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Linking Cultural and Postindustrial Heritage with Potential Economic Activities—A Proposal to Revitalize a Demographically Degraded Area in Spain

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Abstract: Mining and quarrying were important economic activities in Europe in past centuries, but during the 20th century, raw materials became vital to societal development. Mining has been subject to fluctuations related to wars, economic crises, and advances in environmental rights. A series of events led some European countries, such as Spain, to assume a leading position in the market for certain raw materials, such as tungsten. However, most of Europe's mines have been abandoned. This paper considers several postindustrial heritage sites that can used to illustrate how metal and stone were extracted in past centuries. Such sites have become a tourist attraction in the context of heritage in some countries. This area in western Spain, which contains ancestral quarries that helped build the architectural heritage of UNESCO World Heritage Cities and artisanal mines that contributed to building the economy of an extremely poor population, has a story to tell. All these mines and quarries can be used to explain the cultural heritage of the area as part of a postindustrial heritage landscape.

Keywords: cultural heritage; postindustrial heritage; heritage landscape; Salamanca; silver route; circular economy

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1. Introduction

1.1. Historical Background

Many countries in Europe experienced significant economic and industrial development over the 19th and early 20th centuries based on activities such as mining and quarrying. Now that such activity is mostly defunct, industrial heritage sites, including visiting trails and thematic museums, have been created in many of these countries. Examples of these areas include South Wales; the Black Country and Yorkshire in England; Strathclyde in Scotland; the Ruhr and Saar in Germany; Alsace, Nord-Pas de Calais, and Lorraine in France; Wallonia in Belgium; Veneto and Lombardy in Italy; Catalonia, Asturias, and the Basque Country in Spain; Silesia and Lodz in Poland; and Karvina-Ostrava in the Czech Republic [1]. Of the areas mentioned, the Ruhr area in Germany is the most well-advertised, and several publications about this site are important references when discussing industrial heritage (e.g., [2–4]). In fact, the Ruhr area has become the model for the European Route of Industrial Heritage (ERIH) (https://www.erih.net/ accessed on 25 August 2023). In Spain, two sites serving here as case studies (Almadén [Ciudad Real, Castilla-La Mancha] and Sabero [León, Castilla y León], which were mining sites for mercury and coal, respectively) are categorized as Anchor Points in the ERIH and have been awarded quality certificates as destinations for industrial tourism [1]. The above-mentioned extractive activities were terminated due to the associated level of environmental contamination, awareness about climate change resulting from the CO_2 released by fossil fuels, the toxicity of cinnabar, and the loss of competitiveness in the international market. These raw materials will probably remain banned forever. However, other raw materials, such

as tungsten and other metals, are currently needed and are included in the list of critical raw materials (https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661, accessed on 30 August 2023). Critical raw materials (CRM) are elements and materials that are economically and strategically important to the European economy but that have a high risk associated with their supply [5]. They are also critical for the sustainable functioning of the European economy. Spain has a long and productive industrial history of mining and quarrying and has rich resources of many metallic mineral resources such as copper, gold, iron, lead, nickel, silver, tungsten, and zinc [6]. Quarry products are still important in Spain, and quarries account for the largest number of extractive sites in the country (https://www.statista.com/statistics/1330197/number-mines-spain/ accessed on 31 October 2023).

The western part of Spain was once one of the main producers of raw materials, but activity there declined sharply from constituting almost 30% of industrial activities in the 1980s to less than 15% in 2020 [1]. However, an increase in production has been observed in recent years, probably due to European politics related to self-supply (see below) (https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736167628&menu=ulDatos&idp=1254735576581 (accessed on 19 July 2023) (in Spanish). Mining areas have been abandoned, both by the population and by governments, on an international scale. A debate has arisen around the resilience of peripheral former mining territories that are seeking development alternatives. In 2021, Spain had 10 active mines engaged in the extraction of metallic minerals and ranked fourth in the world in tungsten reserves (https://www.statista.com/topics/10382/mining-industry-in-spain/#topicOverview, accessed on 15 August 2023). Tungsten is one of the raw materials that are currently extracted, but tungsten mining has suffered several fluctuations associated with economic crises. In fact, the number of mines has declined by around 20 percent since 2012. With great geological diversity and a wide range of mineral resources, Spain was at the forefront of mining activity for much of the last century. Tungsten extraction was one of the main drivers of mining activities. Changes in tungsten mining are reflected in trends in the rate of growth in gross domestic product (GDP) in the country. From the 1970s and 1980s onwards, a strong decrease was observed in GPD in general. This decrease was more pronounced in industry, including in the mining sector (Figure 1). However, mining production in Spain increased 12.38 percent in August of 2023 over the same month in the previous year. This change is also related to tungsten mining (Figure 2, [2]). Mining production in Spain averaged −2.56 percent from 1993 until 2023, reaching an all-time high of 73.88 percent in November of 2022 and a record low of −44.60 percent in June of 2012 (National Statistics Institute (INE): https://www.ine.es/ (accessed on 19 July 2023). These figures include tungsten, the extraction of which underwent a continuous increase. In recent years, tungsten production amounted to some 642 metric tons, with the production volume peaking in 2018, at more than 850 metric tons. This increase is partly related to the increased activity in the tungsten mines in Salamanca [6].

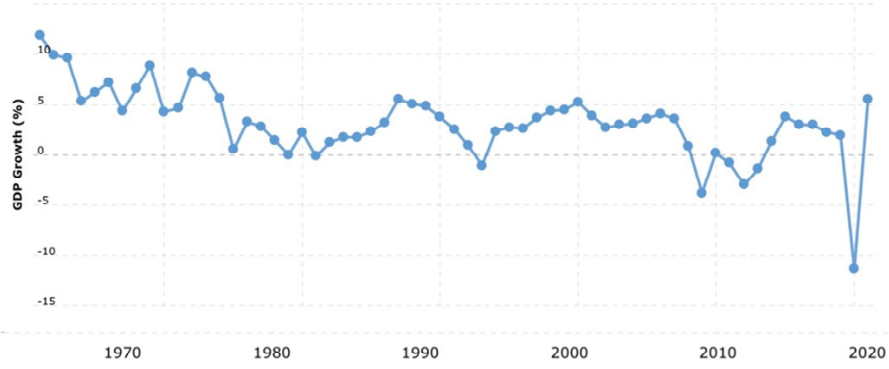

Figure 1. GPD growth rate in Spain, from 1970 to 2020. Modified from source: https://www.macrotrends.net/countries/ESP/spain/gdp-growth-rate, accessed on 25 August 2023.

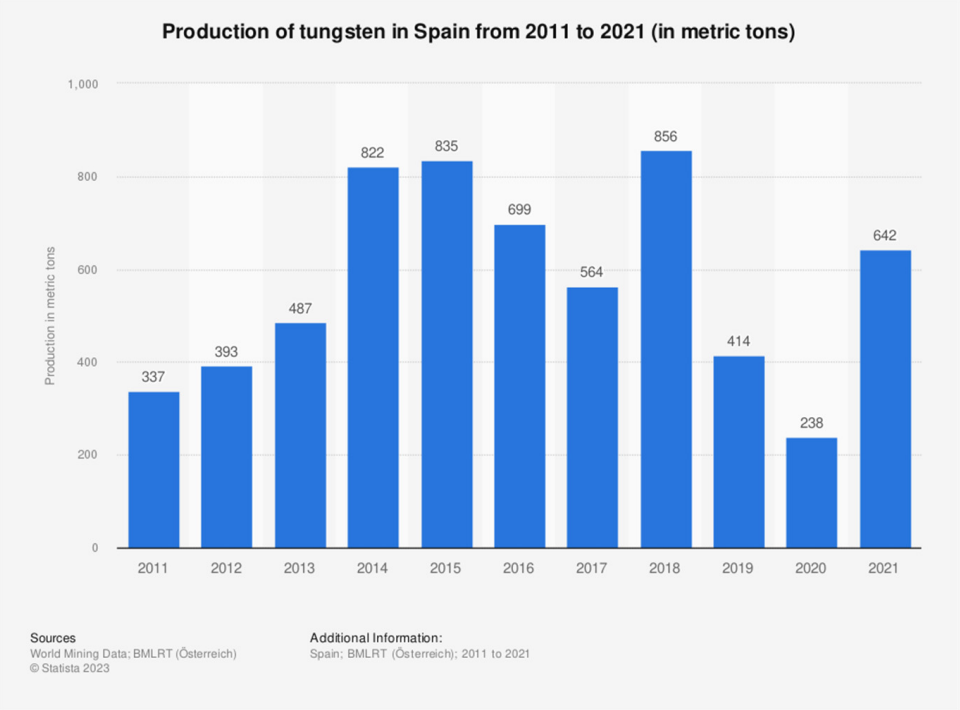

Figure 2. Tungsten production in Spain between 2011 and 2021. https://www.statista.com/statistics/1338727/tungsten-production-volume-spain/, accessed on 25 August 2023.

During the Spanish Civil War (193-1939), Spain was an extremely poor country. International isolation was also a contributing factor [7]. The Spanish economy grew after the Civil War and the end of Franco's dictatorship. Modernization, including the complete electrification of the country and railway construction, contributed to the industrialization of the country, although the impact of technology modernization was not evident until after Spain joined the European Union (EU) [8]. In addition, mining was a clear driver of the increase in the standard of living in Spain. In times of war (mainly during the First and Second World Wars), the production of tungsten in Spain reached high levels, with Spain being one of the first countries in the world to produce this resource [8]. Calvo et al. [9] observed three peaks in production, each coinciding with a period of military expansion and war. Prices became very high, triggering the exploitation of even the smallest pits by farmers, who found mining a better and easier way of life than farming. Spain was theoretically neutral during the Second World War, but favors had to be returned. Franco, the Spanish dictator, was indebted to Hitler, the German dictator, for the help the latter had given him during the Civil War in devastating parts of Spain that were unwilling to succumb to his dictatorship. Such was the case in Gernika, in the Basque Country, in northern Spain, which was declared the First Site of Democratic Memory by the Spanish Government (https://www.boe.es/diario_boe/txt.php?id=BOE-A-2023-10202, accessed on 25 August 2023). Therefore, the Spanish dictatorship helped the fascist German government through the preferential sale of tungsten, which was indispensable in allowing Germany to build more cannons and thus to continue the war. The province of Salamanca was one of the main producers of tungsten, tin, and copper. Other areas of western Iberia, including Portugal, were also involved in production during and after the Second World War [10]. The price of tungsten was so high that smuggling became a common activity in the area. Smuggling was also common between Spain and Portugal. Tungsten was so profitable for families that many of them started very basic artisanal excavations throughout the region. There is a large amount of historical information on legal and illegal activities on both sides of the border, and even fiction has been published on this subject [11,12]. When the price of tungsten dropped in the 1970s–1980s, the tungsten economy collapsed,

and excavations were abandoned. The remains can now be found all over the fields. The landscape surrounding Salamanca, towards the south of the province, is full of abandoned mines, most of them from artisanal extractions. These mines should be considered part of the cultural heritage of the area. They are witnesses to a past prosperous society and could be used as educational sites relating to the cultural or industrial heritage of the area. So far, no one has shown interest in such a possibility. In addition, the pits can also represent a safety concern for animals, cattle, and people walking in the vicinity, as there are no signs warning of the presence of deep holes in the ground.

Besides artisanal mining, which can be considered a part of national heritage, the same area contains ancient stone quarries that were used to build the heritage architecture of Salamanca (Figure 3). Salamanca is a tourist city, a UNESCO World Heritage Site since 1988, with a university that is the oldest in Spain and one of the oldest in Europe. In Salamanca, most buildings were constructed from the sixteenth to the eighteenth centuries using the various stones from quarries around the city, from sedimentary stones to igneous and metamorphic stones. Salamanca's monuments and historic buildings must be preserved using the same type of stone for restoration as was used in their construction, per a mandate from UNESCO, to maintain Salamanca's status as a World Heritage Site [13]. Although Villamayor sandstone is the best-known stone in Salamanca because it is the material responsible for the golden color of the entire historical center of the city (the reason why Salamanca is known as the Golden City [14]), many other stones also contributed to the nomination of the city as a World Heritage site. The Villamayor sandstone outcrops are located around five km north of the city, in the village of Villamayor (Figure 3). Its local name was Piedra Franca (Honest Stone) because it was very easy to extract from the quarry, it becomes more durable under dry conditions, and it is very easy to carve when wet. For these reasons, it was used in all the Baroque- and Plateresque-style façades of important buildings in Salamanca. With time, this sandstone develops a golden color due to the oxidation of the ferrous components, giving a golden color to the entire building (see [15] and references therein for a full description, and [14] for images depicting the effect of the color change). Another stone used as ashlar material to avoid the differential erosion in the lower stories of the buildings was an opal-cemented conglomerate, known as Salamanca Sandstone, or Piedra Tosca (Rude Stone) to differentiate it from the delicate Villamayor Sandstone. This stone is found in the basal parts of historic buildings because of its lower capillary absorption (see [15] and references therein for a full description). It is also used because it is the substrate upon which Salamanca was erected centuries ago. Granite was also a commonly used stone, with many quarries relatively close to the city because of the geology surrounding Salamanca [16]. The closest quarry was Martinamor. Martinamor granite can be found in a village about 20 km south of the city of Salamanca (Figure 3). The main feature of this granite is the presence of nodules of tourmaline, and it is easy to recognize in the basal parts of monuments in Salamanca [13,15]. Another type of granite used in the construction of historical buildings is Los Santos granite, a cordierite granite extracted from a still-active quarry 60 km away from the city. Other granites and slates were used in the construction of the historic buildings, but in lower proportion. A full description of all lithologies can be found in [13]. Most of the quarries are well preserved, and some of them can be considered cultural heritage (e.g., Villamayor Sandstone, Salamanca Sandstone, Martinamor granite) (Figure 3).

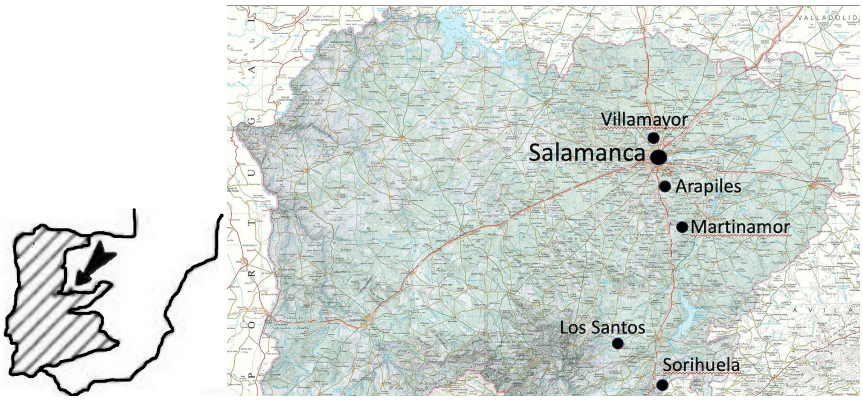

Figure 3. Map of Salamanca province, showing the sites of interest regarding quarries: Villamayor (Villamayor sandstone); Salamanca and Arapiles (Salamanca sandstone); Mozárbez (Mozárbez slate); Martinamor (Martinamor granite); Los Santos (Los Santos granite); Sorihuela (Sorihuela granite). The striped zone in the map drawing represents the Variscan terrains in Iberia [16]. Modified from Mapa provincial de Salamanca, published by the National Geographic Institute of Spain, Scale 1:200,000 (W 6°55′54″–W 5°5′23″/N 41°17′39″–N 40°14′20″), Madrid, 2017.

1.2. Mining and Economy

During the 20th century, mining of tungsten, tin, and copper was an activity that enriched many areas of the Iberian Peninsula. These raw materials were of great importance during the Second World War, especially for Germany, the United States, and England. At that time (1939–1945), the price of these raw materials was even higher than that of gold because the Germans needed it for tungsten carbide tools and armor-piercing ammunition, among other things. The Allies tried to prevent the Germans from buying the Iberian tungsten by buying it themselves at a better price, so its value increased dramatically. Many tungsten mines opened in the western part of Spain and, when prices dropped, extraction activities were closed or stopped. However, significant amounts of waste and tailings were left in the surrounding areas [17]. Today, all those mine tailings are sought after because tungsten is a CRM, highly valued in a challenging time in which wars in Europe and the Middle East are not only a memory.

The percentage of the GDP coming from industry decreased in Spain from 25.9% in 1980 to 14.02% in 2020 (https://www.macrotrends.net/countries/ESP/spain/gdp-growth-rate, accessed on 25 August 2023). Tungsten is an important raw material due to its high number of applications in industry (e.g., environmental technologies, consumer electronics, health, steelmaking, defense, space exploration, and aviation). Recently, there has been renewed interest in the sector, in line with the European Union's need for critical minerals and the attempt to reduce its dependence on imported raw materials. The mining works of the past can help interested parties find the best mining sites, which will be important if Europe is to take charge of its own progress. In the last two years, GDP has increased, with an increase of 20.76% in the amount coming from industry (including mining; manufacturing, which is also reported as a separate subgroup; construction; electricity; water; and gas), according to the World Bank collection of development indicators, compiled from officially recognized sources (https://tradingeconomics.com/, accessed on 30 July 2023) (Figure 1).

Mine tailings can be considered part of the circular economy [18–20], and several mines in western Spain, such as La Parrilla in Extremadura (Figure 4) and Los Santos in Castilla y León (Figure 5), are active in the exploration of tungsten reserves and the quality of the tailings. The low price and the difficulties of extraction in the 1980s contrast with the new reality, wherein modern technology can extract valuable raw material from waste (Figures 6–9).

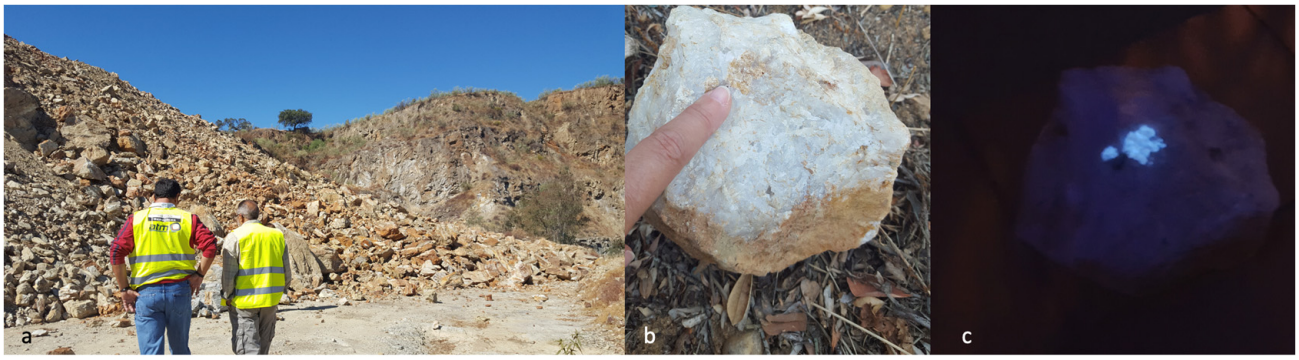

Figure 4. Exploitation of an old mine in La Parrilla (Extremadura, Spain). (**a**) The surrounding waste is currently being analyzed. (**b**) Sample containing scheelite. (**c**) The same sample shown in Figure 6 under an ultraviolet lamp. Pictures taken by D. Pereira.

Figure 5. Previously exploited site in Los Santos mine, Salamanca (Spain). Tailings can be observed around this mine pit. Picture taken by D. Pereira.

Figure 6. Infrastructure for recovering tungsten from waste and tailings in La Parrilla (Extremadura, Spain). Picture taken by D. Pereira.

Figure 7. Flotation table used for the concentration of tungsten from mine tailings in Los Santos mine, Salamanca (Spain). Picture taken by D. Pereira.

Figure 8. Inside of the infrastructure used for the separation of tungsten from mine waste in Los Santos mine (Salamanca, Spain). Picture taken by D. Pereira.

Figure 9. Outside of the infrastructure used for the separation of tungsten from mining waste in Los Santos mine (Salamanca, Spain). Picture taken by D. Pereira.

In Western countries, mining is being scrutinized due to strict environmental laws. Operating a mine is almost impossible without a complete, highly strict opening/closing protocol that includes all the stakeholders involved in the activity. That group also includes social stakeholders with strong links to environmental activists who may or may not be correct in their claims. However, if the aim is to evolve into a more efficient and more sustainable society, responsible mining should be given an opportunity to play a part, mainly because the raw materials we need to transition towards a zero-CO_2 society should come from a controlled industrial system and not from places that do not respect human rights and workers' rights. At present, raw materials are the main focus of many research programs (e.g., Horizon 2030). In this context, mining should also be considered of great interest, as it is an activity that should evolve to meet current standards for safety, environmental, health, and other related issues if it is to be considered a sustainable activity. Many organizations and environmental groups are under the impression that all mining activities should be banned because full compliance with all these standards cannot be guaranteed, especially as the standards also undergo modifications over time. However, it has been demonstrated that if extractive industries follow strict rules, they can contribute to the advancement of modern society with minimal negative impact. This assumption is valid no matter the type of resource, be it metal or stone, the exploitation method, be it surface or underground, or the size of the affected area [21–25].

Following EU recommendations to provide the maximum possible percentage of raw materials domestically and to avoid imports from developing nations, some European countries are investigating the re-opening of pits, as well as the more environmentally friendly option, which is waste mining. Mines from the past can shed light on potential resources to explore. Regions in Spain where tungsten was mined that are of high potential interest are Salamanca (Castilla y León) and Cáceres (Extremadura). La Parrilla mine is currently operating after 30 years of closure. In addition to research on the geology and mineralogy of the deposit, the company in charge of the mine is focused on waste mining, with high expectations of success (Figure 4). Galicia is also a mining site of interest, as tungsten was also extracted in this region during the Second World War. In the area around Salamanca, millions of tons of mineral reserves are still present in the outcrops [6,7]. Those mines were closed in the 1970s and 1980s, but because of the importance of tungsten as a CRC, companies are working to obtain permits to reopen them so that the provision of this metal can be guaranteed. Barruecopardo mine, which was the largest tungsten mine in Spain between 1942 and 1945, is currently in the process of renewing permits for its reopening [1,6]. Other projects in the province of Salamanca, such as the Morille tungsten-tin project, are of great interest because this mine, until its closure in 1985, produced high-quality tungsten concentrate and was a major source of tungsten in the 20th century. The remains of the mine are worth preserving as heritage, but also as a potential source of tungsten if permissions are approved, as drilling in 2014 revealed interesting results [1,6,26].

The unexpected war that arose from the Russian invasion of Ukraine and the present war between Israel and Hamas in the Middle East, the increasing effects of climate change, the moral position of the EU against disrespect for human rights, and other factors have triggered an emergent need to create a secure and resilient EU CRM supply chain. This need aligns with the position of the USA and recent movements in this context. As a result, the EU will reduce the administrative burden and simplify permitting procedures for CRM projects in the EU, support national programs for exploring geological resources, and protect the environment by improving the circular economy and sustainability of CRM. Therefore, the authors of this paper consider it important to show citizens that almost a century ago, mining was an important activity that supported our evolution as a society, but also that mining procedures (from research [27] to exploration) have changed to respect the land and the environment for future generations. Raw materials once played a key role in the economy of Spain. Consequently, it is essential to develop a good knowledge of the past in order to better understand the present and the future.

1.3. Mining and Heritage

As discussed above, the western part of Iberia (i.e., Spain and Portugal) was crucial in providing raw materials that were essential to continuing the Second World War. When prices of metals fell, especially with the arrival of peace in Europe in the mid-1950s, most mining activities ceased, and family-owned artisanal mines were abandoned. It is possible to find the scars left by those mines in the countryside. They are part of our memory and are worth preserving to help us understand our history (Figures 10–12).

Figure 10. Santa Filomena abandoned mine, 5 km west of Martinamor (Salamanca, Spain). Small abandoned artisanal mines are found in the surrounding area (see following figures). Picture taken by D. Pereira.

Figure 11. View of an abandoned artisanal mine from a drone.

Figure 12. Abandoned artisanal mine. Picture taken by D. Pereira.

The most important heritage site in the context of stones is related to Martinamor granite, which was called *Piedra Pajarilla* ("little bird stone") by the quarrymen of centuries ago. Martinamor granite is a tourmaline leucogranite that outcrops in thin sub-horizontal sheets (less than 1 km wide) within the Martinamor Complex in the Spanish Central System [16,28]. Tourmaline displays cumulate speckles, giving the stone luxullianitic textures that sometimes resemble an image of flying birds. (Figure 1 in [13]), giving this stone the local name *Piedra Pajarilla* (little bird stone). Builders stopped using this granite as a construction material in the early 20th century due to the easier availability of other granites, like those from Los Santos and Sorihuela, quarries for which lie very close to a main road (Figure 3) [13]. Currently, the Martinamor granite quarries are abandoned and used for farming, but extraordinary quarry marks can still be found. So far, all these quarry areas are well preserved (i.e., the quarry fronts are accessible and have not undergone topographic modifications; there are even loose, already-dimensioned blocks in the quarry). It is possible to observe several quarry faces defined by joints. There are even some vestiges of earlier quarrying methods like those used in ancient Egypt and prehistoric sites in Europe and South America ([29] and references therein; see also http://www.ancient-wisdom.com/quarrymarks.htm, accessed on 25 October 2023). These marks are caused by the tools used to separate the blocks, in both the vertical and the horizontal planes. Several types of marks are observed, such as wedge marks, triangular drill holes, and circular drill holes. Wedge marks are the oldest of these. Several publications mention the Roman period as the origin of these marks ([29] and references therein). However, only a detailed archaeological investigation will allow us to draw

accurate conclusions about the wedge marks observed in the area. The triangular drill holes are rarely seen in quarries and are not commonly found in the literature. In the case of the ancient Martinamor quarries, some of the triangular holes observed in the outcrops show one corner aligned with natural fractures, illustrating the practical purpose of such holes [29]. Unfortunately, old quarries and quarry marks are unprotected and are subject to vandalism and the effect of meteorological agents that can destroy them, possibly leading to loss of the heritage forever.

Another site found in the same area and linked to the aforementioned mining and quarrying sites, is the San Pelayo Orthogneiss, which is considered a Point of Geological Interest (POGI) (IGME) (https://info.igme.es/ielig/LIGInfo.aspx?codigo=CIs027, accessed on 25 September 2023). This orthogneiss was also the target of mining activities in the area and is now surrounded by large quantities of tailings and waste (Figure 13) that contain significant amounts of scheelite, as observed by the authors using an ultraviolet lamp.

Figure 13. Mine tailings in San Pelayo. This mine waste was used to pave the road at the end of the last century and at night it is possible to detect the remains of scheelite within the gravel using an ultraviolet lamp.

We have noticed that the few people still living in the area know nothing of their past. There is little knowledge of the importance of tungsten mining during the past century or of the importance of tungsten as CRM for developing better technologies to support modern societal development. The same population is ignorant of the importance of the granite that was extracted in the area to build the UNESCO heritage site of Salamanca, with its impressive monuments and historical buildings that have been recognized internationally.

This paper aims to describe the geological sites around the city of Salamanca associated with ancient mining and quarrying. We aim to activate interest in the area as a heritage site by protecting these sites and ensuring that the pits do not represent a safety problem for people or animals. To this end, we grapple with the questions of how we can link the cultural and postindustrial heritage of the area with present, highly important economic activities such mining and waste mining [19]. We will discuss how we can promote the creation of a trail that will allow tourists to visit the sites of both heritage activities and link these sites to the already appreciated cultural heritage of the city of Salamanca, thus activating a demographically abandoned area with an aging population who are forgetting the architectural and economic value of their resources.

2. Methodology

Traditional methodology and digital technologies have been used to locate ancient quarries and mining sites in the province of Salamanca. These sites are the main subject of this paper. Before fieldwork began, Google Earth and digital aerial orthophotographs from

the Spanish National Orthophoto Program (PNOA) (https://datos.gob.es/en/catalogo/e00125901-spaignpnoama, accessed on 25 August 2023) were used to locate abandoned quarries and mines, as well as mining tails, in the study area. Visits to active mines were scheduled as part of the European project "Smart and Green Mining Regions of EU (REMIX)", and a review of relevant literature (on, e.g., mining, heritage stones, industrial heritage, and the economy) and official documents from various sources (e.g., the National Statistics Institute of Spain, the Geological and Mining Institute of Spain [IGME], and the Association of Research and Mining Exploitation in Castilla y León [SIEMCALSA] (Figure 14) was carried out. In addition, the energy and mining section of the Castilla y León regional government website (https://energia.jcyl.es/web/es/mineria.html, accessed on 25 August 2023) was also consulted. Detection of scheelite in both old mines and mine tailings was done using a shortwave 254 nm UVC-filter ultraviolet lamp with a scheelite detector.

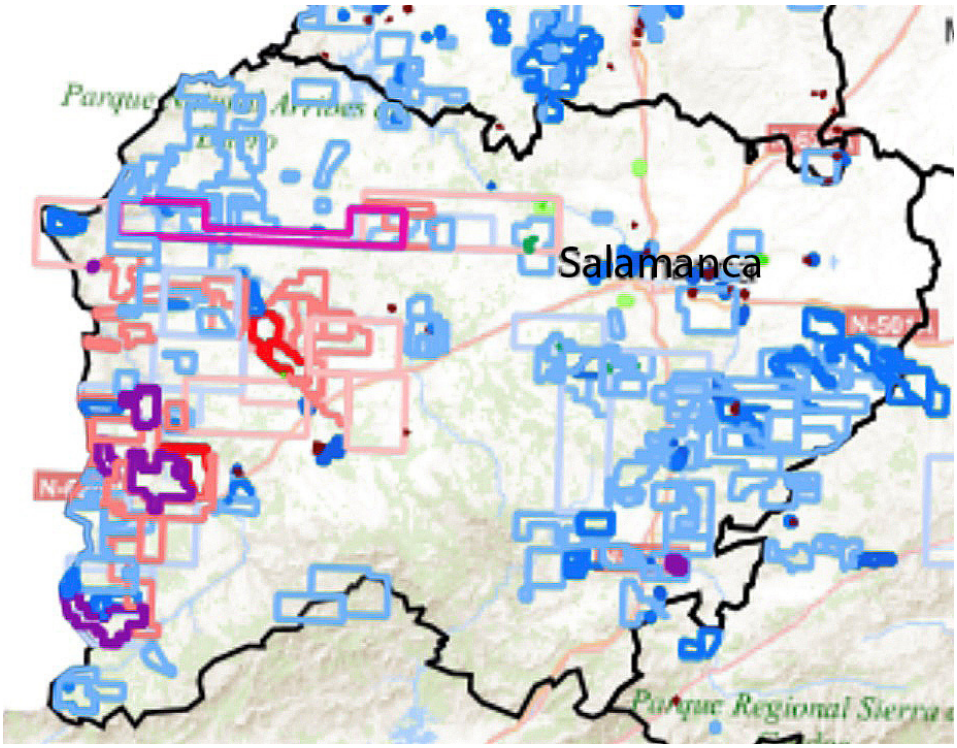

Figure 14. Exploration rights in the province of Salamanca. Most of them are for tungsten and tin. Many have expired and are under review, while some are still active. This paper focuses on mining in the southern part of the city of Salamanca. See interactive map at https://energia.jcyl.es/web/es/mineria.html, accessed on 25 August 2023. Blue and purple colors are for active exploration rights. Reddish colors are for expired exploration rights. See Figure 3 for the location of the province in Spain.

Other methods employed include the use of satellite and topographic data and drone images. The drone images (in JPEG and RAW formats) of the abandoned mines and quarries were taken with a professional multirotor drone (Figure 15) with GPS (NAVSTAR) and GLONASS constellation positioning and a 24.3-megapixel CMOS APS-C camera sensor. The drone was contracted to the Aer3D company.

Figure 15. Technical expert with a drone, preparing to locate abandoned mines and quarries.

3. Studied Area

This study focuses on the Southern part of the province of Salamanca, which is located in the western part of Spain, on the border with Portugal (Figure 3). The geology in the province of Salamanca is diverse, ranging from sedimentary rocks to igneous rocks [16]. All of these types of rock have been used as sources of industrial raw materials in the past, and there is increasing interest in using them now and in the future. Abandoned mines and quarries can be recognized as part of the cultural and industrial heritage and thus stimulate economic growth in a highly underdeveloped area of Spain. Most of these sites are located around Martinamor, a small village about 20 km south of the city of Salamanca (Figure 3), where Variscan granite (Martinamor tourmaline leucogranite) and pre-Variscan orthogneiss (San Pelayo orthogneiss) outcrop [16,17]. Mines were once opened in the granite and the orthogneiss. The granite was one of the main construction materials used in building the historically important city of Salamanca, but other granites and other lithologies were extracted, as seen above. The area if interest in terms of mining and quarrying heritage spans some 80 km, from 5 km north of the city of Salamanca to 70 km to the south of the city.

4. Discussion

The goal of this paper is to describe and study the possibility of revitalizing a demographically degraded area in Spain by promoting the historical importance of its cultural and postindustrial landscape, which contains remnants of past economic activity. It is also of interest to use this area as a source of information regarding CRM in high demand, such as tungsten. The ultimate objective would be to develop a tourist attraction associated with tourism in the city of Salamanca based in its highly appreciated cultural heritage, creating this connection through the city council in the frame of an European project (LIFE Vía dela Plata project, LIFE19 CCA/ES/001188: https://www.lifeviadelaplata.com/proyecto/ accessed on 30 October 2023). Similar approaches have has been used in other European areas. The best example is the Ruhr area (Germany), which was once the largest industrial region in Europe, known for its coal mines, steel works, and polluted environment. The Ruhr area is now Europe's fourth-largest metropolitan area and consists of several postindustrial cities with well-developed services that are mainly focused on tourism. Its industrial heritage includes mines, factories, administrative buildings, workshops, housing, communications infrastructure, and heavy machinery, in addition to commercial products, business documentation, tools, vehicles, clothing, and even the everyday foods of that glorious past [1]. This is a past that had great value in terms of socioeconomics and identity, thus justifying its resurrection and reinterpretation in the present, especially when some of the activities that stopped in the past can be important fuel for progress in the future. Somoza-Medina et al. discussed in detail the regional tourist project entitled "The

Industrial Heritage Trail", and describe landscape parks created for the trail to replace the industrial objects [1]. They discuss whether it is worth the investment to convert areas such as Almadén and Sabero (Spain) into industrial heritage sites, even if these two case studies are both categorized as Anchor Points in the ERIH and as such have been awarded quality certificates as destinations for industrial tourism [1]. This type of project could be one of many good practices to be implemented in Spain. It could also trigger debate in Spain concerning the proposed study area.

Abandoned mines and quarries are part of the postindustrial landscape of Salamanca province. Restarting the mining and quarrying activities in these areas would be difficult, if not impossible. However, work involving the scientific, educational, and tourist potential of the area's industrial heritage would help to preserve it and could trigger the launch of a new economy in a region that is currently economically neglected. The development of industrial tourism in Europe was implemented following the closure of numerous industrial complexes during the economic crisis of the 1970s. After several decades of disuse, these former industrial sites were successfully rehabilitated as centers for cultural and recreational activities [1] and could represent successful model initiatives to be imitated in the case of the study area that is the focus of this paper. The objective is to avoid losing the heritage by finding a use for these sites that will benefit the economy and prestige of the region. Sousa et al. [29] proposed promoting awareness of the importance of geological resources with the aim of contributing to the preservation of the architectural heritage of the city of Salamanca and the postindustrial heritage of the surrounding area and similar regions. Through education and outreach programs and activities, local, regional, and national governments should try to maintain knowledge of past mining and quarrying traditions as part of our cultural heritage. A geoconservation safeguarding plan should be undertaken to ensure the protection of this important postindustrial area and all the heritage features within it. The only possible path to success will involve local and regional governments, together with the local population and tourism stakeholders. One possibility is to promote the area's industrial heritage through a trail that will allow tourists to visit the places where important mining and quarrying activities were developed during the last century. This trail should be linked to the city of Salamanca, a UNESCO World Heritage City. Along that trail, visitors would learn not only about past activities, the quarrying of stones to build the architectural heritage of Salamanca, but also about the importance of raw materials and sustainable methods of their extraction, as well as the concept of using mining waste as part of a "circular economy" philosophy.

Due to the new European policy of mining necessary CRM locally, freeing us of our current total dependence on developing nations, geological studies that were conducted a century ago can help to find new ways to obtain these metals, while new sustainable ways of extraction and use of mine waste are being studied to make it possible for this activity to meet European environmental standards. The studied area was once a pioneer in providing raw materials to the world. It provided the best construction material used to build the architectural heritage of the UNESCO city of Salamanca Now, it could also become part of mining and circular-economy projects. Options for mining critical raw materials there are being studied, following the mandate of the European Union to provide materials for the sustainable development of Europe. Promotion of this effort by local, regional, and national governments is required for success. Preserving the postindustrial heritage of the area will add value to the established cultural heritage of the city of Salamanca and should help to promote an abandoned and empty part of Spain. In addition to the abandoned artisanal mining operations, modern mining operations to extract metals from mine tailings could also be visited, if such visits were arranged with the owners of the mining facilities.

If we could involve the various stakeholders in developing the proposed trail around Salamanca, this trail could be connected to other sites in Galicia, Extremadura, or even Portugal, taking advantage of the Jacobean route, which is also called the Silver Route (https://santiagoways.com/en/things-to-see-in-the-silver-way/, accessed on 25 October 2023). This route connects the south (Sevilla) with the north (Gijón) of Spain, and also to

Portugal and Galicia, ending in Santiago de Compostela. Along the way, active mining operations in La Parrilla (Cáceres, Extremadura) and in Los Santos (Salamanca, Castilla y León) can also be visited, adding heritage-related value to that mining activity (Figure 16).

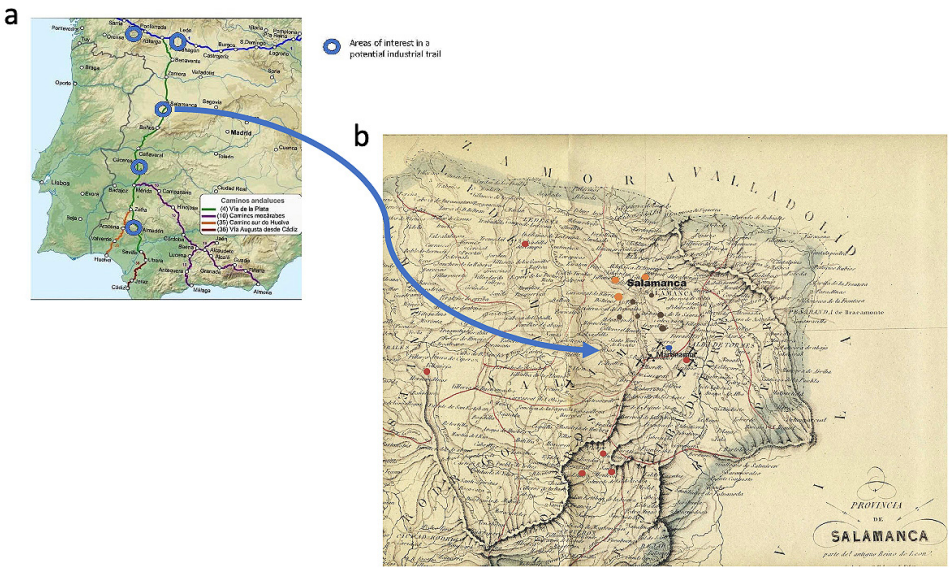

Figure 16. (**a**) Proposal for a route visiting abandoned mines and quarries in parallel to the Silver Route (Jacobean Route). Modified from source: Paulusburg, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=73942109, accessed on 25 August 2023. (**b**) Detail of ancient mining (little hammer symbol) and quarrying (round symbols) sites in the area of Salamanca province. The base map was drawn by Domínguez Chaves in 1971, from a drawing by Coello, dated 1858. Symbols for ancient quarries: brown for opal cemented conglomerate; orange for Villamayor sandstone, red for granite (including vaugnerite), and blue for slates. The map is a facsimile of that by Deogracias, 1860, deposited at the provincial government of Salamanca. Modified from source: Pereira and Cooper [15].

It has to be considered that most areas of interest are close to other UNESCO cultural sites (e.g., Salamanca's old town, Cáceres, León, Santiago de Compostela's old town, the Roman walls of Lugo, the Tower of Hercules lighthouse in A Coruña, Sevilla, and Córdoba). Therefore, visits to the postindustrial sites will complement visits to these UNESCO sites along the already well-established cultural trail.

5. Conclusions

Tourism is the main driver of the economy in Spain. In 2022, tourism represented almost 13% of the GDP. However, this activity is mainly restricted to the coastal areas of Spain. More than 80 million tourists, both international and national, visited Spain (taking into account those who made use of accommodation facilities), and around 31 million opted for domestic tourism (without using accommodation facilities) (https://es.statista.com/estadisticas/474658/visitantes-extranjeros-en-espana-por-tipo/, accessed on 25 August 2023). The study area of this work is located in the interior of Spain, an empty region that is losing industry and population every year. Governments should try to promote activities that improve the economy in these areas. Salamanca is a tourist city, a UNESCO World Heritage Site since 1988. Its university is the oldest university in Spain and one of the oldest in Europe. The main reason for the success of its candidacy as UNESCO site was the heterogeneous construction of buildings in downtown Salamanca, which used local stones, some of which are considered "heritage stones". Many tourists make short visits to the city (i.e., a one-day visit), mainly from Madrid, which is one of the main attractions in the interior of Spain and is about an hour and a half from Salamanca by train. The city council has developed a trail in the context of a European project (LIFE Vía dela Plata project, LIFE19 CCA/ES/001188: https://www.lifeviadelaplata.com/proyecto/, accessed on 30 October 2023) linking key elements or subjects such as Adaptation to Climate Change,

Green Infrastructure, World Heritage City, Ecosystem Services, Machine Learning, and Citizenship. The industrial or postindustrial heritage in and around Salamanca was not included, probably because it is little known, although this province was a major driver of the economy in the middle years of the last century, and the stone with which its monuments were built centuries ago is still found in the quarries. In those quarries, ancient quarrying marks can still be seen, as described in the Introduction. The final purpose of this paper was to give more information on the postindustrial activities related to mining and quarrying in and around Salamanca city to connect the sites to the already well-developed cultural route in the city. This connection can be made tangible through a visiting trail that includes both the historically significant city of Salamanca, using it as the main attraction, and the postindustrial heritage that is only a few minutes from the city by car. If this plan is successful, the eventual aim is to extend the route along the Silver Route, connecting it to other postindustrial sites such as Almadén (Ciudad Real) and Sabero (León), which are Anchor Points of the ERIH. Preliminary contacts have been made with the LIFE project responsible, and representatives have shown interest in widening the scope of the project as a next step.

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References

1. Somoza-Medina, X.; Monteserín-Abella, O. The Sustainability of Industrial Heritage Tourism Far from the Axes of Economic Development in Europe: Two Case Studies. *Sustainability* **2021**, *13*, 1077. [CrossRef]
2. Ćopić, S.; Đorđević, J.; Lukić, T.; Stojanović, V.; Đukičin, S.; Besermenji, S.; Stamenković, I.; Tumarić, A. Transformation of Industrial Heritage -an Example of Tourism Industry Development in the Ruhr Area (Germany). *Geogr. Pannonica* **2014**, *43*, 43–50. [CrossRef]
3. Berger, S. Industrial Heritage and the Ambiguities of Nostalgia for an Industrial Past in the Ruhr Valley, Germany. *LABOR Stud. Work. Cl. Hist.* **2019**, *16*, 37–64. [CrossRef]
4. Zhang, Y. Sustainable Development and Comparison between Three Provinces of Northeast China and Ruhr Germany from the Perspective of Industrial Tourism. In Proceedings of the 2022 6th International Seminar on Education, Management and Social Sciences (ISEMSS 2022), Chongqing, China, 15–17 July 2022; Series: Advances in Social Science, Education and Humanities Research. Atlantis Press: Amsterdam, The Netherlands, 2022. [CrossRef]
5. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661 (accessed on 29 July 2023).
6. The Mineral Industry of Spain by Lindsey Abdale and Loyd M. Trimmer III USGeological Survey. 2022. Available online: https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-spain.pdf (accessed on 31 October 2023).
7. Prados de la Escosura, L.; Rosés, J.R. The Sources of Long-Run Growth in Spain, 1850–2000. *J. Econ. Hist.* **2009**, *69*, 1063–1091. [CrossRef]
8. Simpson, J. Economic Development in Spain, 1850–1936. *Econ. Hist. Rev.* **1997**, *50*, 348–359. Available online: https://www.jstor.org/stable/2599064 (accessed on 29 July 2023). [CrossRef]
9. Calvo, G.; Valero, A.; Valero, A. How can strategic metals drive the economy? Tungsten and tin production in Spain during periods of war. *Extr. Ind. Soc.* **2019**, *6*, 8–14. [CrossRef]
10. Wheeler, D.L. The Price of Neutrality: Portugal, the Wolfram Question, and World War II. *Luso-Braz. Rev.* **1986**, *23*, 107–127. Available online: https://www.jstor.org/stable/3513391 (accessed on 25 July 2023).

11. Guerra Garrido, R. *El Año del Wólfram*, 1st ed.; Catedra Ediciones: Madrid, Spain, 1984; 354p.
12. Wilson, R. *A Small Death in Lisbon*; Harper Collings Publishers: London, UK, 1999; 440p.
13. Pereira, D. *Natural Stone and World Heritage: Salamanca*; CRC Press: Boca Raton, FL, USA, 2019; 106p, ISBN 978-1-138-49954-6.
14. Stock, D. *Old City of Salamanca*; Discovering Stone: Victoria, Australia, 2012; Volume 21, pp. 54–56.
15. Pereira, D.; Cooper, B. Building Stone as Part of a World Heritage Site: "Piedra Pajarilla" Granite and the City of Salamanca (Spain). In *Stone in Historic Buildings: Characterization and Performance, Geological Society Special Publications*; Geological Society of London: London, UK, 2014; Volume 391, pp. 7–16.
16. Díez Balda, M.A. *El Complejo Esquisto-Grauvaquico, las Series Paleozoicas y la Estructura Hercínica al Sur de Salamanca*; Ediciones Universidad de Salamanca: Salamasca, Spain, 1986; 162p. (In Spanish)
17. Murciego, A.; Álvarez-Ayuso, E.; Pellitero, E.; Rodríguez, M.A.; García-Sánchez, A.; Tamayo, A.; Rubio, J.; Rubio, F.; Rubin, J. Study of arsenopyrite weathering products in mine wastes from abandoned tungsten and tin exploitations. *J. Hazard. Mater.* **2011**, *186*, 590–601. [CrossRef] [PubMed]
18. Kinnunen, P.; Karhu, M.; Yli-Rantala, E.; Kivikytö-Reponen, P.; Mäkinen, J. A review of circular economy strategies for mine tailings. *Clean. Eng. Technol.* **2022**, *8*, 100499. [CrossRef]
19. Castro-Gomes, J.P.; Silva, A.; Cano, R.; Durán Suarez, J.; Albuquerque, A. Potential for reuse of tungsten mining waste-rock in technical-artistic value added products. *J. Clean. Prod.* **2012**, *25*, 34–41. [CrossRef]
20. Han, Z.; Golev, A.; Edraki, M. A Review of Tungsten Resources and Potential Extraction from Mine Waste. *Minerals* **2021**, *11*, 701. [CrossRef]
21. Yang, Y.-Y.; Xu, Y.-S.; Shen, S.-L.; Yuan, Y.; Yin, Z.-Y. Mining-induced geo-hazards with environmental protection measures in Yunnan, China: An overview. *Bull. Eng. Geol. Environ.* **2015**, *74*, 141–150. [CrossRef]
22. Essalhi, A.; Essalhi, M.; Toummite, A. Environmental impact of mining exploitation: A case study of some mines of barite in the Eastern Anti-Atlas of Morocco. *J. Environ. Prot.* **2016**, *7*, 1473–1482. [CrossRef]
23. Ozcelik, M. Environmental pollution and its e ect on water sources from marble quarries in western Turkey. *Environ. Earth. Sci.* **2016**, *75*, 796. [CrossRef]
24. OECD. *Managing Environmental and Health Impacts of Uranium Mining*; NEA: Paris, France, 2014.
25. Mensah, A.K.; Mahiri, I.O.; Owusu, O.; Mireku, O.D.; Wireko, I.; Kissi, E.A. Environmental impacts of mining: A study of mining communities in Ghana. *Appl. Ecol. Env. Res.* **2015**, *3*, 81–94.
26. Wheeler, A. Technical Report on the Mineral Resources and Reserves of the Valtreixal Project, Spain. Prepared for Almonty Industries. 2015. Available online: https://almonty.com/wp-content/uploads/2019/06/AII_Feb_1_2018_AIF_FINAL.pdf (accessed on 29 July 2023).
27. Tejado-Ramos, J.-J.; Chocarro-León, M.; Barrero-Béjar, I.; Valverde-Calvo, A.; Giraldo-Pavón, F.; Tarragona-Pérez, C.; Morales-Sotaminga, E.S.; Fernández-Cedrón, L. Drones and ultraviolet radiation for the detection of scheelite mineral. *Remote Sens. Appl. Soc. Environ.* **2023**, *30*, 100949. [CrossRef]
28. Bea, F.; Pesquera Pérez, F.; Montero, P.; Torres Ruiz, J.; Gil Crespo, P.P. Tourmaline 40Ar/39Ar chronology of tourmaline-rich rocks from Central Iberia dates the main Variscan deformation phases. *Geol. Acta Int. Earth Sci. J.* **2009**, *7*, 389–412.
29. Sousa, L.; Lourenço, J.; Pereira, D. Suitable Re-Use of Abandoned Quarries for Restoration and Conservation of the Old City of Salamanca—World Heritage Site. *Sustainability* **2019**, *11*, 4352. [CrossRef]