mine history and extraction techniques; Panel 5 - Geomorphology and hydrogeologic issues of the site.

Conclusions

The old Lungro salt mine is a significant part of Italy's industrial and mineralogical heritage, as well as a place of geological interest, that can be used for educational or touristic purposes. The mine's origins are linked to peculiar geological processes (i.e., the Messinian Salinity Crises) that favor the formation of wide evaporitic deposits in the Mediterranean area. Part of these deposits represent the core of the Lungro area, which was the foremost salt mining site in Italy during the 1800s. Today, its historical and geological significance continues to make it a prominent social reference. In recent years, the restoration of abandoned sites has become a significant challenge for tourism. The Lungro salt mine serves as a prime example of this. Through the use of two assessment methods, valuable insights have been gained. Despite its importance as a scientific, tourist, and educational site, the risk of degradation from natural events like landslides has led to a reduction in its overall score according to the *Brilh*a and *IELIG* methods. To enhance the value of this exceptional geological site, it is essential to implement conservation measures such as addressing landslide risks and refurbishing existing infrastructure. The establishment of a "Geotourism Route" would be the most effective solution in terms of economic, social, and tourism benefits, attracting visitors from around the globe. Additionally, revitalizing the area will boost geotourism and generate significant economic advantages for the region. This approach can be utilized for various types of geosites, persuading stakeholders, investors, and public authorities to initiate actions and revitalize neglected sites.

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