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Injuries in the landscape: The Suseni quarry – A case study from Transylvania, Romania

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Abstract: Mining and quarrying operations exert a substantial influence on both the environment and nearby communities. Plenty of them can be found in mountainous areas of Transylvania. These activities, which involve the excavation of expansive open pits and the disruption of soil and vegetation, can lead to adverse consequences such as soil erosion, deforestation, habitat degradation, and water contamination. Mining and quarrying operations carry notable consequences for both the environment and the nearby communities. The interventions of contemporary humans have changed the landscape on an unprecedented scale. The signs of human involvement are apparent in numerous locations in the Giurgeului Depression; the Suseni quarry site is an example of a place that necessitates a comprehensive rehabilitation plan.

Keywords: mining site, rehabilitation, footprints, NBS (nature-based solutions)

1. Introduction

In his book titled *Urban Space*, architect and urban planner Rob Krier writes that: "I have yet to see a tree which looked aesthetically wrong or defective. The same is true for landscape" [1]. While Krier's statement may hold true in natural environments, in human-influenced territories, there are many landscapes that can appear visually unappealing or flawed. Human interventions in contemporary times have significantly altered landscapes, resulting in many "wrong or defective" landscapes that require remedial action. The formation of landscape wounds or scars

resulting from mining or quarrying leaves enduring impacts on the environment and nearby communities. These effects give rise to a variety of ecological issues, including soil erosion, deforestation, habitat loss for both plant and animal species, and potentially leading to water and air pollution.

According to Professor Mihály Mőcsényi, landscape planning is a discipline that seeks to shape the human environment by applying contemporary ecological and technical knowledge as well as aesthetic principles. Its objective is to enhance the productivity, visual appeal, and overall well-being of the landscape. This is achieved by improving the living conditions of human residents, extending their physiological and aesthetic enjoyment of life. [2].

For centuries, humanity has engaged in the manipulation of the Earth's terrain. Well before the introduction of modern construction materials like drywall and plywood, natural caves, pits, abode, and turf were fashioned to provide shelter. Mountainsides were shaped to support agricultural terraces, roads, canals, and mines, enabling people to sustain their livelihoods. These altered landscapes often bear an artificially shaped character, a design form that becomes an indelible part of the surrounding environment. Interestingly, modern mining activities continue to face criticism despite the presence of similar geometric patterns created by other industries and even by nature itself [3]. These patterns etched on and within the landscape are a testament to the ongoing human impact on the Earth's surface, footprints.

Despite the role of mining in providing an economic foundation and a source of natural resources to enhance the quality of human life [3], quarrying operations have generated a wide range of physical and environmental consequences on a global scale over the course of recent decades. In the past 20 years, there has been an increasing recognition of the importance of addressing the rehabilitation and requalification of quarry sites. To be truly effective, such efforts should be closely aligned with the available local resources and context, as evidenced by diverse rehabilitation strategies implemented in various regions around the world [4].

The industrial landscape stands as a distinctive category, broadening our understanding of landscape to encompass locations like production sites, originally devoid of aesthetic intent. Abandoned extraction sites, in particular, form a distinctive landscape where technological heritage and the natural environment intertwine, creating a multifaceted heritage that necessitates innovative methods of preservation and appreciation. The significance of the industrial landscape is linked not only to the emerging aesthetics connected to workplaces but also to the preservation of the place's cultural value [5]. This can be called the "genius loci", saving the atmosphere of the place while the reclamation of the quarry zone is taking place by allocating a different and original function, multiple functions, compatible with current human activities, adequate to our society and its needs, based on the aims of a sustainable development.

The UN World Commission on Environment and Development defined the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [6]. This definition emphasizes the importance of balancing current socio-economic needs with the preservation and responsible use of natural resources to ensure that future generations can also fulfil their own needs.

Nature-based tourism is widely recognized as a rapidly expanding sector within the world's largest industry, and it plays a vital role in supporting conservation efforts. While visitation rates may be declining in certain affluent countries, as evaluated through two different methodologies, data from around three-quarters of nations with available information indicate an overall increase in visits to protected natural areas [7]. This suggests that the trend of visiting protected natural areas is on the rise in many parts of the world, highlighting the significance of nature-based tourism as a contributing factor to conservation.

2. Methodology

The literature review component of the research methodology aims to provide a comprehensive understanding of the subject matter, specifically focusing on mine reclamations, nature preservation, and related aspects. This contextualization helps establishing a foundation for the subsequent analysis. The analysis itself involves a detailed examination of the territory by utilizing map documentation techniques and culminates in the development of a recovery proposal. This proposal aims to maximize the ecological, economic, and social benefits of the territory, ensuring a holistic approach to its restoration and preservation.

The territory requires a comprehensive reclamation concept and landscape rehabilitation plan. The objective of this paper is to analyse the territory and to identify optimal strategies for promoting a more sustainable relationship between humans and nature in the quarry's anthropic environment, with a focus on providing ecological, economic, and social benefits. Nature-based solutions and nature-based tourism must constitute the base of the concept.

3. Case Study

Location

Transylvania, a region in Romania, boasts a rich mining history that traces its origins back to the Roman Empire. Throughout its historical timeline, this area gained renown for its plentiful reservoirs of precious metals such as gold, silver, copper, and various other metallic resources [8]. Today, mining operations primarily focus on extracting salt, coal, and other minerals, with quarries being

a common sight. These open-pit mines, which are used for extracting various types of rock, stone, sand, and gravel, are situated in the mountainous regions of Transylvania.

The Suseni quarry is located in the Giurgeului Depression in Harghita County, Romania, near the settlement of Suseni (*Fig. 1*). It is situated in its administrative area, next to a valuable natural environment [9].

Figure 1. Location of the studied quarry

Historical development

Mining operations in the Suseni quarry began in the late 1930s. Nowadays, after a few changes of ownership, Lafarge, a French mining company operates the Suseni quarry, which is one of the largest and most modern quarries in Romania. In a few years' time, the extraction will end because the area is running out of good-quality stone [9].

Similar quarry areas in the Giurgeului Depression and near-by

Analysing the territory on a larger scale can unveil some important aspects. Traces of human intervention are conspicuous in numerous locations within Transylvania, including the Giurgeului Depression, and the Suseni quarry area is no exception. The map (*Fig. 2*) shows several quarry and mining areas in the Giurgeului Depression and its vicinity.

Such mining areas are the Voslobeni quarry and the Sândominic quarry, which extract dolomite. The Bălani mine was an iron and copper mine until 2006. The Topliţa site is an andesite quarry, and the Gura Haitii quarry was a sulphide exploitation. The Borsec quarry is known for its travertine extraction, and the Bicaz-Chei quarry for limestone. This reveals a diversity of mining material in the mountainous areas of Transylvania.

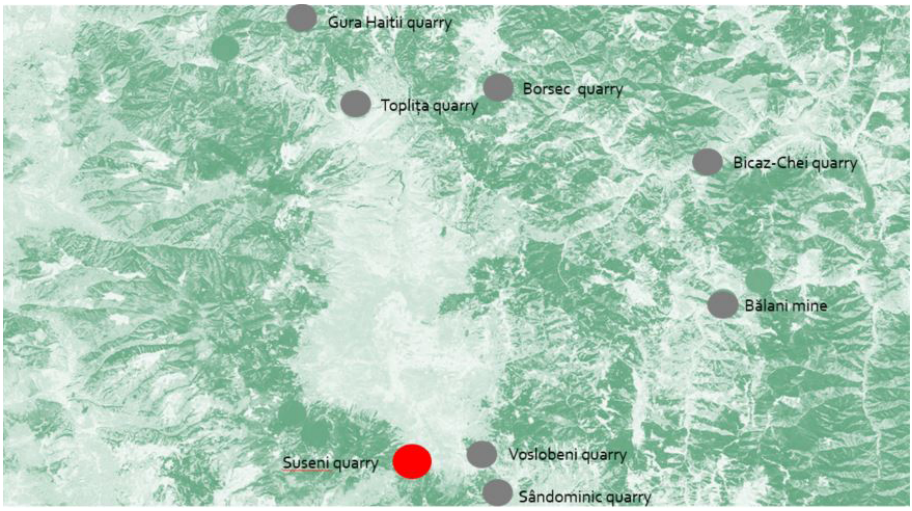

Figure 2. Similar quarry zones near-by

Ecological networks

The protected areas of Natura 2000 [10], as parts of green corridors, constitute the backbone of the European green ecological infrastructure and are located near the studied quarry zone (*Fig. 3*).

Figure 3. Natura 2000 infrastructure in the study area

The territory surrounding the quarry is home to a diverse range of protected and endangered species, underscoring its significant ecological importance. The conservation efforts within this territory are dedicated to preserving the habitats and ensuring the long-term survival of these vulnerable species.

Accessibility

Regarding the quarry's current situation, it can be accessed via County Road 138 and secondary dirt roads. Additionally, there is a railway line that connects in Voşlobeni to the main Ciceu–Deda line. The location of the quarry is thus favourable in many ways. It is situated in a very spectacular location and can be reached via multiple routes, making it a potential tourist destination (*Fig. 4*).

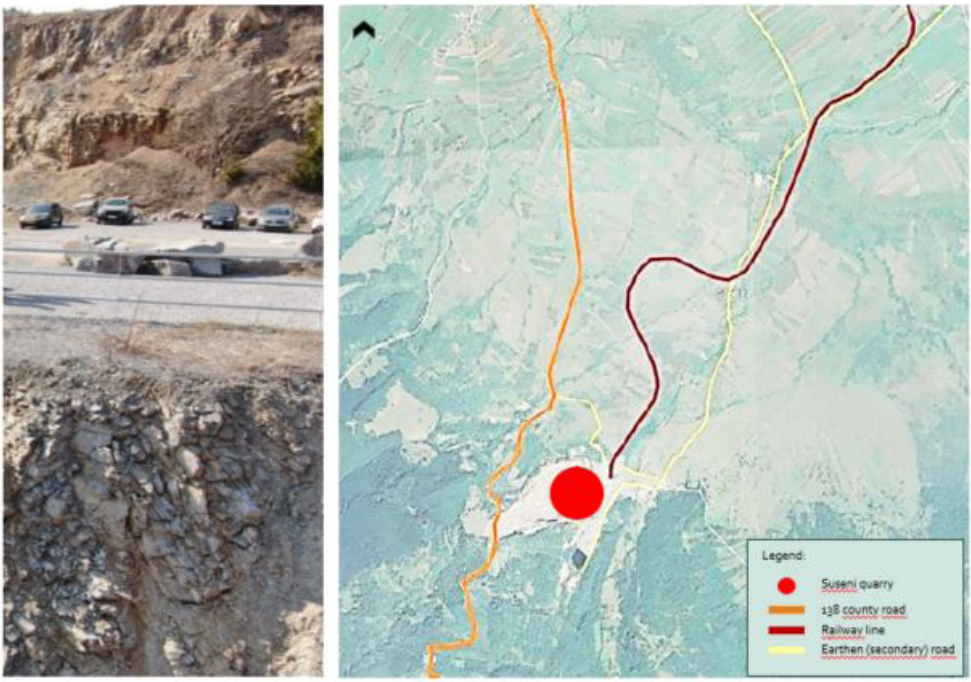

Figure 4. Accessibility analyses

Shape and size

The quarry has an amorphous shape, with approximately 100 hectares of land. Two thirds of the area are occupied by the extraction zone, while the remaining third is used for processing, including loading, transport, and storage (*Fig. 5*). This large area provides ample space for a multitude of activities following rehabilitation.

When studying mining patterns, one can discern elemental shapes and identify potential design possibilities. Barren and harsh landscapes are typically perceived as unappealing unless a distinct and prominent pattern is present [3, 11]. The landscape's character, determined by irregular topography, steep vertical stone

walls, the potential for water features, and a range of microclimates, offers advantages for design and after-use proposals.

Figure 5. Visualization of the shape of the quarry

Material

The material extracted here is hard rock, specifically andesite, which is a volcanic rock formed about 6.5 million years ago (*Fig. 6*) [9]. This is processed using crushing and screening installations. Mining operations have led to surface water loss and soil erosion, exposing a substantial amount of bedrock and greatly impeding the establishment of vegetation.

Figure 6. Extracted material

Pollution analyses

Through the extraction process of the stone, massive air and sound pollution is caused along with significant visual pollution and land pollution in stone quarries. The visual pollution stems from the alteration of natural landscapes, as quarries often result in vast excavations, creating unsightly scars on the surface of the earth. These enormous pits can disrupt the visual harmony of the surrounding environment, replacing scenic vistas with barren, industrialized landscapes.

Additionally, the mining and processing of stone often involve the use of heavy machinery, which can further damage the land. The constant movement of vehicles and equipment contributes to soil compaction and fragmentation, reducing the ability of the land to support vegetation growth. The release of chemicals and contaminants from machinery and processing facilities can also seep into the soil, potentially polluting groundwater and further degrading the quality of the land.

Terrain dynamics

The walls of the pit are almost vertical. Examining the terrain dynamics of the quarry, this has six production levels, and it can be noticed that the area ranges from 800 m above sea level to 920 m, resulting in a difference in elevation of around 120 m, creating a unique landscape (*Fig. 7*).

Figure 7. View of the terrain dynamic

In order to address safety concerns arising from high walls, it is needed to restrict surface reclamation grades from exceeding a 35-degree slope, which is typically the angle of repose for spoil material. Stone quarries possess specific physical characteristics that may necessitate blasting or backfilling to adhere to such regulations, consequently resulting in higher reclamation costs. Moreover, fill material must meet engineering standards to ensure minimal settlings and suitability for future applications [3].

Water elements

There are two water elements on the quarry's territory, a rainwater-accumulating pond (*Fig. 8*) in the middle of the extraction zone and a lake (*Fig. 9*) in the lower part of the territory, which was once used for washing the extracted stone. Those water elements can be integrated in the concept and can be an additional argument for the after-use proposals.

Figure 8. Rainwater accumulation

Figure 9. View from the lake

Flora and fauna

The original soil surface in the mining area has been entirely removed, resulting in the complete destruction of the local ecosystem.

Figure 10. Ruderal plants on the territory of the quarry

Over the past 90 years, quarrying operations have decimated the flora and fauna while giving rise to a range of environmental issues. However, there are some patches of natural elements, such as ruderal plants, attempting to recover the territory following the closure of the mine (*Fig. 10*).

Given enough time, nature has an inherent ability to regenerate and restore itself regardless of the disturbances it may have faced, whether human intervention is involved or not. This gives rise to the saying "time heals all wounds" [3]. In adopting a conscious natural design approach, it may be prudent to adopt a hands-off approach, allowing natural processes to unfold and guide the regeneration process.

4. Proposal

In the rehabilitation proposal, it is firstly important to establish the context for rehabilitation. Clear achievable objectives and goals need to be established. Every site is different, so it is advisable to start on a small scale. Regular monitoring of revegetation is necessary.

Planning applications for quarries in modern times must include detailed proposals for the after-use of the quarry, which must be achievable. Sustainability policy for quarry areas involves several steps in the after-use proposal, including natural regeneration, nature conservation, landfill, leisure and recreation, agriculture, residential and other buildings, and other industrial uses.

The life cycle and impact of a quarry on both society and the environment are intricately connected to the effective planning, operation, and rehabilitation of the site [12]. Efficient planning involves considering factors such as location, extraction methods, and potential environmental and social impacts. During the operational phase, responsible management practices are crucial to minimize the negative effects on the environment, including measures to control dust, noise, and water pollution. Additionally, community engagement and addressing social concerns are essential for fostering positive relationships between the quarry and residents. Rehabilitation plays a significant role in mitigating the long-term impacts of the quarry [13].

This phase involves restoring the site to a condition that is environmentally sustainable and socially beneficial. It may include activities such as reclamation of disturbed areas, landscaping, reforestation, and creating habitats for wildlife. By prioritizing proper planning, responsible operation, and effective rehabilitation, the quarry industry can strive for sustainable practices that minimize adverse impacts and maximize positive contributions to both society and the environment.

Reviving abandoned quarries cannot be accomplished by merely concealing the excavation walls. It is crucial to establish a multifaceted cultural framework for reintegrating these disused areas into a fresh network of shared purposes.

This approach offers a chance to redefine the human-made landscape and its connection with the natural environment. By repurposing former extraction sites, the region gains new prospects in both the economic and ecological domains. In this context, quarries transition from being dormant "grey elements" into versatile "green elements" within an infrastructure system [5].

In the table below (*Table 1*), the possibilities of reclamations for the quarry are presented. This table combines the approaches for reclaiming mine sites from Engler's work, which focused on landfill and sewage treatment, exploring eight different design approaches for waste landscapes. It also incorporates insights from the Arbogast team's work, which emphasizes the human factors in mining reclamation. These two works share similarities and form a basis to a reclamation proposal that can be adopted to the Suseni quarry as well.

Table 1. Quarry reclamation based on Engler's and the Arbogast team's work [3, 15]

Approach	
Natura	Allow nature to reclaim the site with minimal human influence
Camouflage	Conceal the mining facility using visual screens and buffers
Restoration	Restore the land to its approximate original contour
Rehabilitation	Utilize the site for public amenities
Mitigation	Repair a mined-out site from extensive damage
Recycling	Recycle man-made or natural resources on site
Education	Communicate mining- or resource-related information through outreach
Art Integration	Treat the site as a work of beauty and a unique experience
Celebrative Integrative	Combination of approaches integrating art and science

Additionally, it is important to recognize that physical rehabilitation and revegetation are separate tasks. Preparing the site for native vegetation planting can take up to a year or two. It is essential to approach each site individually, as plants will behave differently in different environments. Embracing a progressive rehabilitation approach allows for learning and adapting strategies based on site-specific conditions, as what may work successfully in one place may not yield the same results in another.

In the context of hard rock environments, certain features within the quarry can serve as valuable biodiversity assets. Additionally, cliffs present in the area can serve as rare habitats that are beneficial to certain species.

In order to establish the initial vegetation structure, it is advisable to utilize colonizing species. For example, wattles can contribute by fixing nitrogen and aiding in soil structure establishment, while grasses can offer erosion control.

It is important not to rush the process of revegetation and approach it gradually instead. This approach allows for careful evaluation and adjustment, ensuring that resources are not wasted on ineffective strategies.

5. Conclusions

In modern times, it is important to recognize that protecting a specific area, even a quarry zone, is not sufficient. Instead, we need to consider a larger area or region and think about the surrounding environment and its relationships from the perspective of the multiple interconnected habitats, flora, fauna, and human communities. This approach requires an understanding of the larger ecological context in which the area exists. Therefore, a holistic approach is necessary to ensure the long-term sustainability of the environment and its inhabitants.

While the extraction of rocks has a history as old as humanity itself, the issue of revitalizing abandoned production sites has become a central topic in contemporary discussions about land regeneration.

When engaging in rehabilitation efforts, it is crucial not to commit to unrealistic expectations for obtaining approval. Regulators should be approached with a sense of realism. It is important to understand that the establishment of vegetation communities can be a lengthy process, potentially spanning decades and involving multiple stages. Proper rehabilitation necessitates meticulous planning and preparation.

In conclusion, it can be underlined that the location of the Suseni quarry is appropriate for tourist after-use or recreational zone, but being in the middle of an extended natural area, restoration of the natural environment must be taken into account in the proposal. Quarry restoration requires addressing abiotic and biotic constraints holistically to encourage the self-sustainability of the system. Restorations need not mimic pristine conditions, as alternative approaches can uphold valuable natural assets. Analyses of local plant community composition and structure allow for the assessment of restoration effectiveness, while alternative approaches relying on NBS (nature-based solutions) can avoid expensive and inadequate restoration practices.

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