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The Rationale for Restoration of Abandoned Quarries in Forests of the Ślęża Massif (Poland) in the Context of Sustainable Tourism and Forest Environment Protection

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Abstract: The manuscript presents the current state and proposals for the management of the old granite, quartz, and serpentinite quarries located in the Ślęża Massif (SW Poland, 50°51′51.22″ N; 16°42′26.80″ E), an area entirely covered by forests and protected by various legal protection measures. The quarries are abandoned and subjected to intense natural plant succession, so they are disappearing from the landscape. Nine quarries were analyzed regarding their natural and landscape characteristics. Due to the variety of their sizes, specific locations, geological–topographical traits, and forest and site conditions, the quarries may be turned into tourist attractions enhancing the social function of forests while, at the same time, ensuring their protective functions. If properly managed, they may contribute to the multifaceted development of tourism, performing scientific-cognitive, educational, sports, or cultural functions, and, as a result, to a partial reduction in the tourist pressure on biotic and abiotic natural resources along the presently most frequently used routes. This paper attempts to present arguments indicating that a former mining working site may be a positive and attractive landscape element in harmony with the vegetation cover, beneficial for both nature and humans.

Keywords: quarry; natural succession; geoheritage; landscape attractiveness; tourist activity

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1. Introduction

In Poland, the State Forests cover 7.6 million hectares. These forests are accessible to everyone. Over 17 thousand tourist facilities are available throughout Poland, including both rudimentary campsites and comfortable camping sites, luxurious resort facilities, bed and breakfast accommodations, walking, cycling, and horse-riding trails, as well as parking sites, scenic viewpoints, and other tourist attractions. Tourist and recreation services generate huge costs; however, such activity is included in the forest management strategy in Poland, aiming at the performance of the primary forest functions, including social functions. Social needs related to using forest resources in the context of tourism, recreation, and health are growing in Poland, as in many places worldwide. It results from the increasing public awareness of the beneficial effect of exercise and physical activity on human health and psyche and the general quality of life, as well as the need to improve fitness and the overall sense of wellbeing [1–3]. Increased public interest in leisure activities in forested areas has been observed for many years; however, this phenomenon has recently accelerated considerably since 2019 along with the COVID-19 pandemic threat and particularly became clear after the strict restrictions on movement were lifted [4–6].

In line with the development of new tourism forms, modern tourist facilities dedicated to the general public have been established in forested areas. The development of silva-tourism is observed throughout Poland, particularly in Lower Silesia. This region (SW

Poland) is a true trove of tourist attractions—a land of well-preserved castles, picturesque towns, scenic mountains, and magnificent forests with numerous valuable plant and animal species. Mount Ślęża and the vicinity are one of the most popular tourist and recreation sites in Lower Silesia.

In Poland, we may observe a shift from the 3 × S model (sun, sea, and sand) towards the 3 × E model (entertainment, excitement, and education). The analyzed area perfectly meets the demand for active leisure activities [7].

A specific limitation for developing tourism and recreation in forested areas is preserving natural resources, nature components, and landscape value. This publication presents an analysis of the directions of tourism and accessibility of a forested area to mass-scale tourism while, at the same time, reducing the environmental impact. The abandoned quarries in the forests of the Ślęża Massif are indicated as areas for potential tourism development.

There are many methods to revitalize post-mining areas. In Poland, after decades of exploitation of mineral resources, such areas were abandoned with no reclamation measures implemented (e.g., quarries of solid rocks such as limestone, dolomites, and sandstone), or, in specific cases, they were managed under binding legal regulations, typically for forestry, agriculture, recreation, or municipal utility purposes. The latter variant included the leveling of the exploited area and its allocation for a construction investment or a waste disposal site [8,9], which is similar to the trend observed in other countries, especially in terms of the afforestation of problematic post-mining areas [10–15].

In post-mining areas, not only pits but also post-mining waste dumps are subject to reclamation. Heaps associated with coal or metal ore mining are a huge environmental problem, as they can be a source of chemical pollution, a problem known primarily in Polish coalfields but also from many other mining areas [16–20].

The abandoned quarries are often devastated: they are overgrown with undesirable vegetation, are flooded by groundwater, or become illegal landfills. In recent years, practitioners in the area of Earth science have repeatedly emphasized that geoheritage and geodiversity are not sufficiently appreciated, and their importance is frequently ignored [21]. At the same time, they indicated that some workings might be perceived as an integral element of the landscape, having high cultural and utility value and enhancing the geodiversity of the geoenvironment [8,22]. Hence, the abandoned quarries issue was incorporated into the concept of geomorphosites developed by geomorphologists over the last two decades [23,24]. The term "geomorphosites" describes geomorphological landforms that have acquired cultural, historical, aesthetic, social, and/or economic value due to human use or perception. In this context, some excavations, which are man-made anthropogenic landforms, are a specific type of geomorphosite with all of the attributes mentioned above [22,25–27].

Abandoned quarries are gaining popularity worldwide as tourist facilities or public facilities. Many examples may be given here, both from Poland and other countries. The primary aim of renovating and revitalizing quarries is to provide them with new social and economic functions. This direction of management for former mine workings is being implemented in Poland. Examples include significant investments in former limestone quarries, in areas of large urban agglomerations, such as Kraków, where recreation and rest areas were created; in Jaworzno, located within the large Upper Silesian-Zagłębie agglomeration, an old quarry was changed into the "GEOsfera" Center for Ecological and Geological Education [28]; the "Centre of Geoeducation" and "Kadzielnia" amphitheater were built in the former quarry in Kielce, in the Holy Cross Mountains [29], and the "European Center for Geological Education" was built in Chęciny [30]—a research, development, and conference center. There are many similar examples in Poland, frequently on a smaller scale but nevertheless of great importance for the local community and tourists. Impressive examples in other countries include large-scale architectural investments such as the St. Margarethen Quarry in Austria, an amphitheater complex constructed within a former quarry, considered to be the largest outdoor concert hall in Europe [31], or luxury hotels, e.g., in Songjiang at the outskirts of Shanghai or Cap-d'Ail in Côte d'Azur (the French Riviera), France [32]. The world's experience in mine excavation development is rich and historically grounded as far back as ancient Roman times. Since the Renaissance era, a landscape context for the use of post-mining pits has emerged; there are known examples of the transformation of ancient quarries into parks or gardens at that time [32], and this trend is still relevant today. Furthermore, today, it is taking on new faces: in Lithuania, the former dolomite mining site in Petrašiūnai has been proposed for creating an "entertainment theme park complex" within the specially formed entertainment landscape [33]. Another way to recover the post-mining excavations is to use them for sports and recreational purposes with a water management component to create a reservoir with coastal beach infrastructure and sports facilities. Such an example is known from Almaty (Kazakhstan) [34]. Following the challenges of recent years, completely new ideas are emerging for land development in former quarries, such as the construction of photovoltaic farms. Such installations are reported from the Republic of Korea [35,36].

In the Ślęża region discussed in this paper, the post-mining objects—being small in size—have not been reclaimed in any way and, at present, are not being managed for any specified purpose. However, from year to year, it has been subjected to the expansion of vegetation, which may be evaluated from two distinctly different points of view: foresters and geoscientists. This paper presents forest and geological–geomorphological aspects related to those former quarries and also considers the possible social functions of these places. Various threads and issues were combined: protecting animate and inanimate nature and enabling multifaceted tourist exploration for people interested in contact with nature and the region's cultural heritage. In the initial chapters of the article, an attempt was made to explain why the study area is so unique and noteworthy: the geological characteristics and historical outline of mining activity, which are a direct cause of the quarries' existence. These aspects may be important in view of the development of geotourism and heritage tourism in the Ślęża region. The characteristics of tree stands, which are now one of the major values of the region, attracting crowds of tourists, are also presented. In the following part of the paper, details of the individual quarries are provided, followed by a discussion of the future opportunities for their further development.

2. Scope, Materials, and Methods

The aim of the analyses was to indicate whether the present-day tourist management of the Ślęża Massif may be further improved and enriched with new elements. Are the geological values exposed sufficiently to be considered a significant tourist attraction, or may they be enhanced and, as a result, draw tourist traffic from those interested in such an aspect of hiking? If so, is it desirable or needed at all? Might abandoned quarries constitute areas conducive to the further development and construction of new infrastructure to be used both by tourists and the local community? Will the forest environment, within which former mine workings are located, suffer in the case of such a new management type, or will it gain value thanks to minor modifications in individual sites? Will the biotic value be more effectively exposed, enhancing a given site's landscape and scenic value? Finally, might a slight modification of the existing network of trails, adding access to former quarries, result in the dispersion of the tourist traffic, which would at least partly solve the problem of the considerable spatial and temporal concentration of this traffic in the Ślęża Massif?

First, a review of cartographic materials concerning the Ślęża region was conducted to ensure familiarization with the location of remnants of mine workings. The mineral extraction sites created in modern times are marked in the 1:10,000 topographic maps prepared several decades ago. This scale is the largest available for topographic serial maps produced in Poland after WWII. The study area is located within the region covered by six sheets of a topographic map, of which five were prepared in 1985. One is more recent, from 1997, and all are available from the Head Office of Geodesy and Cartography in Poland (GUGiK) database. In terms of the topographic data being up to date, these maps are sufficient for this study since all of the mineral exploitation in the Ślęża area, the Kiełczyn, and the Oleszna Hills had been abandoned before these map sheets were published; thus, the location and the number of the mine workings are consistent with the current status today. However, the precision of marking these workings on the maps is problematic. The state-of-the-art airborne laser scanning (ALS) technology makes it possible to obtain information on land relief features with excellent resolution. In the present study, a handy analytical tool was provided by a high-resolution digital elevation model (DEM) generated from such data (LiDAR—light detection and ranging) at the resolution of 1 m, valid for 2021, available as ready-to-use digital sheets from the GUGiK geoportal [37]. The DEM supplied high-quality data on the location of objects, their precise range, shape, and dimensions of the workings, and the currently preserved relief in the analyzed mining sites. Precise quantitative information concerning the investigated objects was collected through simple DEM analyses. Moreover, preliminary information on the degree of the vegetation surface cover in the workings was read from the orthophoto map. LiDAR DEM and the orthophoto map were provided by GUGiK.

Furthermore, 1:50,000 geological and geoenvironmental maps are made available by The Polish Geological Institute-National Research Institute (PGI-NRI), comprising information on rocks and related human activity. Good accuracy is found in the forestry maps used in this study, which contain information on the biotic environment and protection forms—available online in high-resolution thanks to the State Forests National Forest Holding (SF NFH).

The study objects for field investigations were also selected based on the information in scientific publications in geology, geotourism, and archaeology. For field studies in this project, the selected objects were min. 1000 m^2, had distinct, interesting land relief features, could be attractive for tourists, and were potential locations for small tourist infrastructure.

The present condition of the mine workings was assessed during field studies conducted during successive visits to the quarries, and during the regular site survey performed by the Bureau for Forest Management and Geodesy.

The inventory of quarries consisted of the following activities: field verification of the access paths and roads, previously determined using the cartographic materials; quarry accessibility verification; measurements of the physical elements of the excavation; field recognition of the geological features of the rocks (type of rock and mineralization, structural, tectonic features, and mainly the presence of fractures); and assessing the degree of weathering of rocks in the outcrops and their preservation (the vegetation coverage of the outcrops, coverage rate by debris and clay—erosion products). The inventory of biotic features consisted of field verification of data from forest inventory documents previously made for regular forest management if they were made specifically for the mining site. Some excavations had no inventory documents. In each case, the dendrological method was used: identifying the species, estimating the species structure, and measuring the diameter at breast height, tree height, and tree habit characteristics. General characteristics of the undergrowth were also noted; however, the focus was primarily on the stand, and attention was paid to the presence of specific specimens by age, size, or other dendrometric characteristics.

Natural plant succession has already encroached on former workings, while a stand has often developed. For this reason, routine forest management operations are performed there, including forest inventories. This paper was prepared based on information collected in this manner. Moreover, a simple valuation of the analyzed sites was conducted, focusing on their attractiveness and potential use for tourist purposes, combining nature and forestry, geological, landscape, technical, and logistics aspects (related to their accessibility, safety, the input of labor required for their potential management, etc.). All of the operations were supported by the GIS tools provided by QantumGIS v. 3.18 and GlobalMapper v. 16.

3. Study Area

3.1. Location and Its Tourist Implications

In the physio-geographic division of Poland into mesoregions, the Ślęża Massif belongs to the Sudetic Foreland macroregion [38] and covers an area of approx. 140 km^2. It is distinguished by the highest elevations within the foreland, including the Ślęża peak, reaching a relative altitude of over 500 m in relation to the surrounding plains. In this investigation, the study area comprised this part of the mesoregion, with areas dominant in its topography, with a large part being outcrops of bedrock and, at the same time, characterized by the presence of forests administered by the State Forests National Forest Holding, an organization administering forests owned by the State Treasury. Such a defined study area covers approx. 50 km^2, and, in this paper, the term "Ślęża Massif" is used in reference to this particular area (Figure 1).

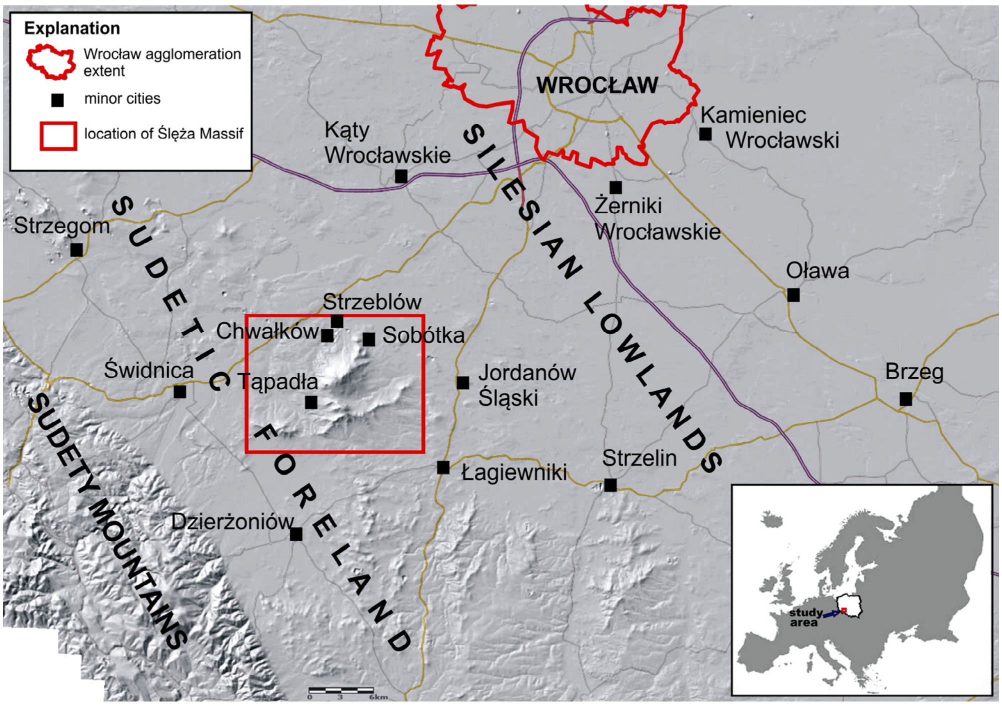


Figure 1. Location of the study area.

The considerable relative altitude makes Ślęża a distinct landmark in the region's topography [39], which must have made a tremendous impression on the residents and visitors for thousands of years. In specific historical periods, Ślęża was treated as a sacred place. The remnants of mysterious rituals from premedieval times are still seen in the area and constitute one of the numerous tourist attractions. The Ślęża region also has a rich development history in more recent historical periods, which has been connected with the transformation of the natural environment. Today, the Ślęża Massif is a tourist destination for thousands of regions' inhabitants, notably residents of the city of Wrocław, a capital of the Lower Silesia province located 35 km away (Figure 1). This city and smaller satellite towns comprise a metropolitan area inhabited by approximately 1 million people.

The principal town at the massif foothills is Sobótka, the area's leading tourist, recreation, and cultural center. Numerous tourist trails extend from this town towards the Ślęża peak. In terms of forest management, the entire massif is situated in the Miękinia Forest District, within four subunits, i.e., Chwałków, Sulistrowiczki, Tąpadła, and Uliczno. The massif area is almost completely covered with forests, in contrast to the extensive plains and small hills surrounding the massif, with farmland and agricultural areas within a radius of many kilometers. As a result, the Ślęża Massif constitutes a vast forest enclave. The forest's nature value is a significant factor determining its tourist attractiveness.

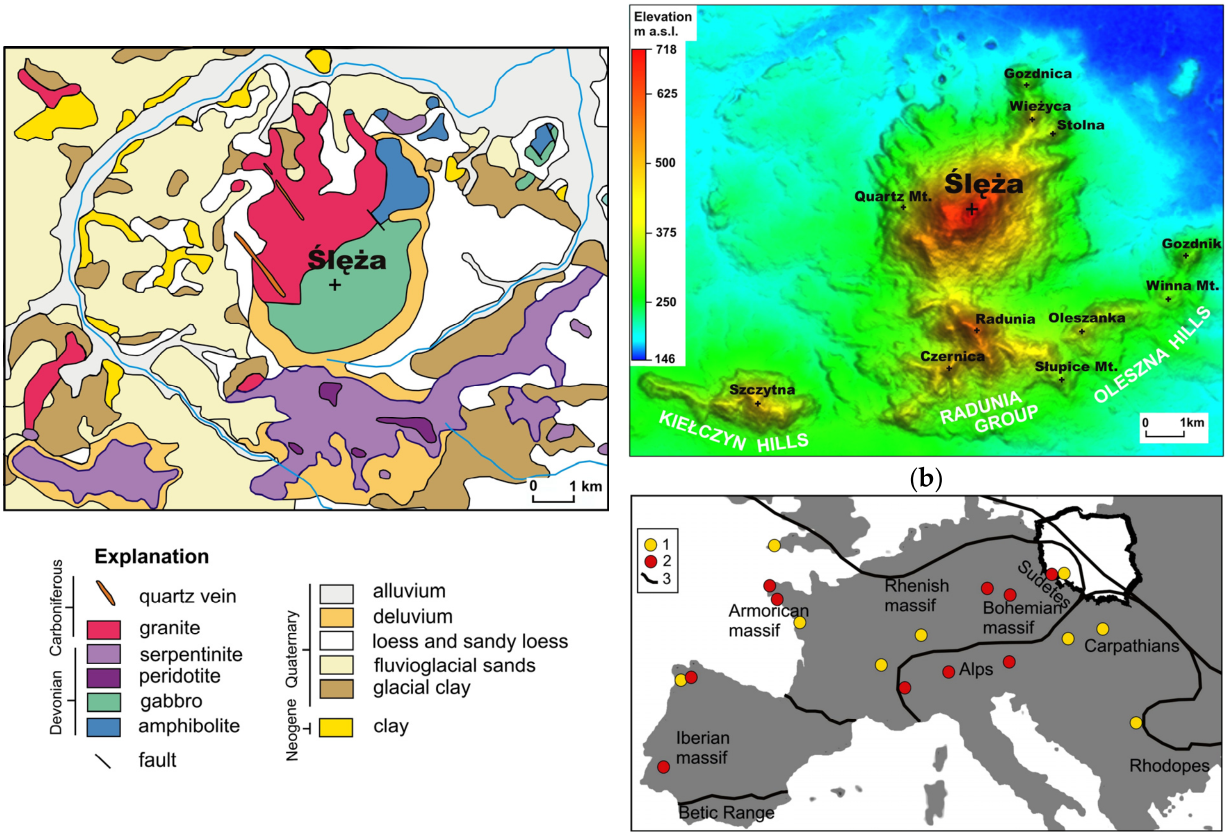
The study of the sources of tourist inflow to the Śleża region showed a definite dominance of residents of the Lower Silesian province, with 41% of the surveyed tourists declaring that they came from the city of Wrocław, 24% from the surrounding area, i.e., Wrocław County, and tourists from other counties of Lower Silesia accounting for 29%. Only 6% were tourists from outside the Lower Silesian province. Such a structure of tourists' origin testifies to the solid regional importance of recreational services offered by the Ślęża Landscape Park [40]. A study of tourist traffic conducted for the area called the Ślęża subregion (the Ślęża Massiff and several municipalities around it) showed a very unfavorable seasonality, with a peak in the summer months and out-of-the-season months of June, May, September, and October. Nearly 90% of visitors to the subregion spend only a day, without an overnight stay, in the subregion's area, and most of them (about 64.4%) get there by private car. One in four tourists visits the Ślęża region regularly [41]. Such a characteristics of tourist activity raises problems, including a lack of parking spaces at peak tourism, parking in unauthorized places, which causes damage to vegetation, and soil being torn up by car wheels. The most popular way of spending time in the Ślęża region is hiking, and biking is becoming increasingly popular. Here again, problems arise: the most frequented hiking trails are those leading directly to the top of Ślęża. At peak times, these trails are crowded and bear manifestations of environmental impact in the form of soil erosion and exposed tree roots. On other trails, there are conflicts between hikers and cyclists, as the routes are mostly combined (hiking and biking). Mass sports and recreational events are organized several times a year in the Ślęża Massif, and cycling competitions are among the largest in Poland. During these short periods, the area is visited by thousands of competitors, service staff, and spectators. Such events are consistent with the abovementioned highly variable, irregular characteristics of tourist traffic intensity.

3.2. Topography and Geology

In terms of surface relief, the area of the massif may be divided into two distinct parts, which are closely related to their geological structure (Figure 2a,b):

- The northern part extends from the town of Sobótka to the Tąpadła Pass; it comprises the most northerly summits of the area: Gozdnica (317.6 m.a.s.l.), Wieżyca (414.2 m.a.s.l.), and Stolna (368.4 m.a.s.l.), along with the centrally located Ślęża (718 m.a.s.l.), composed of Paleozoic igneous rocks, which are primarily granites as well as gabbros and amphibolites; granites in this part of the massif are transected by two massive quartz veins, extending in the NW-SE direction [42];
- The southern part, behind the Tąpadła Pass, is composed mainly of Devonian serpentinites and peridotites, with scarce amphibolites and aplites [43], morphologically constituting, as it were, a separate series of lower hills, which may be further distinguished: a segment with the peaks of Radunia (the Radunia Group Hills) (577.6 m.a.s.l.) and Czernica (487 m.a.s.l.), ranking second and third in the Ślęża Massif in terms of altitude, respectively, while the SE part of the massif contains a narrower belt of the Oleszna Hills with its highest hill Oleszenka (388 m.a.s.l.). The serpentinite belt in the westerly direction extends into the Kiełczyn Hills with the highest peak of Szczytna (466 m.a.s.l.).

In terms of its geology and structure, this area of morphologically distinct hills with the dominant peak of Ślęża comprises three parts. The granite part is a fragment of a larger geological unit, referred to as the Strzelin-Sobótka granitoid massif. It was formed as a result of intensive granitoid plutonism during the Carboniferous period (approx. 280–330 Mya) [44]. At that time, the magma intruded within the already existing gabbros of Ślęża. Gabbros are distinguished geologically as the "gabbro Ślęża Massif". The series of hills in the southern part of this area is called "the Jordanów–Gogołów Serpentinite Massif". The serpentinite part, along with the gabbro segment, forms the Ślęża ophiolite, one of several such rock sequences in the central Sudetes (the Central Sudetic ophiolites) [45]. Ophiolite, as an allochthonous fragment of the oceanic crust and the upper Earth mantle, constitutes a chronologically formed sequence of rocks related in terms of their petrogenesis, comprising ultramafic rocks (the oldest): peridotites and then serpentinites through felsic igneous rocks (gabbros) and up to volcanic rocks [46,47]. The geodynamic processes, which led to the formation of Sudetic ophiolites, took place in the early stages of the Variscan (Hercynian) orogeny; geochemical analyses of ophiolite rocks made it possible to date them back approx. 400–420 million years [48,49]. The ophiolite of Ślęża, as the most exposed on the ground surface, has been investigated for decades both by Polish researchers and international teams, as it is an element of regional studies concerning the geodynamic evolution of the European continent [50–52].



(a) (b) (c)

Figure 2. A simplified map of the Ślęża Massif geology (according to [42,43], modified) (**a**) and geomorphology (DEM [53] (**b**); the location of the study area within the tectonic sketch map of central and western Europe with the ophiolitic occurrences (**c**): 1—Devonian ophiolites, 2—Cambrian-Ordovician ophiolites, 3—main tectonic sutures (according to [49,54,55], modified).

3.3. History of Mining Activity in the Ślęża Region

Due to the rich geological deposits in the Ślęża region, various minerals have been explored and extracted for thousands of years. The beginnings of serpentinite mining and processing date back to the late Neolithic period. Numerous finds of the so-called "Ślęża axes" made of serpentinite originate from this period. The archeological studies show that the extraction site for the material of most excavated axes was located at the slopes of Jańska Góra, a hill located some distance to the east of the Oleszeńskie range, as well as the area of the Tąpadła Pass [56–58]. Traces of serpentinite extraction of an unspecified age are found in many locations in the Kiełczyn and the Oleszna Hills. Several old mine workings are considerable in size and attractive in location. Notable objects include the quarries in Przemiłów and on the Słupice Mountain, where serpentinite was mined in 1950–1965 and where the land relief features are still evident, with interesting mineralization and tectonic traits, exposed in the outcrops as a result of former mining activity.

Archeological and historical studies also showed numerous ancient traces of granite extraction and processing in the northern foothills (near Strzeblów) and on the northern slopes of Ślęża. The aplite granite from the blocks found in this part of the massif was used to carve the famous cult statues, the age of which is still being debated; however, according to archeologists' estimates, they date back to the early Middle Ages or even earlier periods [58]. Statues representing a bear and a boar, and sculptures called the Mushroom and the Monk, are associated with Celtic influences, which in the present-day Lower Silesia were prevalent around the 4th–3rd centuries B.C. [59,60]. These exciting and mysterious granite archeological objects may now be seen when wandering along the tourist trails within the massif. In more recent times, the Ślęża biotite granite was used to produce medieval quern stones, whetstones, and other small objects and tools needed in the household, as well as elements of building structures, nowadays found primarily in buildings associated with religious worship in the vicinity of Ślęża [57,61–63]. Up to the 15th century, the rock material was typically mined from shallow workings—ditches [62]. Groups of such workings constituted mining fields, still visible in topography as debris fields with partially buried pits between them. Archeological studies have revealed more than a dozen such ancient and medieval objects. Former mining fields found in the granitoid part of Ślęża are termed "ancient quarries". They are accessible for tourists traveling along the archeological tourist trail established in this area. Specific medieval and even earlier extraction activity sites were also used in modern times, such as, e.g., the quarries in the northern foreground of the Ślęża Mt. or workings in the northern, granitic slopes and the southern (serpentinite) part of the study area. These contemporary mining sites, at present already abandoned, are evident in the terrain morphology; in many places, outcrops of several to over a dozen meters in height have remained, exposing diverse types of rock materials at varying degrees of weathering, which are sometimes explored by tourists interested in geology. One of the most interesting examples in this respect is the so-called prehistoric quarry in the northern part of the massif, between the mountains of Gozdnica and Wieżyca. As reported in some sources, granite was extracted there as early as approx. the 12th century B.C. At that time, it was on a limited scale; nevertheless, mining activity there lasted intermittently until the early 19th century. After mining operations had ceased, an amphitheater was constructed in the quarry for events and performances. The abandoned quarry served this function periodically until the 1980s [64–67]. Eventually, the amphitheater infrastructure was disassembled, the facility was abandoned, and it has not since been managed.

Workings with probably the most recent history of mining activity in the Ślęża Massif are the small quartz quarries situated on the western slopes of Ślęża, near the towns of Sady and Biała. They were established in the vast quartz vein transecting the granite part of the mountain in the NW-SE direction, as clearly marked in the topography over a distance of approx. 1.8 km. Milky quartz was mined there from the late 1960s until 1975, as shown in the geological deposit documentation in the PGI NRI archives.

We also need to mention an episode of mining operations in the chromite deposit at the southern slope of Czernica Mt. (near Tąpadła). The deposit has been known since 1887, with the peak of mining activity during WWII. The chromite ore was initially extracted from loose blocks and later mined from shallow underground workings. At present, only small mine waste dumps and remnants of drifts have remained as traces of the former mining activity [68].

No mining activity is currently conducted within the slopes of Ślęża and neighboring hills. The area of the Ślęża Massif is legally protected; a landscape park has been established there. In turn, within the park buffer zone, in the northern foreland of the hills (out of the study area) in Strzeblów and Chwałków, several currently operating open-cast mines extract granite for commercial purposes.

3.4. Stands in the Ślęża Massif

As a result of human activity, the forest plant communities in the Sudetic foreland, with small exceptions, have been strongly transformed, or after clear-cutting, they have been replaced by other plant communities. The area of the Ślęża Massif is an exception since a considerable diversity of forest communities is observed there (Figure 3). This results from the land relief features, altitude, substratum type, and soil. The least anthropogenically transformed area is found in the Ślęża Massif forests located topographically the highest, which is due to hindered accessibility in a rocky, steep terrain and costs of potential economic management of this area. A considerable part of the central sections of the Ślęża slopes and a greater part of the peak are overgrown with the acidophilous mountain beech forest (Luzulo luzuloidis-Fagetum), along with fragments of the fertile Sudetic beech forest. The European beech (*Fagus sylvatica*) is the dominant species, with a small admixture of the silver fir (*Abies alba*), sycamore maple (*Acer pseudoplatanus*), and Norway spruce; rowan (*Sorbus aucuparia*), Scots pine (*Pinus sylvestris*), and silver birch (*Betula pendula*) were found on the stone runs [69]. Because of its unique plant communities, the Mount Ślęża nature reserve was established in the summit zone.

Most of the stands in the lower parts of the slopes are spruce monocultures established artificially by human intervention in places interspersed with acidophilous oak forests with the dominant sessile oak (*Quercus petraea*), an admixture of Scots pine and the forest floor vegetation composed of very few species. The best-developed fragments of this association are found in the hill Wieżyca, the eastern slopes of the Oleszna Hills, and the summits of the Kiełczyn Hills, where common oak is dominant (*Quercus robur*).

On the mountain Ślęża, apart from the reserve, a nature landscape protection complex called the *Skalna* complex was established, covering a group of gabbro outcrops, bluffs, and blockfields. The stand growing in this protected rocky area consists mainly of common beech with a high share of silver birch, a small admixture of silver fir, Norway spruce, and sessile oak. This habitat is characterized by infertile soil deposited over a rocky substratum, which determines the habit and size of trees, a poor shrub layer, and sparse forest floor vegetation.

In the southern part of the study area, two other nature reserves were also established: at the peak and on the northern slopes of Radunia. The former, called the Mount Radunia reserve, comprises a xerothermic oak forest of great floristic value (Quercetalia pubescenti-petraeae). Xerothermic oak forests were inventoried, apart from Radunia, also on the northern slopes of Gozdnik, the most westerly located hill of the Oleszna Hills. On Radunia specifically, with very shallow soils, an upland mesic mixed broadleaved forest developed. In this stand, sessile oak and common oak are dominant, frequently with an admixture of silver birch and Scots pine. Due to the prevalent habitat conditions, oaks exhibit an atypical habit with strongly deformed crowns and bent branches [64]. In the reserve, apart from forest communities, xerothermic grassland communities also developed in a treeless area. A rich flora of spleenworts (*Asplenium*) is found on serpentinite outcrops. Parts of the Radunia slopes are covered by a coniferous stand with Norway spruce and Scots pine predominance.

The other reserve, named the Sulistrowice Meadow, is located at the foot of the Radunia massif. The reserve comprises forest and non-forest plant communities, forming Molinia meadows of varying moisture conditions with the purple moor grass (*Molinia caerulea*) association and sedge fens. Forest communities of the reserve are stands with various tree species, including Norway spruce, Scots pine, oaks, silver birch, and alder buckthorn (*Frangula alnus Mill*.), in wetland areas transformed into willow–poplar riparian groves (Salicetum triandro-viminalis) [69].

In the Kiełczyn Hills, Radunia, and the Oleszna Hills, ten localities were established as ecological areas, protecting valuable localities of serpentinite-associated ferns, spleenworts, from the genus Asplenium. These localities were jointly named the Serpentinite ferns in the Ślęża Massif". All of them are situated in the abandoned serpentinite quarries with steep walls characterized by shading and locally increased humidity compared to their surroundings. They are old quarries of small surface areas (below 1 ha), where land relief sometimes promotes water accumulation in the depressions. The most important species in the plant associations include ladder spleenwort (*Asplenium adulterinum*), black spleenwort (*Asplenium adiantum-nigrum*), serpentine spleenwort (*Asplenium cuneifolium*), maidenhair spleenwort (*Asplenium trichomanes*), and northern spleenwort (*Asplenium septentrionale*).

Moreover, in the massif area, there are several legally protected monumental trees and an unusual natural monument, a red alga (*Hildenbrandia rivularis*), found in the watercourse segment in the lower part of the north-western slope of Ślęża.

The presence of abundant plant and animal species in the Ślęża Massif, the three established nature reserves, and the other nature protection forms were the primary reasons for the establishment of the Ślęża Landscape Park in that region. Currently, the total area covered by legal protection is 15,640 ha, of which the landscape park, along with the nature reserves, covers 8190 ha, while the buffer zone is 7450 ha. The area was included in the Natura 2000 network, establishing two special areas of conservation (SACs): The Ślęża Massif (PLH020040) and the Kiełczyn Hills (PLH020021).

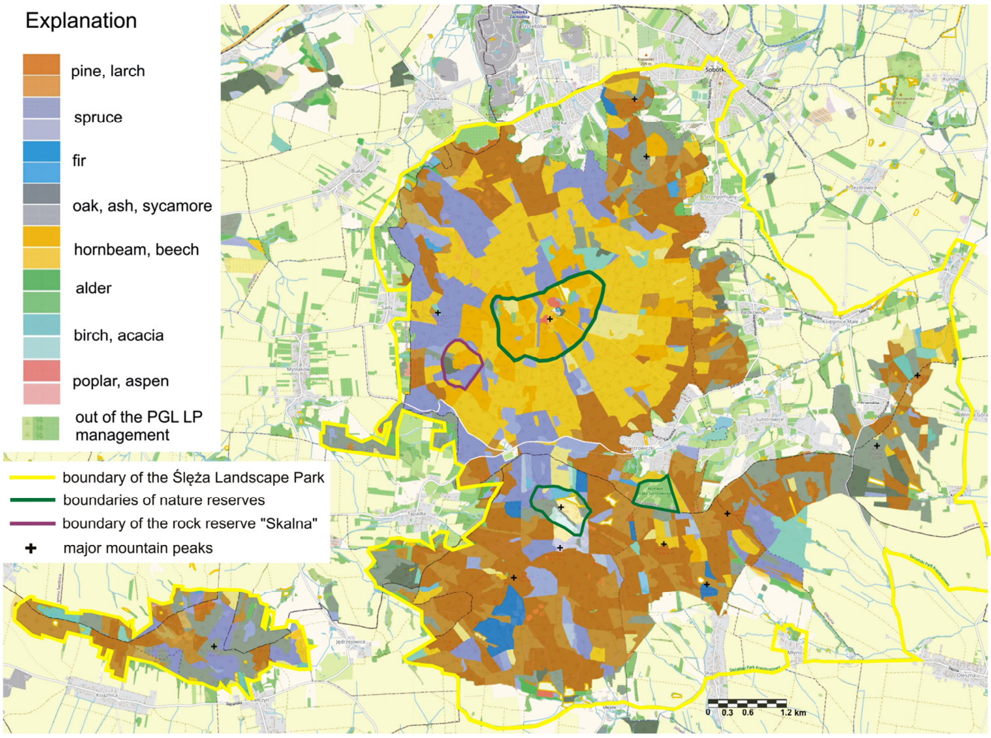


Figure 3. A simplified map of the Ślęża forests presenting dominant species in the stands (light color—younger; dark color—older) [70].

4. Research Results—Characteristics of Selected Workings

At present, the former workings varying in size and preservation status, scattered in forests throughout the massif, are not utilized. Most frequently, they are covered by vegetation or even developed stands; however, their character and location on mountain slopes considerably hinder or prevent cost-effective forest management. While some of them are covered by legal protection due to the presence of rare plant species, they still perform no functions.

The analyses of cartographic materials, particularly LiDAR images, showed the presence of many remnants of open-pit mining activity. These objects include small quarries, smaller open pits, and fields of very small, shallow workings related to the historically oldest mineral extraction operations (Figure 4). Among the forest mining workings, it was decided to select several exceeding 1000 m^2 in area, having distinct relief features and clearly visible in the local topography. It was assumed that these sites may be attractive and suitable for tourism. In order to verify this thesis, survey field works were conducted. Besides this, the digital elevation model analysis supported the identification of the quarries' physical features.

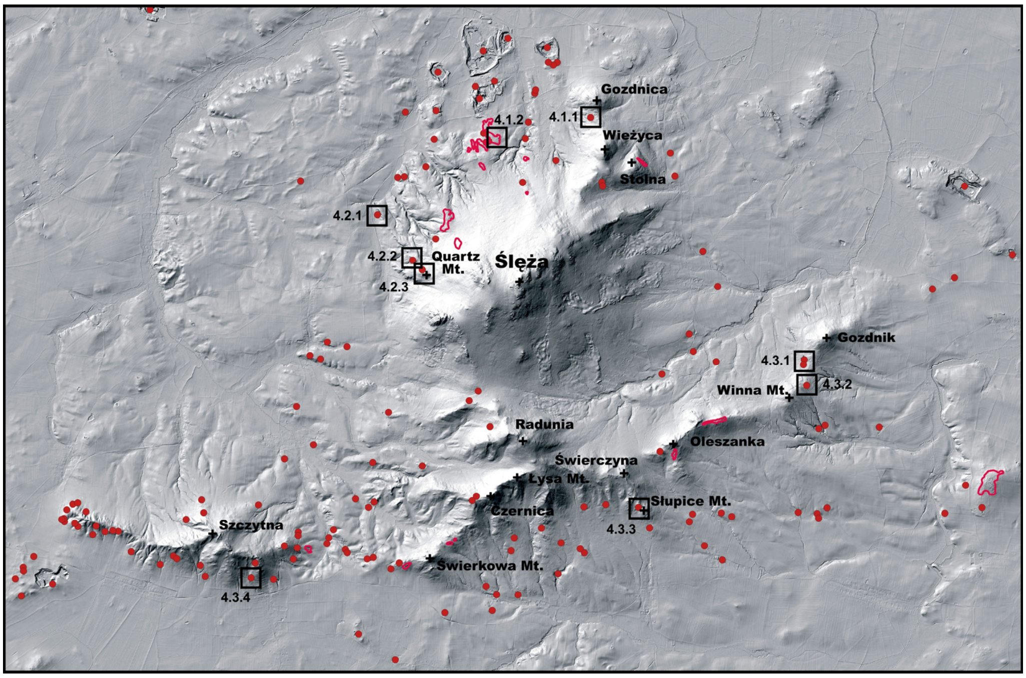


Figure 4. Location of remnants of mining activity in the Ślęża Massif identified based on topographic maps (1:10,000) and primarily the digital elevation model (LiDAR). Red dots show individual workings, while areas outlined with a violet line show mining areas (probably historically the oldest) with serial shallow pit mines. Quarries described in the text are marked with black squares and the number corresponding to the subsections with the description.

4.1. Granite Quarries

4.1.1. "Prehistoric" Quarry

The "prehistoric" quarry, where, in its prime, light-colored granite was excavated, is located at the western extension of the pass between the mountains Gozdnica and Wieżyca, near a tourist hostel, and at an important junction of tourist trails within the Ślęża Massif. The quarry is accessible by an asphalt road from the Górka district of Sobótka or a path directly from the tourist hostel (Figure 5). The quarry has not been managed since the 1980s, and as a consequence, its interior has been overgrown by primarily pioneer vegetation in the course of its natural succession. The mining area covers approx. 4300 m^2. The eastern, highest working face is from approx. 10.0 m to 12.0 m in height, the northern is 5.5 m up to 9.0 m, and the southern is from 5.0 m to 10.0 m in height. The working faces are steep, almost vertical. The exposed rocks are considerably weathered. Access to the working faces is hindered, particularly during the vegetation season, due to the intensively growing vegetation of shrub and forest floor layers.

The working edges are overgrown primarily by pines. The most magnificent specimens reach the age of 118 years, with a trunk diameter at breast height (DBH) of 41 cm and tree height of 18 m. Pine is accompanied here by sessile oak (Figure 6) and, to a lesser extent, also with larch. A greater variety of tree and shrub species is found in the shaded, moist quarry interior. The tree species include pine, sycamore maple, European rowan trees, silver birch, common beech, aspen, white willow, wild cherry, cherry plum, bay willow, and goat willow. The shrub vegetation includes hazel, black elder, cotoneaster, European spindle, and shrubs of silver birch and European rowan. In places, the quarry edges are also overgrown with common heather and bilberry. Trees growing inside the working are young, aged approx. 20 years, while the area surrounding the working is covered by a much older forest with a predominance of Scots pine, European larch, common beech, and sessile oak, sometimes aged more than 150 years.

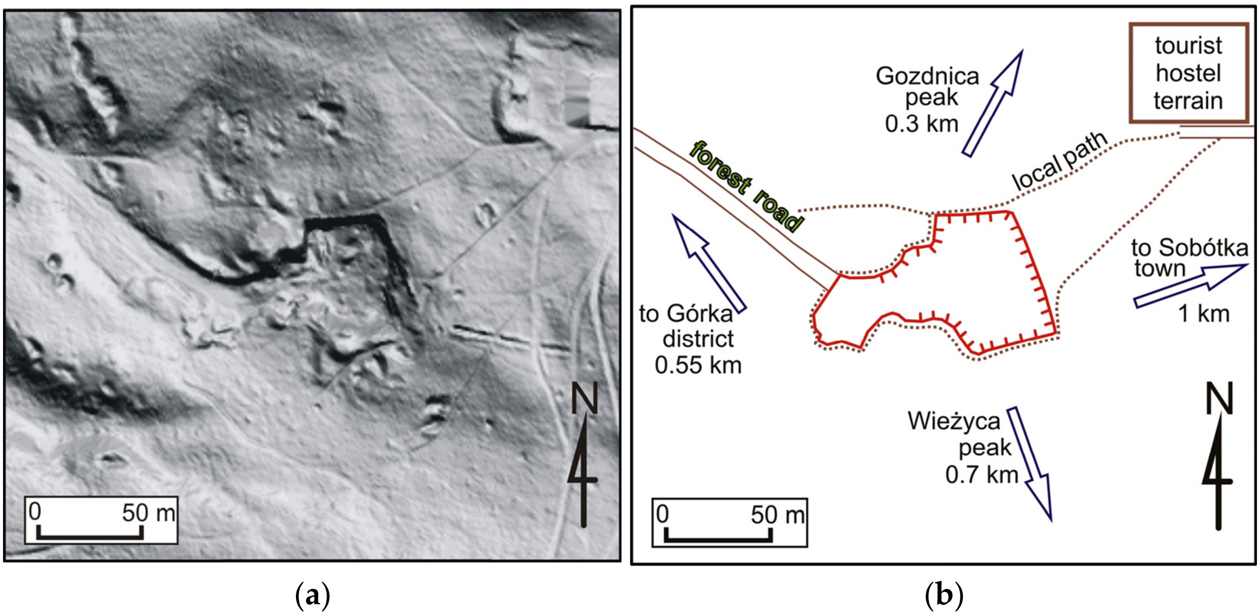


Figure 5. The DEM of the "prehistoric" quarry, with a clearly marked shape of the excavation (**a**) and a site map (**b**).

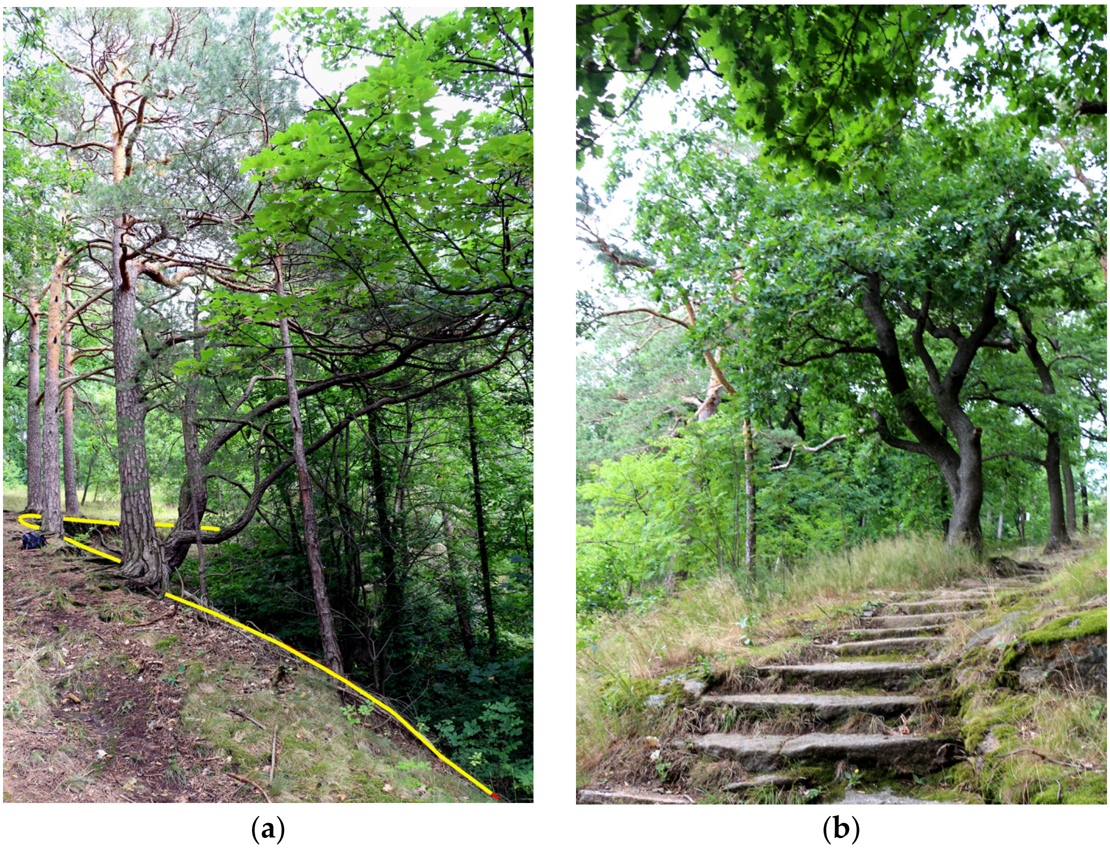


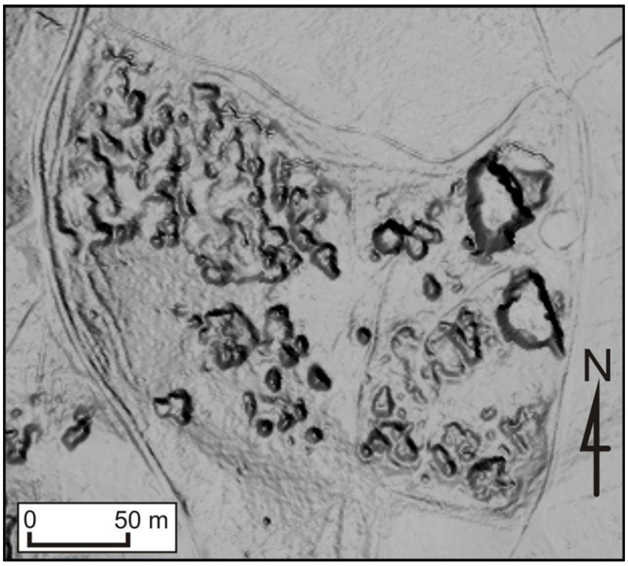
Figure 6. The northern edge of the prehistoric quarry overgrown with pines and the interior with dense shrub vegetation and young beeches visible in the background (**a**); remnants of former quarry infrastructure—steps leading from the tourist hostel to the working surrounded by scenic oaks and pines (**b**).

After the rock extraction had ceased, the local community used the site as an amphitheater, a venue for various performances, events, and social gatherings. The organization of such events was facilitated by the nature of the working with its vertical former working faces, assuring good acoustic conditions.

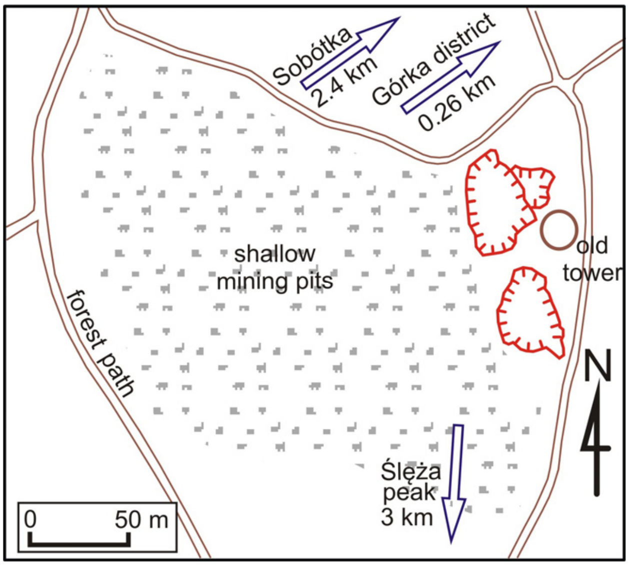
This quarry, characterized by considerable landscape value and an advantageous location, is presently abandoned and derelict, with remnants of the former amphitheater and former mining plant office turning into ruins.

4.1.2. Small Quarries in Sobótka-Górka

Two small granite quarries are located in the northern part of the study area, near a crucial municipal road leading to Sobótka (Figure 7). These are the two deepest excavations in this portion of the study area, used most likely until the last century (as in the case of quarry 4.1.1.), as evidenced by the evident relief and depth of the excavations. They are surrounded by numerous, irregularly arranged, small, and shallow depressions (dug pits), which are most likely traces of older mining (Figure 7). In both quarries, with areas of 1110 and 1485 m^2, the former longwalls, with a maximum height of approx. 5 m, are still quite steep in places; heavily weathered rocks are exposed in almost vertical sections, with a clearly visible fracture system (Figure 7). However, the excavations' walls are usually covered with scree, clay, soil, and a layer of litter. The forest stand in this area consists predominantly of pine; in many cases, the trees are mature and impressive, with DBH 25–54 cm. There is also a significant representation of old oaks (DBH 26–76 cm); beeches and spruces are also present. The undergrowth vegetation, at present, does not preclude penetration of the excavations. Both quarries are closed spaces filled with water, constituting small natural retention reservoirs, valuable in this area struggling with the problem of long-term drought. The water surface is entirely covered with duckweed *Lemna minor* L., which gives a positive visual effect of the water surface with a bright emerald color.



(a)



(b)

Figure 7. *Cont.*

(c)

(d)

Figure 7. DEM of the mining area in Górka with well-seen boundaries of the two main excavations and traces of shallower, historical exploitation (**a**), site map (**b**), the photographs showing the current state of the excavations with prominent rock outcrops, and a water reservoir and natural plant succession, which currently do not interfere with the exploration of the area (**c**,**d**).

4.2. Quartz Quarries

4.2.1. "White Cows" Quarry

The former quartz quarry, locally named "White Cows", is located at the provincial road between the towns of Biała and Sady, at the western edge of the Ślęża Massif. The name of the quarry probably originates from the white quartz outcropping on the site. The mine working was established to extract the material from several dozen meters thick quartz vein. The presence of a series of small rock groupings marks the quartz outcrops. The discussed site is topographically the lowest and the most northern quartz working and most accessible directly from the public road in its immediate vicinity. The quartz deposits both in this working and in several others, located slightly higher at the Ślęża slope, were exploited in the 1970s by the enterprise "Quartz Mines near Sady". The area of the White Cows quarry consists of several workings and rock material heaps, while this paper presents two main workings (Figure 8) of 1716 m^2 (the northern part) and 3600 m^2 (the southern part). We may observe several generations of white quartz in the steep slopes and rock faces. The quarry area is scattered with heaps several meters in height and steep-walled workings several meters in depth. The main rock face, extending several dozen meters along the workings, is over 10.0 m in height, reaching as much as 14.0 m from the bottom.

A forest with a dense shrub layer covers the entire quarry. The forest site type identified in that area is a managed mesic upland mixed broadleaf forest. In the northern part, common oak and ash aged approx. 60 years had the dominant share in the stand. The average DBH was 26 cm at a tree height of 21 m. Moreover, apart from these two species, there are also single specimens of European hornbeam, small-leaved lime aged approx. 60 years, locally black alder and aspen aged 30 years. In the southern part of the mined area, aspen is the dominant species, at a share of approx. 90%, age of 35 years, DBH of 16 cm, and tree height of 16 m. Other species include oak aged 55 years at a share of 10%

and single specimens of silver birch, while in places, there is also black locust aged 20 years, with a DBH of 13 cm and height of 11 m.

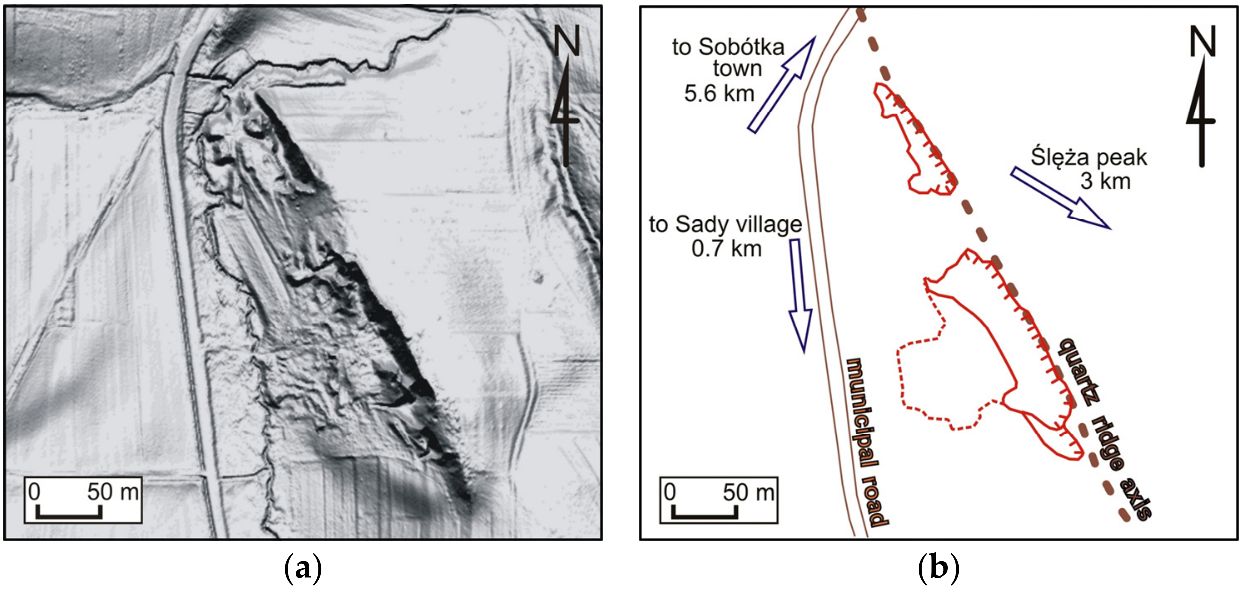


Figure 8. Digital Elevation Model (**a**) and site map (**b**) of the "White Cows" quartz quarry. The division of the excavation (northern and southern parts) is visible.

Other tree species growing in the area include Norway maple, white willow, wild service tree, Scots pine, and sweet cherry. In the shrub layer, the recorded species include hazel, European spindle, alder buckthorn, and rarely large-sepalled hawthorn, whereas lily of the valley is found in the forest floor cover.

4.2.2. Quartz Quarry near Sady Village

This old quartz working is located on the western slope of Ślęża, in the forest, above the Sady village. The excavation is small in size (approx. 1300 m^2), but, at the same time, it is cut deep into the quartz outcrop. The main quarry face and the steep face of the quartz outcrop above it form a bluff with a total height exceeding 30 m (Figure 9).

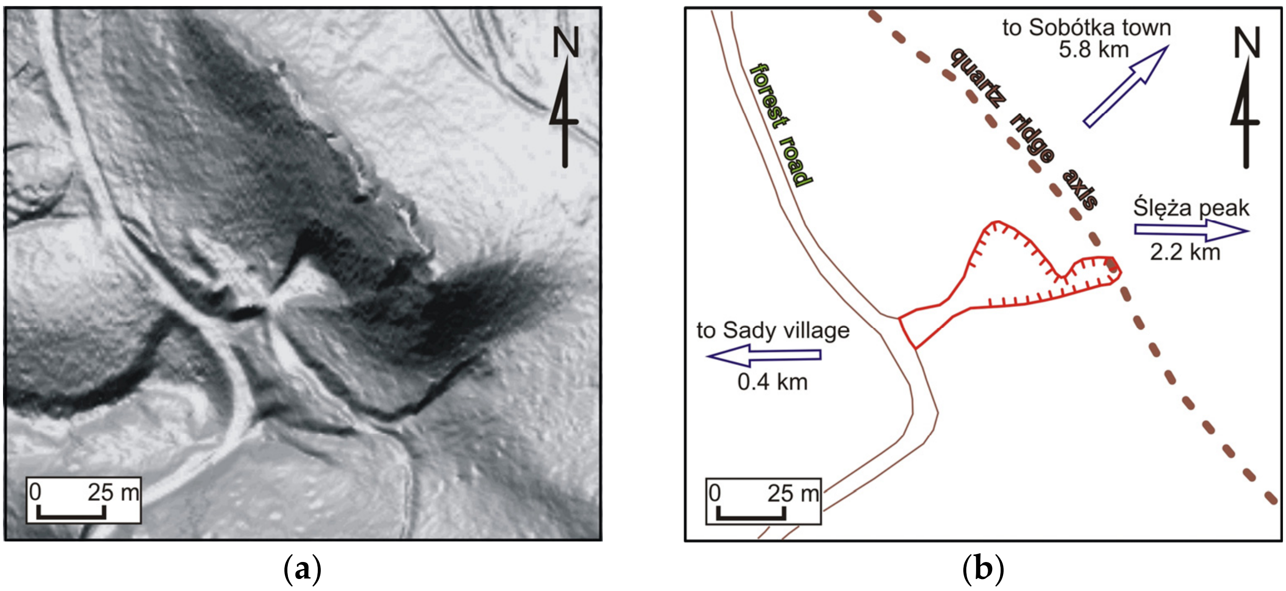


Figure 9. Digital Elevation Model (**a**) and site map (**b**) of the quartz quarry near the Sady settlement on the western slope of the Ślęża Mountain.

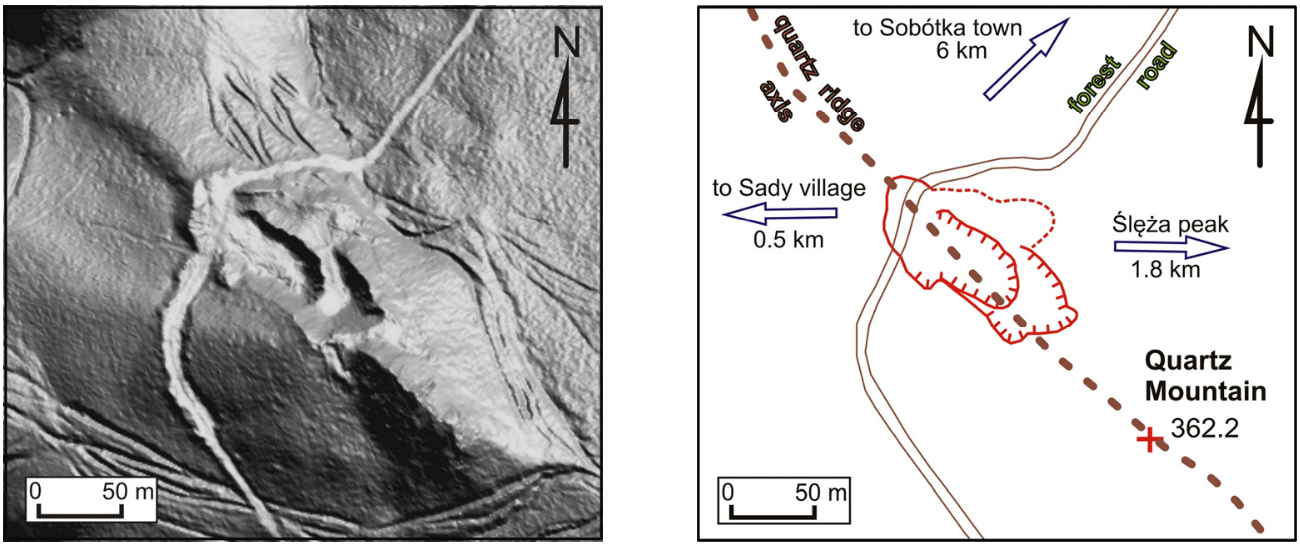
A forest road extends below the quarry and the rock cliffs, serving as a route for a hiking tourist trail marked as the black trail. The trail follows forest roads and goes around the entire mountain of Ślęża. Another trail marked in green has been established nearby, and above it, along small rocks, is another unmarked path, which tourists frequently use as well. The quarry is almost entirely overgrown by the forest, resulting from natural succession. Pioneer tree species and blackberry shrubs cover the interior of the quarry. Only the steepest, highest parts of rock walls are exposed.

The mine working is covered by a stand with a mean age of 53 years, with three dominant species: silver birch with a DBH of 28 cm and height of 19 m, aspen with a DBH of 30 cm and height of 20 m, and oak with a DBH of 18 cm and height of 13 m.

4.2.3. Quarry on the Quartz Mountain

The last excavation within the quartz vein is topographically located at the highest position (320–347 m.a.s.l.), near the top of the local peak of Quartz Mountain. The working area is approx. 4265 m^2 in area, with a maximum length of 117 m and a width of 45 m. It is characterized by the most outstanding landscape value among the quartz workings of the Ślęża slope (Figure 10). There are two working floors, with easy access to the bottom level with a flat floor and access to the quartz exposure of approx. 10 m in height. The upper floor, which may serve as a viewing platform, is a flat, broad ledge with access to the top part of the outcropping quartz vein, where another working face was cut with an approximate height of 10–15 m.

The bottom level of the quarry is covered by a sparse stand, with the dominant Scots pine and European larch and a small admixture of beech and birch. At the bottom floor, trees of the dominant species have a DBH of 26 cm and a height of 21–23 m. The age of the stand is uniform, approx. 70 years, while the top working floor is dominated by a much younger pine stand (approx. 15–20 years), relatively dense in places but tending to die back due to the small thickness of the soil formed over a rock substratum, exposed only recently (several decades ago). At the top level, there are also scarce older aspen and pine trees, but, in many cases, they show limited tolerance to weather conditions (wind and drought) and are often damaged or uprooted (windthrows). For this reason, a relatively large quantity of woody debris is deposited on the top working floor. At this top level, traces of campfires may be seen, indicating that it has been visited by tourists not only exploring the area but also using it for leisure activities, which may not be considered desirable in this site.



(**a**) (**b**)

Figure 10. *Cont.*

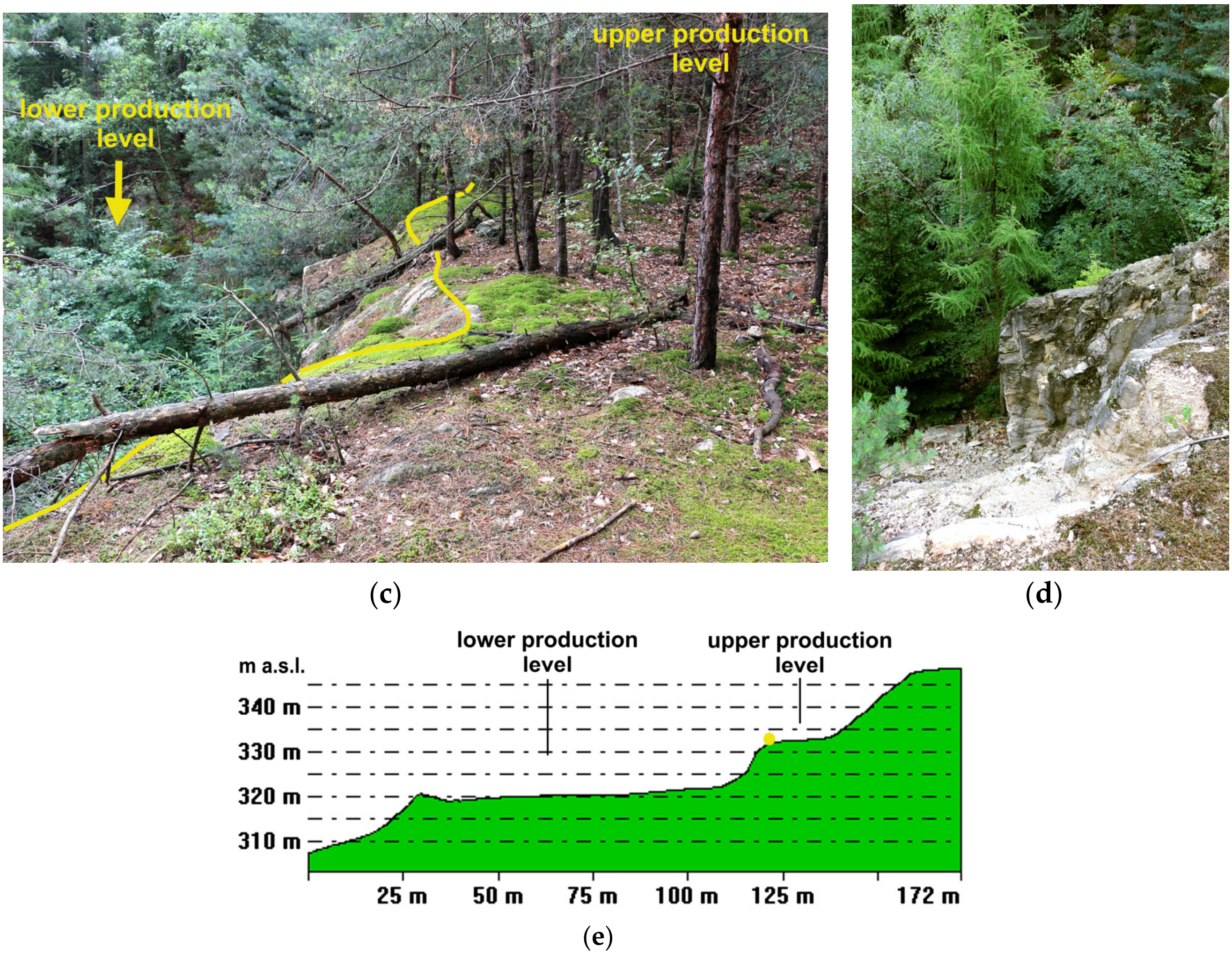


Figure 10. Quartz quarry at the top of Quartz Mt.: Digital Elevation Model (**a**) and site map (**b**); a photograph showing a significant natural expansion of vegetation on both exploitation levels, where the yellow line marks the edge of the upper level (**c**); a photograph showing white quartz outcropping in a quarry wall (**d**); longitudinal morphological profile of the quarry generated based on the Digital Elevation Model (**e**).

The natural succession of plants is spreading in the quarry, overgrowing with increasing density in both the central parts and slopes of each working floor. However, the rock outcrops and quartz debris deposited in places in small waste heaps are still visible; the steep and, in places, vertical walls of whitish quartz are remarkably splendid, enriching the visual landscape values and making the landscape more attractive to tourists.

4.3. Quarries of the Serpentinite Zone

4.3.1. Quarry in Przemiłów

The quarry in Przemiłów occupies approx. 3975 m^2. It is located in the eastern part of the serpentinite massif, in the boundary zone between the settlement of Przemiłów and the forest. The larger, southern part of the working is an open, treeless space, where the terrain slopes towards SW, with periodically stagnating water. The northern part has a diverse topography and is densely covered by trees (mainly Scots pine and oak, with a DBH of 35–40 cm and height of approx. 13 m) and shrub vegetation. The serpentinite rock in former working faces is still well exposed, and we may observe an interesting but partly weathered chrysotile mineralization. The main quarry wall face, extending approximately along the N-S axis, is max. 8 m in height (Figure 11). A rare spleenwort flora was reported within the serpentinite outcrops, characterized by cracks, fissures, and surface irregularities. As a result, the quarry in Przemiłów is covered by legal protection as one of the ten ecological areas located in the serpentinite massif south of Ślęża. The quarry is situated near the main road in Przemiłów, in the vicinity (approx. 700 m) of the next interesting mine working, and in the forested area on Winna Mountain (see Figures 4 and 10 for location).

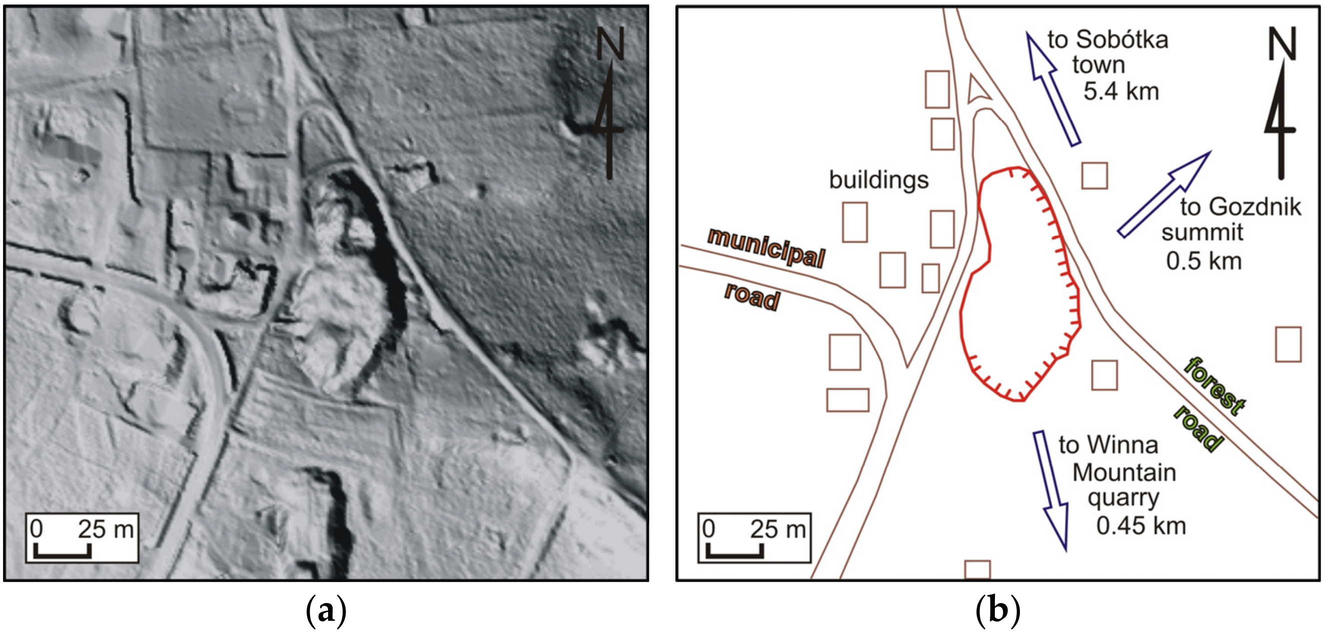


Figure 11. Digital Elevation Model (**a**) and site map (**b**) of the serpentinite quarry in Przemiłów.

4.3.2. Quarry on Winna Góra

The quarry on Winna Mountain, in which serpentinite was extracted in the past, is characterized by a distinct relief, vertical walls forming the working, and two working floors (Figure 12). The upper floor was abandoned at the initial stage of rock extraction and thus is small in surface area; nevertheless, it provides access to the rock in the serpentinite walls of relatively small height (approx. 2 m). The area of the lower working floor is currently overgrown with the tree stand along with pretty dense shrub vegetation; as a result, access to the working faces and examination of their structure are hampered. The faces of the bottom working floor are 3–7.5 m in height, and the entire working is 2950 m^2 in area. Scots pine is the dominant species in the stand of the working floor bottom, and it also grows densely at the edges and the immediate surroundings of the quarry. Additionally, oak, European larch, and common ash are found in large numbers, while spruce, birch, and European rowan are found rather occasionally. The stand's age is approximately 60 years, while tree height and diameter at breast height fall within the ranges of 16–20 m and 18–24 cm, respectively. Many younger specimens are also found, which shows substantial plant expansion in that site. Common hazel and sloe (blackthorn) are numerously represented in the dense shrub layer. The quarry is legally protected as a locality of rare species from the genus Asplenium. Similarly, as in the Przemiłów quarry, the so-called ecological area was established there. Strongly fissured and weathered serpentinites, with numerous surface irregularities, rock cavities, and ledges, stimulate colonization of the quarry faces by rupestrian vegetation, including, e.g., serpentine spleenwort *Asplenium cuneifolinum.*

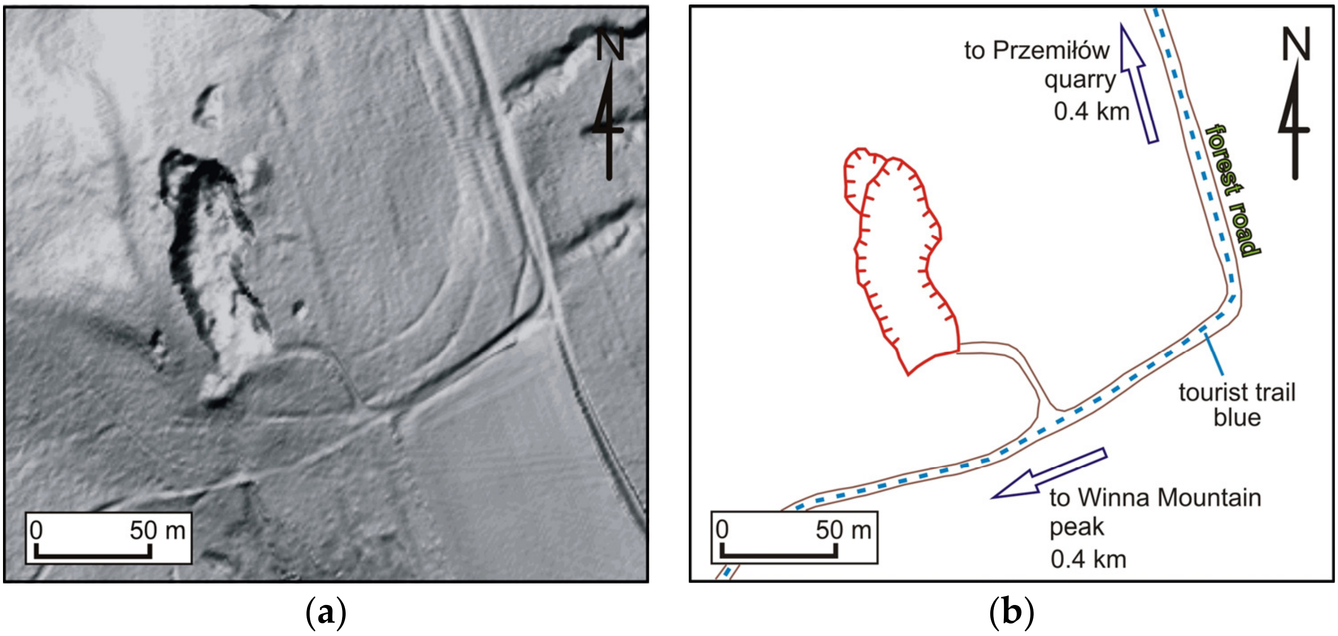
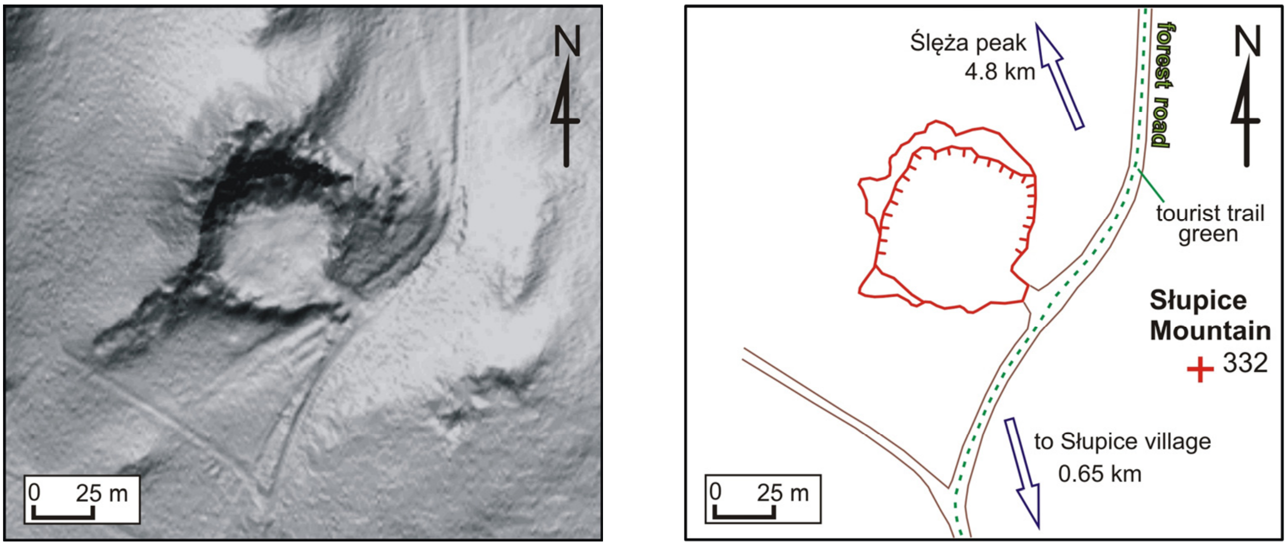


Figure 12. Digital Elevation Model (**a**) and site map (**b**) of the serpentinite quarry on Winna Mountain.

4.3.3. The Słupice Mountain Quarry

The main excavation at the slope of Słupice Mountain, where serpentinite was extracted until the late 1960s, is characterized by a regular, almost square, shape (Figure 13). The working face located in the northern part of the quarry reaches a maximum height of 17 m; it is not a uniform, vertical intact body of rock but a cliff of an irregular morphological profile and a gentle slope of approx. 45°. The serpentinite surface, in places free from vegetation, shows traces of strong weathering with numerous fissures; the relatively flat quarry bottom is scattered with blocks of serpentinite, probably loosened before extraction operations were discontinued. The quarry of 4400 m^2 is not covered by forest; there are sparse trees, mainly Scots pine and black locust aged 60 and 50 years, respectively. Their heights are 11 and 15 m, and the DBH is 25 and 18 cm, respectively. The leveled bottom of the working is covered mainly by grass vegetation. At the same time, at the edges, expansion of the shrub layer is observed, encroaching as dense vegetation mainly on the rock faces, particularly in zones of less steep slopes. Young specimens of black locust are vastly predominant, while common pear is also found along with occasionally present oaks and sycamore maple. The working is another ecological area established to protect the localities of spleenworts (Asplenium), mainly serpentine spleenwort. Inside the working, some traces of campfires are found, indicating frequent tourist visits, which is understandable since the quarry's location is marked on the commonly available tourist map and the entrance to the quarry is situated on a tourist trail.

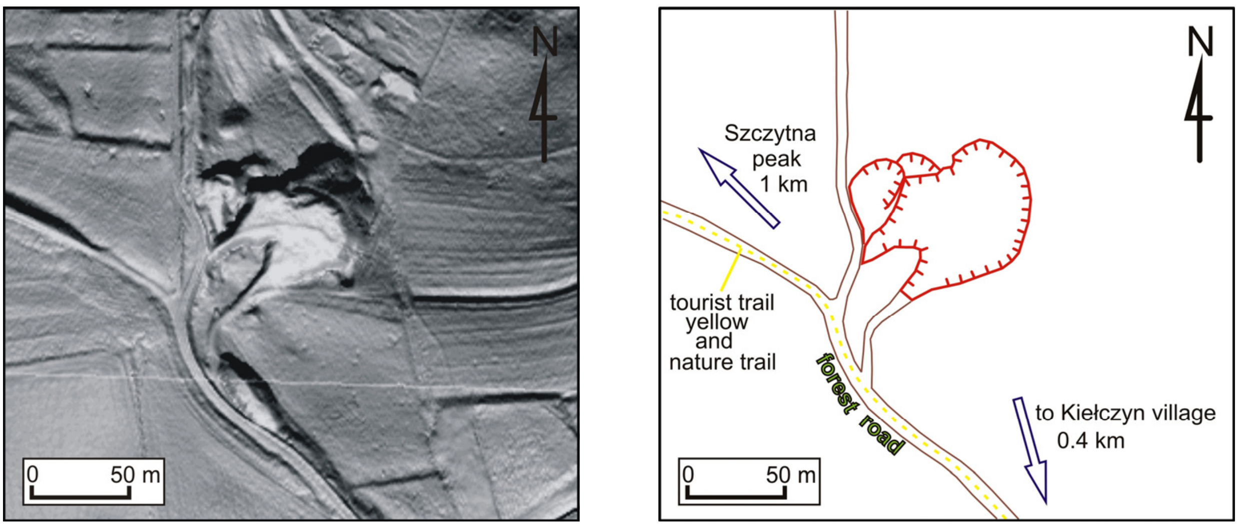


(**a**) (**b**)

Figure 13. Digital Elevation Model (**a**) and site map (**b**) of the serpentinite quarry on Słupice Mountain.

4.3.4. The Quarry in Kiełczyn

In the Kiełczyn Hills, there are over a dozen sites of former serpentinite extraction, all characterized by small dimensions, where several spleenwort protection localities have been established. Currently, the excavations are primarily overgrown by forests. One of the most extensive workings with an interesting and distinct relief is the quarry approx. 0.4 km north of the junction of the main roads in the town of Kiełczyn (Figure 14). Consequently, the mine working is easily accessible, although the entrance to the quarry from a forest path is not visible because of dense vegetation. The working interior is vast (5070 m^2), composed of two working floors: the bottom floor is relatively leveled, while the upper floor, located in the north-western part of the working, is much smaller in area, more irregular, and poorly distinguished. The main quarry face reaches 17 m in height, and it is the wall with the smallest slope angle, covered partly by debris left after former mining operations. The side walls of the working are not so high but steeper and, in places, almost vertical. The serpentinite rock is not very well exposed; the uncovered surfaces are strongly weathered and fissured in places covered with rock debris and vegetation.



(**a**) (**b**)

Figure 14. Digital Elevation Model (**a**) and site map (**b**) of the serpentinite quarry in Kiełczyn.

The entire interior of the working is intensely shaded due to the well-developed stand aged approx. 80 years and a dense shrub layer. The dominant tree species is sycamore maple, accompanied by black locust, oak, Scots pine, and small-leaved lime. Trees have DBHs of 20–35 cm and a maximum height of 24 m. The shrub layer comprises common hazel, rowan, and black locust. The area is densely colonized by abundant common ivy (*Hedera helix* L.), forming a dense cover on the bottom and climbing over trunks and branches of all trees up to several, even more than a dozen, meters. The ever-present patches and vines of dark-green ivy leaves further emphasize the gloomy character of that site.

4.4. Summary of Qualities Beneficial for Tourism

The conducted nature inventory covered both elements of the geoenvironment and selected elements of the forest environment. The inventoried quarries were evaluated in terms of the possibility of making them available to the public to a broader extent than they have been so far, mainly for tourist purposes. Table 1 presents a summary of the physical features of the studied quarries. Table 2 shows the criteria for evaluating these sites' most important qualities and the assessment results for each criterion. This analysis shows that three sites received a high rating (≥80%), and these sites should first be considered in site management plans in the context of realizing the social functions of the forest. Thus, the results of such an assessment of the tourism potential of abandoned quarries in forests may have a very practical effect. The evaluation results will facilitate decision making, the targeting of funds, and organizational activities for those objects whose provision for recreational and tourist purposes is potentially most beneficial.

Table 1. Physical traits of selected abandoned quarries located within the forests of the Ślęża Massif.

Quarry Traits	The Site								
	Prehistoric	Górka [1]	"White Cows" [1]	Sady	Quartz Mountain [2]	Przemiłów	Winna Mountain [2]	Słupice Mountain	Kiełczyn [2]
	No. in the Text and Figure 4								
	4.1.1.	4.1.2.	4.2.1.	4.2.2.	4.2.3.	4.3.1.	4.3.2.	4.3.3.	4.3.4.
Excavation area (m^2)	3800	1485 (N) 1110 (S)	1700 (N), 3800 (S)	1300	4450	3865	2950	4400	4700
Excavation perimeter (m)	316	170 (N) 135 (S)	375 (N) 475 (S)	205	300	263	250	255	325
Maximum length (m)	93	57 (N) 50 (S)	100 (N) 165 (S)	58	117	106	98	64	80
Maximum width (m)	65	33 (N) 33 (S)	28 (N) 38 (S)	34	47	52	36	62	72
Number of quarry faces, orientation	3: N, S, E	4: NE, SE, W, NW 3: NE, SW, NW	1: NE	3: NE, NW, S	3: NE, SE, SW	3: NE, SE, SW	3: W, N, E	3: W, N, E	3: NW, NE, SE
Maximum height of rock faces (m)	12	5,5 (N) 4,8 (S)	14 (N) 14 (S)	20–30	10 (L) 15 (U)	8	7.5 (L) 2.5 (U)	17 (L) 2.6 (U)	17
Tilt of the faces	35–60°	29–69° (N) 13–51° (S)	36–44° (N) 35–55° (S)	33–58°	45–65 (L) 35–38 (U)	18–53°	30–59 (L) 24–46 (U)	31–43	28–48 (L) 21–36 (U)
Number of production levels	1	1	1	1	2	1	2	1	2
Elevation range (m.a.s.l.)	252–276	226–234	203–233	268–306	319–347	245–255	290–299	323–348	316–337
Position on the slope	W	N	SW	SW	NW	W	E	S	SW

[1] northern (N) and southern (S) excavations. [2] lower (L) and upper (U) exploitation levels.

Table 2. The results of evaluating the suitability of the Ślęża quarries for tourist activity, especially ecotourist.

Criteria for Evaluating Suitability for Tourist Use	Points-Based Assessment								
	Prehistoric	**Górka**	**"White Cows"**	**Sady**	**Quartz Mountain**	**Przemiłów**	**Winna Mountain**	**Słupice Mountain**	**Kiełczyn**
	No. in the Text and Figure 4								
	Section 4.1.1.	**Section 4.1.2.**	**Section 4.2.1.**	**Section 4.2.2.**	**Section 4.2.3.**	**Section 4.3.1.**	**Section 4.3.2.**	**Section 4.3.3.**	**Section 4.3.4.**
Interesting shape of working, interesting surface topography, and presence of working floors 1—less impressive, 2—moderately impressive, 3—impressive	2	2	2	1	3	2	3	2	2
Height of rock faces and steepness—visual effect 1—less impressive, 2—moderately impressive, 3—impressive	3	1	2	3	3	1	3	1	2
State of preservation of rock faces and accessibility for direct geological observation (ability to observe mineralization, petrographic, tectonic features of the rock, degree of weathering, presence of debris, and screes) 1—bad, 2—moderate, 3—good	1	2	1	3	3	3	2	2	1
Exposure/visibility of rock faces—degree of their overgrowth with vegetation 1—bad, 2—moderate, 3—good	2	2	1	2	2	3	2	2	2
Status of expansion of natural plant succession within the excavation 1—dense cover of uncontrolled vegetation, significantly hindering the penetration of the excavation; 2—medium dense vegetation cover; 3—vegetation well integrated into the landscape	1	3	1	2	2	3	1	2	1
Presence of invasive plant specie and excessive growth of undesirable species (nettle and brambles) 1—yes, 2—no	1	2	1	2	2	2	1	1	1

Table 2. *Cont.*

Criteria for Evaluating Suitability for Tourist Use	Points-Based Assessment								
	Prehistoric	Górka	"White Cows"	Sady	Quartz Mountain	Przemiłów	Winna Mountain	Słupice Mountain	Kiełczyn
	No. in the Text and Figure 4								
	Section 4.1.1.	Section 4.1.2.	Section 4.2.1.	Section 4.2.2.	Section 4.2.3.	Section 4.3.1.	Section 4.3.2.	Section 4.3.3.	Section 4.3.4.
Presence of surface waters 1—no, 2—yes	1	2	1	1	1	2	1	1	1
Presence of mature/precious stand in the working and presence of trees with impressive development forms 1—no precious/impressive trees; 2—presence of some impressive trees; 3—many old/precious, impressive trees	3	3	1	1	3	2	3	2	2
Instability of steep rock faces—the need for safety measures 1—yes, 2—no	2	2	2	1	2	2	2	2	2
Interesting stand/interesting habitats in the quarry surroundings 1—no, 2—yes	2	2	1	1	2	1	2	2	2
Vicinity of tourist trail 1—far from the trail, 2—short distance from the trail; 3—next to the trail	3	2	1	2	2	3	3	3	3
Accessibility, location near a public road 1—far from the road, 2—short distance from the road, 3—next to the road	3	2	3	2	2	3	1	2	2
Other value (vicinity of other interesting cultural or historical objects, etc. (within the radius of max. 500 m)) 1—no other attractions, 2—one interesting object, 3—several attractions	3	3	1	1	2	1	1	1	3

Table 2. *Cont.*

Criteria for Evaluating Suitability for Tourist Use	Points-Based Assessment								
	Prehistoric	Górka	"White Cows"	Sady	Quartz Mountain	Przemiłów	Winna Mountain	Słupice Mountain	Kiełczyn
	No. in the Text and Figure 4								
	Section 4.1.1.	Section 4.1.2.	Section 4.2.1.	Section 4.2.2.	Section 4.2.3.	Section 4.3.1.	Section 4.3.2.	Section 4.3.3.	Section 4.3.4.
Possibility of placing small infrastructure (bench, shed, footbridge, and educational board) 1—no, 2—yes, but outside only, 3—yes, inside the excavation	3	3	3	2	3	1	1	2	3
Instability of steep rock faces—the need for safety measures 1—yes, 2—no	2	2	2	1	2	2	2	2	2
Final score max. 40 (100%)	**32**	**33**	**23**	**25**	**34**	**31**	**28**	**27**	**29**
	80%	**82.5%**	**57.5%**	**62.5%**	**85%**	**77.5%**	**70%**	**67.5%**	**72.5%**
High score (≥80%)	•	•			•				
Medium score (60–79%)				•		•	•	•	•
Low score (<60%)			•						

5. Discussion

In the sites discussed in this study, integrated actions to preserve and protect both the biotic environment and the geoenvironment should be undertaken while simultaneously ensuring accessibility of the geological sites, such as the former working faces in quarries, so that they may serve some social functions. Although it is a complicated task requiring an individualized approach to each site, it is feasible, especially since an arbitrary aim was already formulated for creating the Ślęża Landscape Park in 1988. In the justification, it was stated that it aims at the preservation of unique and valuable elements of nature, cultural heritage, and the landscape of the Ślęża Massif while providing the development of recreation and tourism consistent with landscape protection [71,72]. In the subsequent legal regulations amending the original act, it is emphasized that diverse nature values need to be protected considering their geological and geomorphological values [73]. The document entitled "The Protection Plan for the Ślęża Landscape Park" [74], which follows the Polish legal regulations, comprises a list of practical actions and recommendations such as:

- Respecting the natural and man-made geological outcrops by abstaining from filling the open-pit workings or collecting rock and mineral samples directly from the rock faces, except for samples collected for scientific purposes;
- Exposing geological value by the removal of shrubs and young trees, mainly self-seeded, if it is consistent with the interests of the protection of animate nature; if necessary, it includes clearing with the removal of biomass;
- The removal of branches after felling from the area adjacent to rocks and quarries, since it leads to the disappearance of thermophilic and rupestral vegetation;
- The gradual limitation of the share of geographically and ecologically alien species and elimination of invasive species, including black locust, red oak *Quercus rubra*, Douglas fir *Pseudotsuga taxifolia*, and black cherry *Padus serotina*,
- The establishment of protection zones for spleenworts, mainly in the area of the Kiełczyn Hills;
- In the case of tourism, it is recommended to first develop the various forms of cognitive tourism: ecotourism, geotourism, and sightseeing-oriented tourism, as well as hiking, cycling, and horse-riding tourism;
- Equipping the tourist trails and educational trails with structural elements for tourist traffic, including gates, display boards, road signs, roofed picnic and rest sites, benches, footbridges, decks, viewing platforms, etc., provided that such measures do not degrade the natural or landscape value;
- The development of a spatial planning report for the park specifying the catalog of architectural solutions complying with the basic types of building constructions and selected structural elements.

The protection plans related to the Natura 2000 program also contain regulations concerning the overgrowing of xerothermic grasslands by the undergrowth of trees and shrubs; changes in the species composition due to excessive natural succession; the presence of expansive and competitive native species; the presence of alien species, particularly black locust; and the excessive shading of sites by the undergrowth of deciduous trees and the mature stand. What is interesting is that these documents indicate the negative consequences of uncontrolled tourist traffic, as well as of vandals plundering plant localities and collecting specimens probably for sale as material for collectors' herbaria and the uncontrolled use of former quarries for recreation, campfires, and waste disposal [75,76]. Among the actions aimed at eliminating threats, an educational element was also added: enhancing knowledge and awareness of the public on the need for species protection, as well as modifications to the course of tourist trails and establishment of build-up infrastructure dedicated to tourist activity.

These recommendations contained in legal acts regarding the Ślęża Landscape Park are perfectly in line with the feasible (and needed) operations for quarries investigated in this study. A severe threat to the natural habitats, especially in zones with the serpentinite substratum, is observed, where the shading of sites and expansion of invasive species are progressing, mainly black locust and small balsam *Impatiens parviflora* as well as brambles [77–80].

Removing undesirable vegetation from the quarries would be advantageous for preserving and exposing rock outcrops and the natural habitats of animate nature that have developed there. Geological outcrops cleared from excessive vegetation will also become attractive for tourists interested in geology (geotourists). Studies on tourists' perception of the landscape attractiveness of quarries showed that quarries considered to be the most interesting and attractive are characterized by a marked topographic variation, distinct relief features, considerable contrasts in relative altitude, satisfactory preservation of quarry faces, limited progression of natural plant succession, general aesthetics of the surroundings, evident uniqueness compared to the adjacent areas, the presence of surface waters, and accessibility, including road infrastructure [81].

Studies of the attractiveness of stands showed that the favorites among tourists are stands of older age classes with a diverse species composition (mixed forests), a clear structure of the forest interior, no dense understory but an abundant ground layer, no swampy places, a well-designed network of roads and walking paths, tourist routes, and the presence of clearings conducive to recreation, with good sun exposure [82–86]. In the perception of both quarries and forests, tourists highly value the varied and picturesque reliefs, water bodies, and interesting natural and cultural objects. All of these attractive landscape elements, being conducive to active recreation, are in the scope of increasingly popular geotourism and ecotourism, which are finding a growing number of supporters around the world [87,88] and are recommended as directions of tourism development appropriate for the Ślęża Massif. The quarries, the beauty of the landscape, and the multitude of attractions in their surroundings meet all of the criteria for developing these lines of tourism. Such conditions allow the simultaneous exploration of geologically interesting sites with their context, cultural interpretation, and education and the enhanced awareness of tourists, thus promoting the preservation of the geological heritage while providing local communities with certain economic benefits based on their geoheritage [89,90]. The man-made outcrops enable obtaining information on the Earth's evolution (i.e., ophiolite rock sequence) and the history of development (i.e., mining heritage), as well as material for research and education [91]. The Ślęża quarries provide a unique chance to examine the rock substratum, typically covered with younger geological deposits, regolith, or vegetation. They also provide an opportunity to directly examine rocks, minerals, geological structures, and traces of various mining methods. In some locations, they facilitate the collection of rock and mineral samples, which, for geotourists, might be crucial [92,93]; however, in areas of nature value and protection such as the Ślęża Massif, it is not desirable [94,95].

The elements of ecotourism also apply here, in terms of the opportunity to observe and promote nature conservation principles, which have an educational aspect, along with the possibility of the active participation of local communities. As summarized by Horvath and Csullog [82], ecotourism is based on the attractiveness of nature and, at the same time, can develop as a market product when a particular aspect of natural heritage is found in a given area. The Ślęża Massif meets these criteria.

It needs to be emphasized that geological outcrops exposing massive rocks, characterized by a distinct relief, are particularly valuable in biotically diverse forest areas since the coexistence of biotic and abiotic elements frequently constitutes exceptionally beautiful and interesting landscape complexes, as may be observed in the Ślęża region. When properly managed, the uniqueness of such sites may be successfully used, benefitting both nature and society.

In the Ślęża Massif mine excavations, their diverse value may be adapted and exposed, requiring relatively small work input. Some sites are appropriate for sports activities or resting places on the tourist trail, while others may be used for nature education. The analyzed quarries may be managed in a variety of ways. Most of them may provide knowledge on minerals, rocks, and geological processes that have shaped the contemporary geoenvironment. An educational geologic trail presenting the ophiolite sequence in several quarries and rock outcrops would be relevant. Forms of protecting and providing access to geologically valuable ophiolite outcrops are in operation in other parts of the world, such as in the Italian geoparks of the Alpine orogenic range: The Beigua Geopark in Liguria [96] and The Monviso Ophiolite Geopark in Piemonte, Italy [97]. The Ślęża ophiolitic trail, equipped with basic infrastructure such as display boards, would include those outcrops where no protection zones have been established for valuable plant species, e.g., the quarry in Kiełczyn (Section 4.3.4), in which tourists could approach the quarry faces and examine their geology at a close range.

In most of the Ślęża quarries, apart from information boards on the biotic environment, protected species, and geology, it would be worthwhile to install basic infrastructure such as benches, wooden shelters, and small fences protecting valuable rupestral vegetation from direct contact with visitors. Some modifications of the trails may be considered so that they lead tourists along the quarry edge zones through viewing points to observe the interior of the workings and the surrounding landscape while preventing the penetration of the quarry interior itself. In the Kiełczyn Hills, an educational trail concerning spleenwort vegetation has already been established. Thus, a certain modification of the existing trail may be introduced to include geological elements, or a new trail may be established.

Some of the quarries have a distinctive topographical relief, such as e.g., the quarry on Quartz Mountain (Section 4.2.3) with its two former working floors. After an appropriate rearrangement of the surroundings, the upper one may be transformed into a viewing platform or a recreation and camping site.

Quarries are inhabited by unique animal species, such as amphibia reported in the Przemiłów quarry (Section 4.3.1). The installed viewing platforms or appropriately designed wooden footbridges may facilitate the observation of the evening activity of bats and other groups of animals.

The White Cows mine workings (Section 4.2.1) are highly problematic for forest management. Due to challenging terrain, much of the area is excluded from timber harvesting. After clearing excessively dense stands and shrubbery and partial leveling, this area may be turned into a parking space, as it is close to the main road. Such an investment would help solve the severe problem of the lack of parking spaces for the cars of tourists who come to the Ślęża region during specific periods of peak tourist activity.

The most obvious concept of the prehistoric quarry (Section 4.1.1) development is to recreate the former amphitheater infrastructure. For this purpose, removing vegetation of little value (shrubs and trees), reconstructing the stage and the audience, and adapting the outdoor infrastructure for concerts and performances are needed. The scenery of the surrounding forests, easy access, the vicinity of the road, and the existing tourist infrastructure are substantial values. Following some adaptation, the quarry could thus serve various functions. This trend should be supported through adequate planning and management of the area. The management strategy for Ślęża quarries should consist of the following significant steps: 1. conducting a comprehensive natural inventory of the quarries (which has been initiated in this work) and preparation of the study reports; 2. conceptualization, in which the most appropriate functions should be assigned to individual quarries from the proposed ones: educational, sports and recreational, culture-promoting, or possibly protective or scientific (where tourist traffic is not advisable); 3. the preparation of design documentation and work plan; and 4. the implementation of adaptation works to the new functions. For efficient operation, an interdisciplinary team should be set up, composed of representatives of stakeholders, such as the forest district, local government, local entrepreneurs, archaeologists, and tourist organizations, which would manage all activities, including the provision of financing.

6. Conclusions

Adapting abandoned quarries to different forms of tourist activity, a new approach is suggested to combine forestry, geological, and geomorphological aspects in assessing landscapes and cognitive values for suitability for tourism. A multifaceted operation is proposed instead of a unilateral consideration of a single natural element, which further implies the cooperation of experts from several fields to restore the suitability of former excavations for society.

Abandoned quarries can serve social functions: they can popularize science, protect geoheritage and geodiversity, promote culture and, at the same time, be used to promote ecotourism through well-conceived land development. Thus, considering the quarry issues more broadly as environmentally and socially valuable assets that can be useful for sustainable tourism development is essential.

To perform their new functions, the quarries need to be protected from overgrowing with undesirable vegetation and kept accessible to those interested. On the other hand, some quarries have a very compelling plant cover. Due to the unique topography, geology, hydrology, and specific growth conditions, the individual groups of plants need to adapt accordingly. It is particularly evident in the trees growing on the slopes of the quarries. The richness of species and picturesque forms resulting from the adaptation is a significant landscape value.

One of the main elements of the proposed quarry site management strategy is a detailed inventory of the objects, which will later be used to develop specific design documentation. The inventory initiated in this work should be supplemented with more details, such as the geological values of the quarries and their engineering and environmental condition, mainly concerning the side walls, floors, and dumps in each quarry.

The degree of weathering of the quarry walls should be investigated. The spread and depths of the fracture systems should be thoroughly checked to obtain information for safety purposes and to protect potential visitors and the infrastructure possibly sited there from rock fragments falling. So far, environmental studies of quarry bottoms and heaps have also yet to be undertaken. These elements of the quarries now provide a substrate for the forest vegetation, which is an interesting scientific aspect. It would be useful to study the chemical composition of the soils and sediments found in these anthropogenically transformed areas and how the vegetation adapts to such altered conditions.

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