

Review

Quarries: From Abandoned to Renewed Places

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Received: 18 March 2020; Accepted: 28 April 2020; Published: 1 May 2020



Abstract: Numerous industrial pits are discarded after their exploitation in every part of the world. Humanity both transforms the original morphology of the landscape, due to industrial activity in the territory, and, at the same time, rejects this "new" situation. This is to the detriment of the landscape, which is witness to this transfiguration, degradation, and abandonment. What is the future of these impersonal and empty areas? In this article, we present a general survey concerning the notion of quarry reuse to highlight the importance of this current and common problem. Our work approached the topic through a combination of the main concepts and a description of selected cases of study of quarry reconversions, sensitive to the environmental issues, climate changes, and sustainability. According to this premise, the research also provides an innovative matrix of schemes to classify the existing fundamental methods of recovery. For this effect, the investigation was proposed to be an instrument to improve the knowledge in the scientific and theoretical sectors, flanking the practical understanding, which has already started to move in this direction of reconversion, as the paper shows.

Keywords: quarry reuse; recovery; environmental control; biodiversity; geodiversity; sustainability

1. Introduction

The Earth's crust is subjected to constant mutations through physical and chemical fragmentations. Between 2000 and 2005, two scientists, E. Stoermer and P.J. Crutzen, developed a theory related to a new, ongoing geological era, defining it as Anthropocene. In this epoch, which started in 1784 with the invention of the steam engine, humanity is considered to be a real geological agent, due to the strong impact on the atmosphere and on Earth's surface [1]. This acceleration of the human impact was a result of the introduction of new technologies [2]. Humans were the protagonist of the Anthropocene epoch, in which they were also able to understand their mistakes and to intervene, through political strategies, for control of the territory [3]. The extraction industry falls entirely within anthropic activities, which can completely alter the environment. This industry accompanied humans from the prehistoric era when they dug rock to fabricate tools and to obtain construction materials and pigments. Therefore, they usually acted on the earth, modifying and adapting it to their necessities, regardless of the consequences in the aesthetic, ecological, and environmental sectors [4–7].

This paper represents an academic contribution as a literature review article, which provides an exhaustive report regarding the concept of the quarry reuse, after degradation from industrial activity. On the one hand, practical interventions have increased and multiplied worldwide; on the other hand, there is an architectural gap in the theoretical and scientific sector. We analysed the concept of quarry reuse to describe specific examples of regenerations in particular areas, to evaluate the environmental impacts, explain the techniques, and illustrate the recovery methodologies of dust and waste in the construction industry [8–13]. In these examples, the possibility of having a general view of the

topic was lacking, through innovative methodological approaches in the architectural sector. For this purpose, we propose our work as a useful instrument to improve the scientific knowledge surrounding the topic of the quarry recovery. In line with the innovative principles of sustainability, this research explored the transformation possibilities aimed at reintegrating these areas in ecological and territorial metabolisms, and consequently, reestablishing the material flows that occur between humanity and nature. This objective was achieved selecting, among countless examples of quarry reconversions, the most crucial cases of study, deepening and classifying them. In this regard, we developed an innovative matrix of schemes, in which the simple methods of the conversion were classified to give a general and critical view of the existing rehabilitation techniques.

“Will it be possible to investigate and derive new methods of rehabilitation starting from this matrix of schemes?”

This is the key question discussed in the paper; to understand how abandoned and industrial territories can be transformed into unique places, while minding the sustainability concept. Although this study is firmly attached to the environmental design field, it benefits from an interdisciplinary nature that enriches the work. In Section 2, we discuss a brief history of the notion of quarry reuse. In Section 3, we describe the new value of the industrial landscape. These two sections provide the essential theoretical and background basis for the following ones. In Section 4, we address some criteria for the reconversion of the former quarries, by means of the referred matrix of schemes. Moreover, the research methodology, the scientific schematisation, and the discussion of quarries reconversion cases are provided at the end of the section. In Section 5, we explain the concept of reuse in the contemporary era highlighting the current quarry trends. Finally, in Section 6, we draw the main conclusions.

2. A Brief History of Quarry Reuse: From a Utilitarian to an Ecological Approach

Quarries represent remarkable resources from the ground. There are several historic examples where there has been reuse of these areas for utilitarian purposes. Recently, due to the growing sensibility toward environmental issues, the possibility of ecological reuse flanks the utilitarian purposes. To summarise, briefly, the historical concept of the reuse of the extraction places, the range of funeral sites is to be considered; the catacombs represent one of the most significant cases in this sector. The term "catacomb" was born in Rome and it derives from "catacumbas", namely "at the cavity" for the S. Sebastiano funeral complex in the Via Appia located inside an ancient stone quarry. Occupying a considerable number of artificial and abandoned cavities (such as tuff, clay, and stone quarries) became a common habit in the Roman epoch for burial of the dead, to celebrate religious rituals, and to escape from persecution [4]. For this type of reuse, the quarries were subjected to minimal interventions of safety and only in certain cases were they remodelled and frescoed. The Priscilla catacombs in Rome are a beautiful example based on this concept (Figure 1a) [14].

It is significant to note how many cities took possession of quarries in order to obtain construction materials. The city of Naples, for instance, has exploited, since the Roman era, the subterranean tuff quarries, to convey water from the Serino River. This operation permitted the creation of tanks, linked to each other, for the water supply of the city until the seventeenth century, before being emptied (due to the construction of a new aqueduct) and reused as cemeteries and shelters (Figure 1b). In Paris, les Carrieres, Roman limestone quarries, were turned into town ossuaries to resolve the problem of inappropriate sepulchres in the neighbouring cemeteries.

In Siracusa, in Italy, there are several examples of Latomie, ancient stone quarries where the Greeks extracted all the necessary material for the realisation of temples, roads, walls, and defensive works. Some of these pits were also used for the imprisonment of slaves and criminals and, in more recent times, they became dwellings for the humblest classes until, now, where they have been transformed into gardens [4].

With tragic ends, one remembers the Mauthausen concentration camp in Austria (Figure 1c). During the First World War, the Austrians opened the first camp for war prisoners at the quarry of Wiener-Graben, previously used from the exploitation of Viennese granite used for the pavement of Vienna roads. During the Second World War, instead, this camp became one of the cruellest death-camps during the Nazi regime. In these years, countless discarded quarries were rehabilitated and reused as air-raid shelters, as happened in Colleferro, in Italy (Figure 1d). Many people who settled in these refuges also made the space more comfortable, blanketing the walls with lime for hygienic and lightning issues. After the Liberation, the air-raid shelters were partially reutilised as mushroom gardens. The same spaces were also present in Naples, with the difference of being more equipped with the electricity network, toilets, furniture, and distinct areas for the first and second class. These real examples, above enunciated, are essential to highlight the exclusive utilitarian approach for the reuse of the extractive sites, without any environmental and ecological preoccupation or any landscape meaning.

The landscape approach was introduced during the renaissance age in Florence, with the recovery of quarries to be allocated to gardens. The Boboli garden is today the biggest green area inside the walls of Florence, based on an ancient spot already anthropized by agricultural and extractive activities (Figure 1e). The Boboli hill was used as “pietraforte” quarry to provide material for the first paving of the city streets, and the construction of the town palaces, such as the Pitti Palace. The same Florence model was adopted in Paris with the project for the Buttes-Chaumont garden, in Vancouver with the realisation of the Queen Elizabeth Park, and in Ischia (Italy) with the creation of La Mortella gardens (Figure 1f). Each case was based on the transformation of ancient quarries in beautiful parks with aesthetic and environmental qualities [3]. According to the explanations previously mentioned and to the reality of our mutated surroundings, the presence of an industrial landscape, and, specifically, of a quarry on the territory, has always led to alterations of the land and to the urgency and the need to reactivate it.

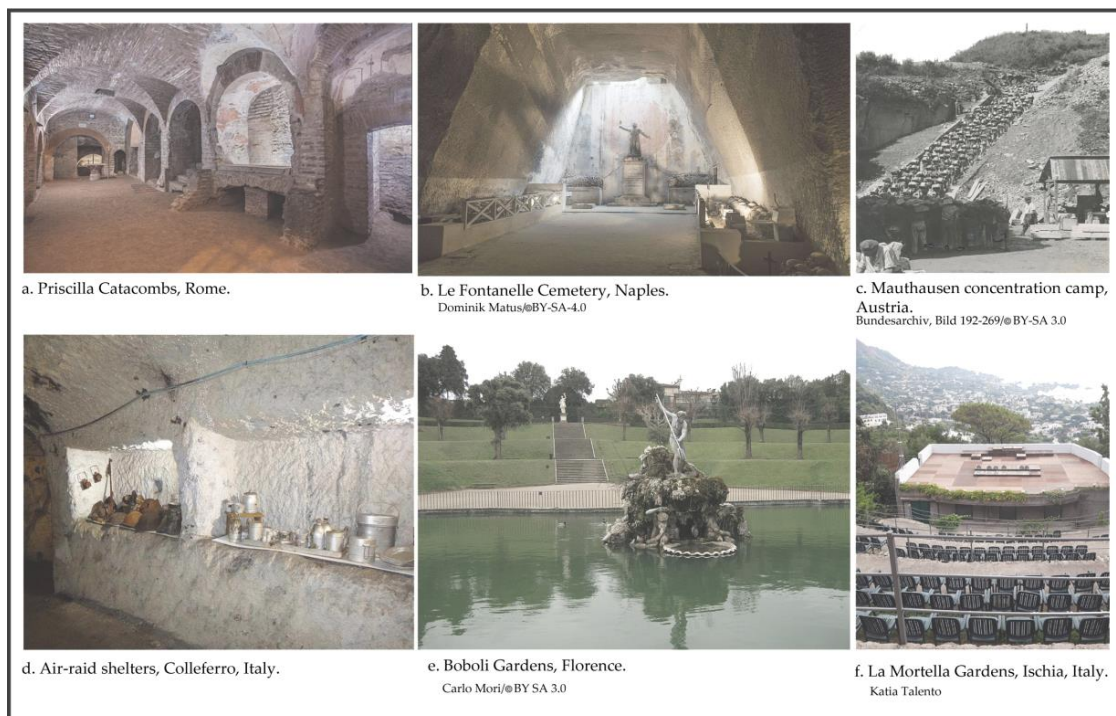


Figure 1. Ancient examples of quarry reuse.

3. The New Value of the Industrial Landscape

The industrial landscape represents an atypical landscape category, as it extends the landscape perception to places, such as those of production, which are born and developed without any aesthetic

purpose from the people who made them. Nevertheless, the industrial spots, once finished in their production activity, reveal unsuspected aesthetics qualities, useful for possible operations of the conservation and valorisation of these sites. The importance of the industrial landscape is related not only to the new aesthetic associated with places of work, but also to the conservation of the cultural value of the place for the allocation of a different and original function, compatible with the society of our time.

The extractive areas in the state of abandonment compose a particular landscape in which the technological heritage is intertwined with the environmental one, creating a patrimonial pluralism that requires innovative forms of protection and valorisation. This conception was reached only at the end of the 1980s. Previously, the "voids" left by de-industrialization were synonymous with *tabula rasa*, which erased all the productive traces jointly with the memory of a past by forgetting. On the contrary, between the 1980s and 1990s, the conservation and the valorisation of the industrial sites were considered as the growth of the cultural heritage of the cities in which they belong [15]. On par with the ancient city squares, in the industrial areas, it is also possible to trace a consistent depth of historical stratification. They are deposits of a more recent history but are no less intense: histories of fights, hard work conditions, solidarity between workers, and antagonism for the industrial discipline. The depth of the memory of the workplaces is undeniable and it represents one of the main components of the immaterial heritage.

The industrial landscape is constituted as an "anti-landscape" rather than traditional; the traditional landscape is a landscape of continuity based on traces of the long-standing history of the territory. The industrial landscape, instead, is the landscape of discontinuity, as its appearance indicates a breaking point, compared to the previous history, and a new beginning in the events of the territory. The industrial landscape is the landscape of the metamorphosis of the values that could be transformed into a place rich in memory with aesthetic dimensions [15]. This transformation implies the need for urban regeneration to re-think the economy, the function, and the destination of use of the abandoned industrial sites.

The recovery of abandoned quarries does not resolve through a bland "masking" of the excavation walls, but through re-appropriating the cultural aspects of the territory. In this way, the definition of a diverse cultural horizon is necessary to reinsert the dismissed quarries into a new circuit, formed by common uses, where there exists the possibility to reinvent the anthropic landscape and its relation with the natural one. Designing the profound spaces of the landscape refers to the modern notion of the hypogeum, able to produce vastly different architectural articulations and an innovative association with the territory and its resources [16].

Even if the activity of digging for rocks is as ancient as the presence of humanity on Earth, the question of the territorial regeneration, focused on the recovery of the dismissed productive sites, is one of the central arguments of the contemporary debate. The considerable amount and extent of the former extraction systems located under our urbanised soils make their protection, recovery, and reuse urgent. Their consolidation and securing are necessary to prevent the eventual phenomenon of instability [17]. These cavities reveal, most often, notable qualities and spatial values, and they represent a typical porous sub-stratum, which crosses the anthropised territory, claiming the need to have a new use.

There are different ways to confer a new meaning to these unused and porous sites. For example, re-organizing the hypogeum cavities into a museum, for visits and thematic exhibitions; through the necessity to allocate useful services for the city; or for structural and consolidation needs. Regardless of the various orientations, the recovery intervention will have a utilitarian valence, being productive, resolute, and a symbol of transformation, innovation, and progress. These are, in conclusion, good for the territory. Recovering and reconvertng a former extractive hypogeal site means to recognise the opportunities and, at the same time, the limits offered by the quarries, and the nature and characteristics of the excavated material [18]. The regenerative force exercisable by these marginal voids is becoming the strong point of the so-called "new ecologies", which utilises the existent heritage at the centre of

the project for the contemporary city. The intention is of generating new life cycles from the devastated territory, which has suffered the most aggressive forms of anthropic degradation [19]. This intervention produces new ecosystems characterised by a substantial complexity that get to live only if they are maintained, incremented, and assisted in their constant mutations [20].

Therefore, with rehabilitations projects, the community can accept the dismissed areas for a multitude of collective uses, taking the opportunity to reorganise and to decentralise the urban poles for a rebalancing of the anthropic cargo on the territory [16]. Through the reconversion of former extractive sites, the territory also acquires other opportunities in both the economic and ecological sectors. In this regard, the quarries are transformed from “Grey Infrastructures” to “Green Infrastructures”. The first category is related to the works drafted for mono-functional specific uses (such as bridges, highways, and dams), constituted, mainly, by manufactured materials, contrasting with natural systems. The second category, instead, includes those natural or semi-natural multifunctional areas, with a rural or urban character, which are designed to increase the livability and the environmental values of the local communities. The Green Infrastructures, by encouraging the utilization of natural capital, are conceived to equilibrate, ecologically, areas and territories, by providing a wide range of ecosystem services (Figure 2) [21].

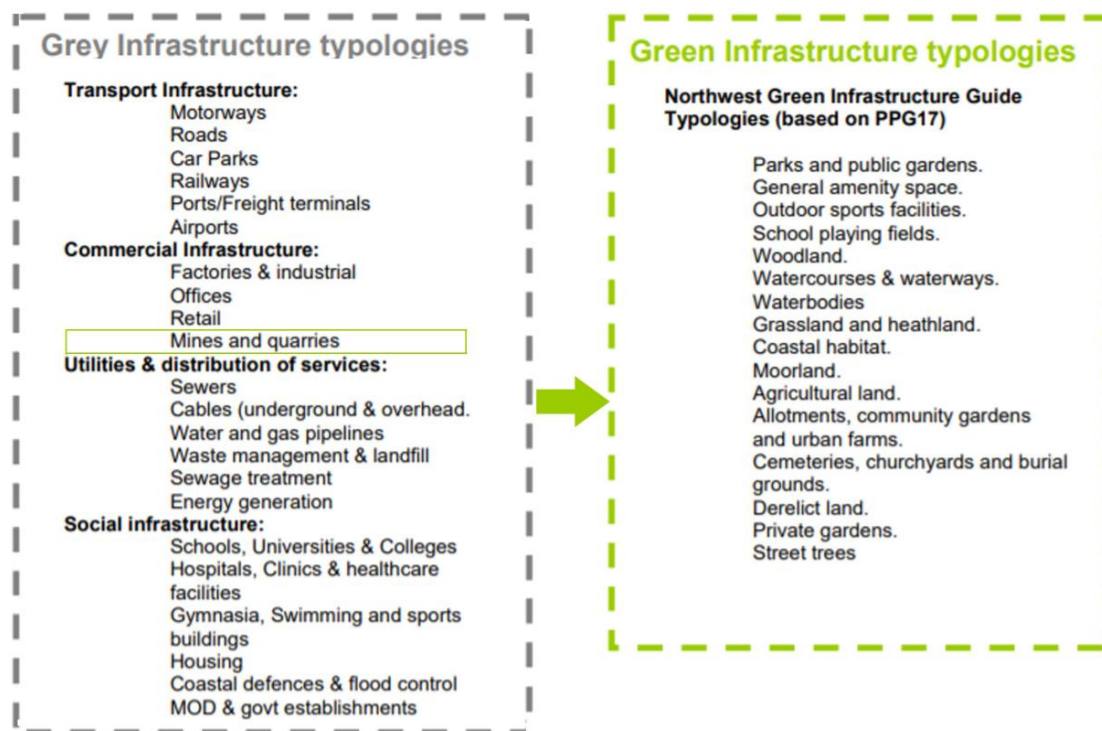


Figure 2. Component parts of Grey and Green Infrastructures. (Source: NENW, 2009 [22]).

4. Some Useful Criteria for the Reconversion of the Former Quarries into Renewed Places

4.1. The Morphology of the Territory and Destinations of Use

The obligation to confer a renovated use and meaning to the degraded extractive sites implies, most often, transformation operations for the place. These metamorphoses can require diverse types of interventions, which span from minimal measures to considerable changes (such as filling, reforestation, and new constructions). Typically, different parameters confront each other in these complex procedures, such as quarry typology, dimensional and formal character, the security of the areas, and the ecology [23]. Any prediction of the transformation presupposes, on the one hand, a comparison with analogue cases to identify similarities and to define concepts and, on the other hand, a close reading and analysis of the site and its context to evaluate and design solutions with a strategic approach [4].

Regarding the transformation processes of a quarry, there are some essential elements to keep in mind. One is the morphology of the territory, which depends on the typology of the extraction site [24]. If one considers the quarries as patches within a landscape mosaic, one notes that they have identifiable geometric features. Since humanity produced them, these characteristics are different from those of natural origin (Figure 3). Entropy leads to casual shapes, convoluted and with irregular perimeters; instead the forms made by humans are normally evident [22].

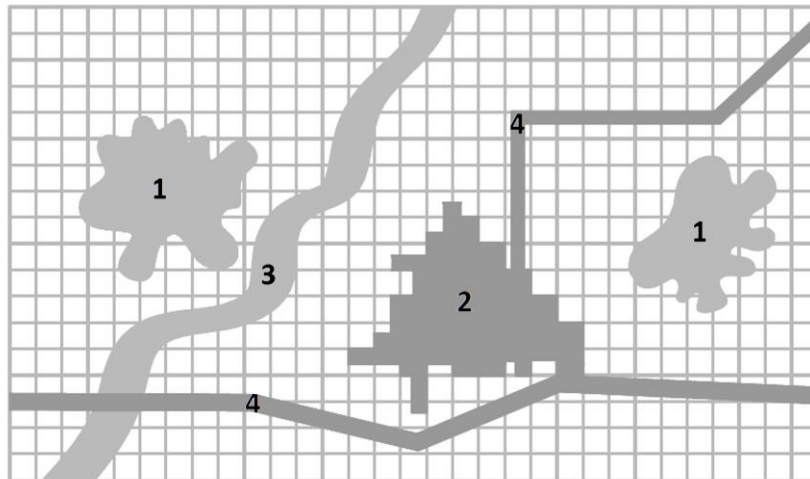


Figure 3. Environmental mosaic scheme composed of different patches and corridors. 1. Natural patch; 2. Anthropogenic patch; 3. Natural corridor; 4. Anthropogenic corridor. (Source: [22]).

In this respect, the question related to the borders of a quarry is crucial to understanding the difference between the artificial and the natural patches. In the first case, the majority of the shapes made by human activity present straight lines, due to the need for managing, regularising, and controlling that part of the territory (tracks, terraces, and large steps). Between the other variables of the form parameters, the aspects linked with the compactness of the borders also gain significant consideration [22]. The compact configurations are determinant to maintain the resources of a quarry, decreasing at the same time, the movement outwards, because of the limited quantity exposed through the margins. The articulated forms, on the contrary, are crucial in increasing this interaction with the surroundings.

After the classification of the primary criteria of form for the quarry rehabilitations, we investigated the design and the transformative possibilities of the extractive areas regarding the parameter “destination of use”. The recovery typologies of the abandoned quarries can be schematised according to the following purposes: naturalistic, recreational, cultural, educational, and productive.

The naturalistic recovery of a quarry is an intervention method based on the vegetational and forest recovery, through the realisation of green areas. This provides the creation or the reconstitution of the natural features of the quarry zone, in connection with the surrounding environment [25]. This type of recovery aims to limit the morphological effect caused by the excavation [26] and proposes to recreate a habitat, as similar as possible, to the natural one. This category of recovery requires an in-depth ecological analysis of the territory to intervene with adequate technical and vegetational choices. This category also includes all those lands, which, after their exploitation, acquired particular geological conditions that need protection. Examples include the quarry or mining areas (e.g., in Sardinia and Apulia), which have assumed the connotation of “geo-mining parks”, a symbol of an important cultural heritage [16].

The recreational rehabilitation, jointly with cultural and educational goals, aims to realise distinct spaces, intended to receive services and equipment with recreational and educational functions: touristic equipment, museums, galleries, musical and sports activities [27], and leisure facilities.

The productive replacement includes the agricultural and touristic recovery. In the first case, the scope is to take back the dismissed quarry to its original condition of an agroecosystem. The second case instead consists of making the territory more attractive to encourage visits from tourists, giving a

renewed meaning to the place. The preferable destination for the productive options include areas rich in population density and residential and productive settlements, or areas that are border places with particular aspects [28].

4.2. Categories of Transformation: Projects Comparing

These considerations are an important premise for the identification of the strategies to requalify the extractive areas. Deepening this study, a synopsis of the distinct categories of quarry transformations is provided. We elaborated a general matrix of schemes in which the fundamental approaches of the conversion have been classified, not to simplify the concept, but to offer a panoramic view of the existing possibilities and rehabilitation techniques. The categories of transformation are subdivided into two macro groups:

- Remodelling: this includes operations of filling, modification, and insertion.
- Not remodelling: this does not entail substantial alterations of the excavation.

Concerning the first macro group and the activity of “filling”, there is a distinction based on the diverse types of materials used, which can result in specific and peculiar conformations. For instance, if the filling matter is the water, the possible configurations are those typical of lakes, reservoirs, and wetlands, where the flat surfaces will prevail, rather than the protruding volumes. One of the most famous examples is the F60, a vast mining area in Lusatia (Brandenburg) [29], formed by extensive open-air deposits of lignite (brown coal). These deposits give the region the nomenclature of “Energy district” [30], in which power stations, briquettes factories, coke ovens, and other establishments were located. After political changes, the majority of the quarries were closed and the government allocated special funds for the rehabilitation of these territories, through the institution of a state company, the (LMBV) (Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft). This association preserved the industrial heritage and created a new way to reuse the brownfield [31,32]. The main characteristic of these post-extractive sites is the presence of new water surfaces due to the filling of the ancient pits to form lakes [33] for recreational and sports activities [34,35] (Figure 4a).

In other situations, solid materials, such as the ground, represent the infill that expands the possibilities of the reshaping, recreating morphological continuity from the margin zones. Belonging to this classification, the project of the Royal Botanic Gardens Victoria in the city of Cranbourne (Australia) was born of a former sand quarry. The goal of the architectural project was to create a large botanic garden, with recreational and educational purposes, to display the different Australian micro-landscapes [36]. The garden was designed by Taylor Cullity (Lethlean firm) in collaboration with the botanist Paul Thompson, who is a massive collector of Australian flora. It was developed along a water path, which crosses, metaphorically, the arid landscape of the Australian hinterland. One pass from the dry riverbed to artificial lakes up to the coast allows the visitor to retrace, ideally, the water travel of the continent. The recovery project has reshaped the ground flows (Figure 4b) and the realisation of wet zones alternate with gardens composed of 17 thousand species of plants that have turned this place into a premier site dedicated to Australian flora and the biodiversity [4].

In addition to the typologies above mentioned, we add another that includes the method of the “constructed void” for the filling technique. This is the case of the un-realised project, Denia Mountain, where the architects simulated, on the one hand, the volumetric reconstruction of the hill and, on the other hand, they “involved” the empty space to allocate for specific functions, such as parking, a hotel, auditorium, etc. However, the project aimed to highlight the artificiality, using a different treatment of the surface, composed by terraced gardens and ramps [37] (Figure 4c).

The operation of “modification” falls in the second subcategory of remodelling and is divided into three definite typologies: new form, emphasising, and camouflage. “New form” refers to new aesthetic, visual, and ecological configurations, designed to reduce the phenomena of the degradation through land movement or rock reshaping [4]. Example cases are the Negev Phosphate Works, in the

homonymous desert in Israel, where a major mining industry for the exploitation of phosphates, used for fertiliser, is located.

For decades, work has removed these materials by open-pit mining. The result has been the creation of a desolate landscape of huge holes with adjacent waste heaps some 40 m high [38]. However, the vast scale of the tipped material was utterly foreign to the landscape of the Zin Valley. This is an impressive desert wadi landscape of crescent Hogback hills, which is also subject to flash floods. After the extraction of the material, in 1990, the Negev Phosphates Company commissioned the architect Shlomo Aronson to design a more environmentally sensitive approach to opencast mining. He devised methods of filling in the excavations, left by mining with the spoil material.

The strategy adopted to resolve the problems has three main elements. First, the conservation of the wadi involves breaking the mounds of wastes in two and, immediately, this reduces the scale of their visual impact, while also conserving the side slopes of the Zin Valley. Second, new landforms reflect the existing topography. Finally, the impact and the scale of the earthwork was reduced by creating 10-meter high setbacks instead of 30 to 40 m. The architect, in this industrial land, acted as a sculptor and the result was the creation of a new landscape, with a new morphology, comparable to a gigantic environmental sculpture [39] (Figure 4d).

The typology of “emphasizing” concerns actions of sculptural remodelling; employing cuts and bevels, these landforms exalt the scenographic features of the form (Figure 4e). An interesting example is the landscape intervention of Bernard Lassus in the Crazannes quarries, along with traits of the French highway. In this rest area [40], some stone masses have been removed or reshaped to open the original views and scenarios in depth, using contrasts between the masses and voids, lights and shadows, the green of the vegetation, and the white of the stone. There is a work of reinterpretation of the places and functions that bring out several rocks of the forgetting quarries, covered by vegetation. In the project, the maintenance of the fern wood represents the vegetal drawing more evidently. The sequences of excavations, invaded by plants, form a vast romantic landscape, in which the succession of distinct points of view unifies the former quarry to the road infrastructure. In this way, the driver, along the highway, recognises the meaning, the form, and the memory of the place [41].

The “camouflage”, in conclusion, aims to hide undesired surfaces or substances through technological solutions [42]. Biovail is a significant project, concerning this concept, in which minimal technological supports (canvas ropes, nets of natural fibres, and recycled tubes) were overlapped to the rock to treat the wounds inflicted on nature [43] (Figure 4f).

Finally, the operation of the “insertion” is a part of the last typology of the remodelling phase. It comprises interventions of new constructions inserted, partially, in the volume of the quarry, causing excavations of subtraction and adaptation. Among the most suggestive examples of this category, there are the Braga stadium in Portugal, made by the architect Souto de Moura, and the Igualada cemetery in Spain, of Enric Miralles and Carme Pinos. The Braga Stadium (Figure 4g) is the result of two major decisions. The first emerged at the particular moment when the architect visited the Monte Castro, in Portugal, recognising the old and deactivated quarry as a perfect place for the stadium implantation [44–46]. He chose a landscape already transformed by men, instead of an untouched one [47]. The second decision was to perceive the stadium as a large infrastructure that made a functioning machine. The construction is within the sports park of Dume, on the northern slope of the Castro Mountain and its strategic position avoided the construction of a dam in the reservoir of the valley [48].

Due to the great importance of football in the sporting world and its “power” of entrainment, the architect chose to realise only two wide and contrasting seating steps. The first was embedded in the rock face; the other one, instead, emerged from the ground reconstructing a basin, closed on one side by a mountain crest and opened, on the other side, to the valley scenic view. Concerning the coverage of the stadium, the original idea showed a long roof similar to that of the Siza Expo pavilion [35], but, subsequently, the firm adopted a different solution, taking inspiration from the Inca bridges in Peru. For this reason, with a height of 40 m, the stadium is formed by two square suspended top floors with the same inclination [49].

The Igualada cemetery was designed to be a place of reflection and memories (Figure 4h). The authors understood it as the “city of the dead” where the dead and the living coexist together in spirit. Therefore, the project is also a place to rest and reflect in the solitude and serenity of the Catalonian landscape of Barcelona. The architects conceptualised the poetic idea of a cemetery for the visitors to comprehend and accept the cycle of life as a link between the past, present, and future. Incorporated in the Catalonian hills, the cemetery is an earthwork located inside an arid river valley [50] that merges in the landscape as if it were a natural feature of it. Thus, the project was conceived, in part, as an element that transforms the surrounding landscape and also, in part, as a metaphor for the river of life. A processional way descends from the entrance, where crossed, rusting, steel poles double as gates, and this is comparable to the crosses at Calvary. The pathway is marked by replicable concrete loculi, which form supporting walls and by the concrete floor. The intention was to bring the bereaved down into the landscape to a “city of the dead” to make it “communicate” with the living [51].

Concerning the recovery category of the insertion, for the two projects, described above, the architects applied morphological grafts with the partial inclusion of new volumes within the edge of the quarries. The second macro category describes the solution of the “not remodelling” for all the places, which, although deformed, present special features of form. For all these cases, only small interventions were performed, related to the securing of the sites and of the excavation. Already throughout history, as mentioned elsewhere, the reuse of a quarry was realised without any morphological modification, taking advantage of the form peculiarities of the site.

This ideology has also been maintained in the contemporary epoch, where there are several examples concerning, mainly, places destined to sport-related, artistic, and cultural activities. We cite the case of the sculptural park La Palomba, in Matera, or the case of the former quarry of Rättvik, in Sweden, transformed in the Dalhalla theatre, in which the architects took advantage of the natural configuration of the basin, using its considerable acoustic capabilities for the promotion of recreational activities, concerts, and events during the summer season. Dalhalla, in particular, is an amphitheatre, with the descending benches down to an emerald lake in the flooded part of the pit (Figure 4i,l) [52].

The sculptural park La Palomba, located in the historical natural archaeological park of the Matera rock churches (Figure 4m) (in Italy), symbolizes an interesting anthropological work [53]. The artist Antonio Paradiso decided to rehabilitate the former industrial space, transforming it into an artistic and cultural area, enriched periodically, by collective expositions and temporary exhibitions. The sculptors create their works according to the practice of the artistic residences with a stay in the “stone city”, in direct contact with the territory. The new site develops in the six hectares of an ancient tuff quarry—material that has characterised, for centuries, the architectural history of Matera city [4].

Within the category of the “not remodelling”, the “attached” is also considered and it is declined in three variants: “attached horizontally”, “attached vertically”, and “suspended”. These are measures, which, although they do not include the morphological transformation of the excavated empty spaces through land movements, adopt the construction of buildings, paths, and facilities to resolve the metamorphosis of a quarry. Three representative projects embody these distinct approaches: the first technique, the Pierre et Vacances Costa Plana in France of the architect Jean Nouvel represents a significant example (Figure 4n). In this case, the architecture and the vegetation (composed of pine trees and agaves), cling to the steep surface of the quarry. It seems almost a cliff, where the buildings appear with simplex and rhythmic volumes, and “disappear” in the rock and behind the flora.

Concerning the second approach, the Intercontinental Hotel of Jade architects and associates in Shanghai constitute the best instance of a building constructed and attached to the vertical wall of the quarry. The studio described it as an “inverted ground-scraper”, since it represents a tall construction (88 m deep) fixed at both ends and the 337-room hotel descends 16 storeys below ground level, within the former quarry. In this regard, the walls of the pit wrap the rooms and a “glass waterfall” structure contains the building’s observation lifts for access to all the floors (Figure 4o).

The Hotel in a quarry in China of the firm Samyn and partners symbolizes an edification closer to the third approach. The present project provided a 20-room hotel facility and a small open-air theatre

in an existing quarry. The 20-bedroom feature hotel at the upper level, in the form of individual cabins, is attached to the cliff and accessible through a funicular lift and horizontal pathways (Figure 4p,q). All these cases can be perceived as “foreign” objects; however, at the same time, they appear well integrated with the natural aspects and with the surroundings.

Concurrent with all these artificial interventions, other typologies of recovery exist, dictated instead by the natural spontaneity of reconversion. This is a concept that is associated with the thought of the scientist James Lovelock and exalts the power of nature to destroy any form of degradation. By the author, despite the excessively long periods, nature will restore the lost balances through spontaneous biological processes [54]. This theory is demonstrated by several examples; for example, the former gold mine, Las Medulas, in Spain (Figure 4r), or other exceptional places, such as the canyons, ravines, or volcanic lakes that have become precious refuges of biodiversity, creating new ecosystems.

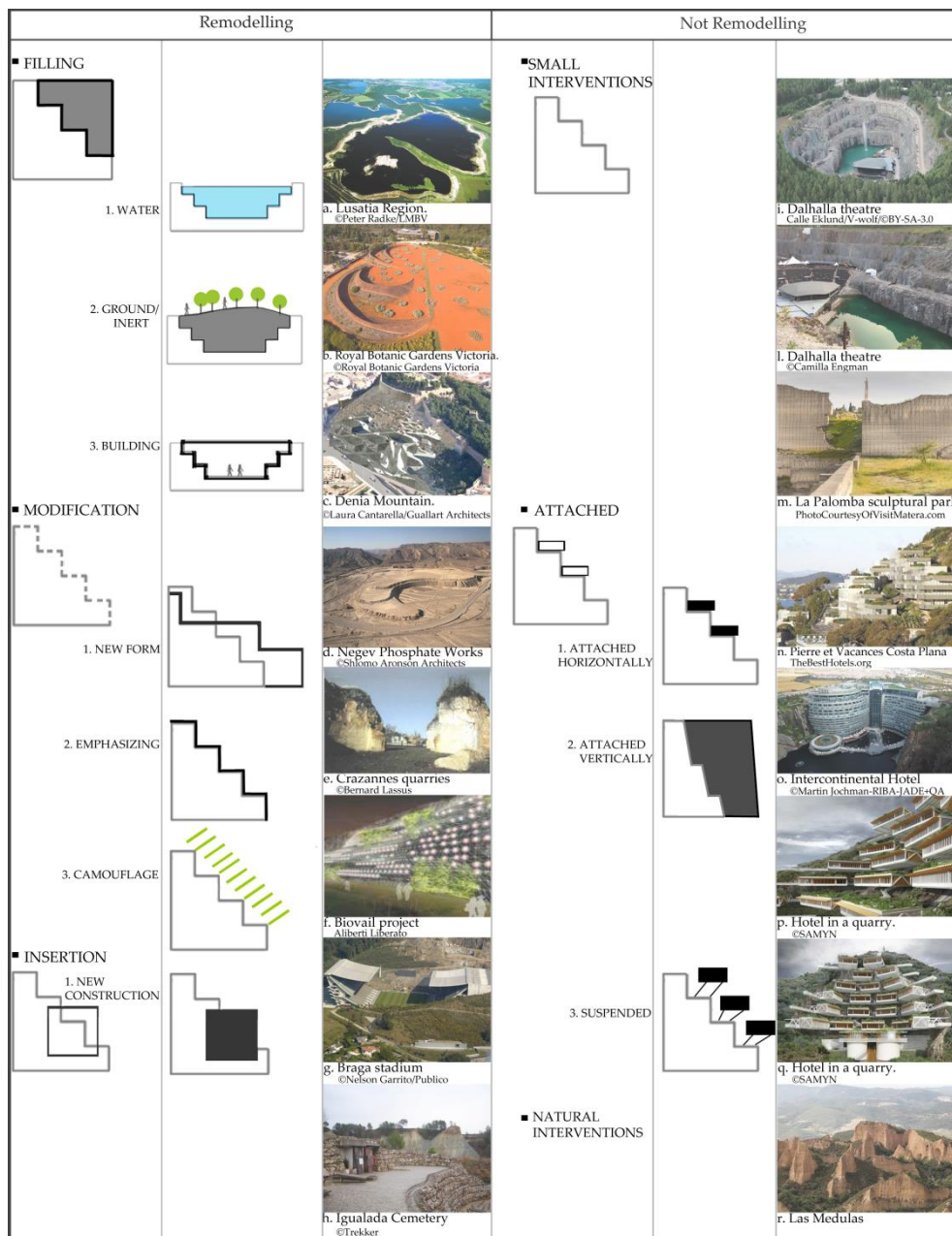


Figure 4. Matrix of schemes of different and existing recovery typologies for quarries (partially elaborated from [4]).

In this regard, natural recovery is a process, still used, in which re-vegetation relies on the presence of seeds and roots in the soils, transported from adjacent lands through natural courses. This process happens through different stages, referred to as primary and secondary succession, which occur through the processes of species colonisation, spreading, and replacement over time. In some cases, because of the limitations of soils in quarries, parts of the excavation could remain exposed, due to lack of vegetation cover. These could provide important habitats for a variety of wildlife, as well as create opportunities for exhibitions of the industrial archaeology [8].

The notion of natural intervention concludes the schematisation of the principal recovery categories for quarries. From this systematisation, we propose our scientific method and describe the selected cases of study (a few of a wide range) to extrapolate the most relevant concepts of transformation, analysing them from an architectural point of view. Several references have been selected for the organization of the literature review and the drafting of the paper. These references have been searched for keywords, mostly related to the concepts of waste, waste reuse, industrial landscape and quarry rehabilitation. The bibliography was then organized following the intention of the paper, namely that of creating a fluent reading about the waste notion, from its origins to its contemporary mutations. The resulting methodological and conceptual approach (illustrated in Figures 5 and 6) could be considered as a reference model for the rehabilitation of several quarries in different surroundings. In recent years, numerous publications [8–13] have addressed issues related to the general conception of the quarries. Most of them are concerned with the explanation of the quarry reclamation techniques, the impacts generated from quarries, the reuse of quarry wastes in construction materials, the reclamation of an extraction site in a specific area, and the reuse of the quarry dust on the soil. The current paper, on the contrary, attempts to highlight the importance of the quarry reuse describing several made examples in a unique text, comparing and discussing them to investigate new strategies of rehabilitation. Through this classification, the work draws a schematization of the different approaches of recovery, not present in previous publications.

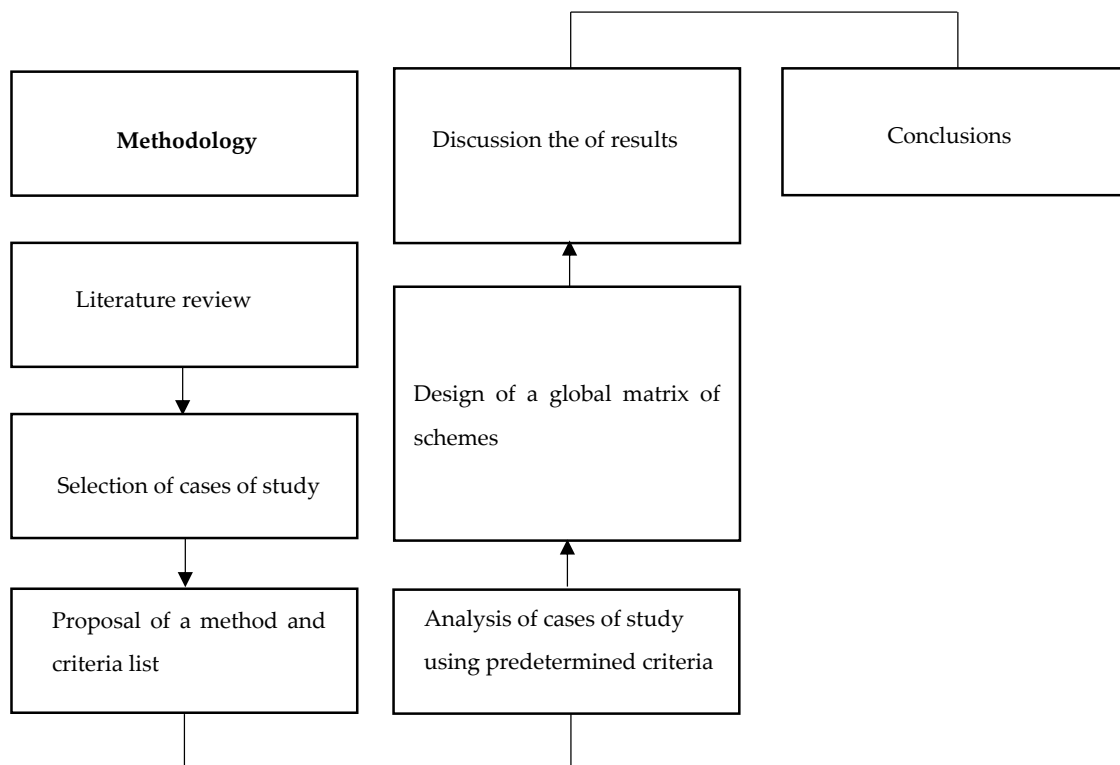


Figure 5. Conceptual graph summarising the research methodology.

Quarry recovery typologies		Quarry type		Excavation method		Pit/ Side sizes		Quarry depth		Pit perimeter		Rainfall abundance	Proximity to the aquifer	Proximity to the village	Context typology		Visual impact degree		Architectural result	
		Mount	Plain	Stepped	Plate	Small	Large	Small Medium	Large	Regular	Irregular				Urban	Rural	Lower	Higher		
Filling	Water		•		•		•		•		•		•					•	Lakes Leisure Spaces	
			•		•	•		•		•		•						•	Swimming pool Leisure Spaces	
	Ground/Inert		•		•	•	•	•	•	•								•	Public Parks Botanic Gardens	
	Building		•		•	•	•	•	•	•				•				•	Shopping Mall Hotel Indoor Parking	
Modification	New Form		•		•	•	•	•	•	•								•	Land Movement Rock Reshaping	
	Emphasizing	•	•	•	•	•	•	•	•	•									•	Sculptural Remodelling
	Camouflage																			Not relevant
Insertion	New construction	•	•	•	•	•	•	•	•	•				•				•	Infrastructures Facilities Touristic buildings	
Small interventions			•		•	•	•	•	•	•						•	•			Quarry Securing
Attached	Horizontally	•		•		•	•									•	•	•		Touristic buildings Housing
	Vertically	•	•	•	•	•	•	•								•	•	•		Touristic buildings Housing
	Suspended	•		•		•	•									•	•	•		Touristic buildings
Natural interventions		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		Revegetation Biodiversity

Figure 6. Scientific schematisation and discussion of quarry reconversion cases.

5. Reuse and Reinvention in the Contemporary Era: Quarry Current Trends

5.1. Some Selected Cases Study Carefully about the Environmental Potentialities

Discussing the criteria, the typologies of quarry recoveries and the general approaches of the interventions are significant for the comprehension of the conversion of an abandoned extractive site into a renewed and attractive place, conferring it with a new utility [55]. In this section, several examples of quarry reconversion and recovery experiences, will be illustrated, schematically, to understand the current tendencies and to identify useful markers and design approaches. By recent studies, the most frequent reuses of dismissed quarries have transformed the industrial environment into leisure parks, public gardens, sport areas, cultural and artistic places, technological sites, and productive spaces for the agriculture.

According to this premise, the present section shows some of the most meaningful interventions and, successively, deepens the more emblematic case studies. This program is far from an exhaustive review compared to the globality of the real examples; therefore, it represents a substantial base of the latest trends, in the transformation sector, which does not provide only the naturalistic recovery of the post-extractive sites. Thus, with the chosen cases of study, we attempted to perform a general screening of contemporary experiences. The selected projects were classified in conformity with the diverse uses, as indicated in Figure 7.

Naturalistic	Recreational	Cultural	Productive	Facilities
Karsdorf Vineyard (Germany) Vineyard and afforestation in limestone quarries.	Brick Pit Ring (Australia) Recreational Park that promotes the biodiversity with the presence of rare species.	Montraker (Croatia) International summer school of sculpture located in an active and Vrsar stone quarry.	Portel winery (France) Winery and quarry museum in a gypsum quarry.	Beinheim port (France) River port on the Rhine for barges and boats boats in a sand and gravel quarry.
Rheinlebe (Germany) Naturalistic Park with garden school, seat of IBA Emscher Park, in a coal mine.	Rordal Lake Park (Denmark) Park for aquatic sports with open-air theatre in a gypsum quarry.	Crazannes (France) Rest area La Pierre de Crazannes with open-air museum in a marble quarry.	Landschaftskunst Goitzsche (Germany) Recovery of lignite mines for touristic-bathing purposes, near Bitterfeld and Pouch.	Hidrachry Project (Italy) The quarries became reservoirs to mitigate hydric system variations.
Zanderij Quarry (Holland) Terraced Park with botanical collections in an aggregates quarry.	Bois-le-Roi (France) Public Park with bathing area in a sand quarry.	Westpark (Germany) Urban Park in Munich suburb with show rooms, exhibition spaces, greenhouses and amphitheater in gravel quarries.	Druridge Bay (UK) Territorial Park with lakes, seaside resort and naturalistic oasis in a coal quarry in Cresswell.	Memory Forest (Sweden) Cemetery Park in Enskede in a gravel quarry.
Blue Circle (UK) Wooded areas and golf course in clay quarries.	Firminy (France) Stadium and Youth and Culture Home in a coal quarry designed by Le Corbusier.	Moray Sacred Valley (USAN) Opencast agronomic laboratory.	Blue Water (UK) Shopping Center in a limestone quarry in Greenhithe.	Igalada cemetery (Spain) Cemetery Park, place to rest and reflect in the solitude.
Vulcano Croscat (Spain) Natural park with geological, botanical, faunistic, and landscape value.	Cergy Ponds (France) Lakes for aquatic sports, swimming pool, tennis golf courts, equestrian trails and naturalistic areas in a sand quarry.	Broken Circle and Spiral Hill (Holland) Land art pieces in a sand quarry in Emmen.	Denia Mountain (Spain) Commercial and touristic center in a limestone quarry, with hotel, auditorium, parking and terraced gardens.	Chicago deep Tunnel (USA) Biggest quarries in the world, transformed in a stormwater and linked, through channels and tunnels.
La Mortella Gardens (Italy) Gardens in a trachyte quarry in Ischia, spaces for artistic manifestations and concerts.	Emscherbruch (Germany) Landscape park with recreational areas (skating rink, mountain bike) in coal mines.	Eden Project (UK) Thematic Park in a kaolin quarry, with greenhouse, experimental gardens and open-air amphitheater	Isola Giarola Quarry (Italy) Area for recreational, naturalistic and productive (fish farming) purposes in a sand quarry near Piacenza.	Spiral Hill (Netherlands) Sand dock revolving around a rock.
Isola Giarola Quarry (Italy) Area for recreational, naturalistic and productive purposes in a sand quarry.	Braga Stadium (Portugal) Stadium in a stone quarry on the north side of the Monte Castro in Braga.	Field of sculptures (Romania) Open-air ethnographic museum in a limestone quarry in Măgura	Ca' Trebbia (Italy) Agricultural recovery in a gravel quarry near Piacenza.	Skogskyrkogarden (Sweden) Cemetery Park and masterpiece of the recycled places.
Luneo Quarry (Italy) Oasis WWF in a clay quarry with spontaneous renaturalization.	Blue Circle (UK) Wooded areas and golf course in clay quarries	Fossar de la Pedrera (Spain) Memorial Park in a stone quarry in Barcelona	Quarries Hotel (Italy) Tourist settlement in white tuff quarries in Favignana.	
Lignite Quarry (Germany) Renaturalization in the Lusatia Region.	Henry Palmisano Park (USA) Recreational Park conceived in a multifunctional and adaptive manner; it also serves as a buffer in flooding situations.	Tindaya Mountain (Spain) Exhibition space and land art intervention in a marble quarry of Tindaya Mountain.	Pierre et Vacances Costa Plana (France) Tourist settlement in the French quarries.	
Las Medulas (Spain) Spontaneous renaturalization in the former golden mines.	Isola Giarola Quarry (Italy) Area for recreational, naturalistic and productive (fish farming) purposes in a sand quarry near Piacenza.	La Mortella Gardens (Italy) Gardens in a trachyte quarry in Ischia, spaces for artistic manifestations and concerts.	Intercontinental Hotel (China) Tourist building constructed and attached to the vertical wall of the quarry.	
Zanderij Crailloo (Holland) Natural reserve, close to the Dutch railway.	Gym Free climbing (Italy) Rock Gym in a stone quarry in Rome	Rubbio Quarry (Italy) Studio and artistic laboratory with open-air amphitheater near Vicenza.	Hotel in a quarry (China) Tourist building suspended on the quarry surfaces.	
Musital Quarry (Switzerland) Naturalistic recovering of a limestone quarry.	Lignite Quarry (Germany) Natural Park with lakes for aquatic sports and recreational activity.	Geo-mining Park (Italy) In Cagliari, Saregna.	Dionysos Quarry (Greece) Touristic park to see the industrial memories.	
	Dalhalla Theatre (Sweden) Recreational activities, concerts and events during all the summer season	Royal botanic gardens Victoria (Australia) Educational purposes to show the different Australian micro-landscapes.	Quarry Botanic Garden (China) Touristic space for visitors approaching natural landscape and experiencing the culture of quarrying industry.	
	Atlanta's Westside Park (USA) Recreational Park water reserve container .	Negev Phosphate Works (Israel) Gigantic environmental sculpture Park.		
	Hedeland (Denmark) Regional park with natural areas, sports facilities, amphitheater and other equipment in a former gravel and clay quarries.	La Palomba Park (Italy) Sculptural Park in the Matera archaeological Park of rock churches.		
	Do Viriato Quarry (Portugal) Environmental recovery with spaces for recreational and sports activities.	Rheinlebe (Germany) Naturalistic Park with garden school, seat of IBA Emscher Park, in a coal mine.		
	St. Margarethen Quarry (Austria) Space with auditorium for open air concerts.	Vulcano Croscat (Spain) Natural park with geological, botanical, faunistic, and landscape value.		
	Tangshan Nanhu C. Park (China) Dynamic public space with recreational facilities.	Lithica (Spain) Public Park, cultural center with also green spaces.		

Figure 7. Some of the selected quarry rehabilitation projects (the projects with sustainable and environmental components are illustrated in green).

From this general selection, we attempted to explore some peculiarities of the extraction sites, scarcely considered until now, deepening some of the specific projects illustrated in the previous table. The previously mentioned peculiarities concern the concept of the environment, due to the strong imbalance started by humanity against the planet. Some of these singularities are related, mainly, to the environmental potentialities, which include environmental control (mitigation and adaptation), microclimates, geodiversity, and biodiversity. The term “environment” has ancient Greek and Latin origins, and it is a central element in various disciplines, both in the scientific and humanistic fields. Despite multiple connotations, the concept represents an open system of relations between biotic and abiotic elements that interact in a common context, using perpetual energy exchanges [56]. Beyond the contextualisation of meanings that the term assumes, this climate of changes, sensible to the environmental factors, embraces, albeit belatedly, the architectural, landscape, and urbanistic culture. It is necessary to consider the ecological study in a broader sense, examining it systemically and on a large space-time scale [22]. The following provides some potentialities of the transformation of the industrial places, concerning specific environmental aspects.

5.2. Environmental Control: Mitigation and Adaptation

Current climate changes are increasing the temperature of the Earth’s surface and seas, and altering the rainfall patterns. This produces considerable effects, including rising sea levels, risks of erosion, desertification, and the probable growing strength of natural disasters of meteorological origins. The tools, currently envisaged, to face the impacts of climate change are dual: first, to reduce the principal cause, that is, the greenhouse gas emissions, and secondly, to prevent actions of adaptation to the impacts of these phenomena [57]. Regarding the second type of action (the adaptation), post-extractive areas can have salient application possibilities, with minimal interventions, to provide answers to future climate challenges, making the territories less vulnerable. This method aims to prevent the risks and the negative consequences to create economic benefits and to decrease the damage to ecosystems, human health, assets, and infrastructures [58].

The concentration of greenhouse gases in the atmosphere is the principal factor that causes a substantial increase in temperature and rainfall. Different problems can include floods, wildfires, and melting glaciers.

The dismissed quarries often present particular features to adapt them to climate change and to control the risks. For this reason, after their exploitation, they can be reused for water storage in the case of fire emergencies, drought, irrigations, or for other agriculture uses, taking advantage of the capacity of the reservoir [59,60]. Unfortunately, not all quarries are suitable for this conversion, only those with special conditions: appropriate dimensions and typology of the reservoir, water volume, soil permeability, capacity of the discharge of water on the walls, loss of water from evaporation, the position of the quarry, and its distance from the community.

Among the numerous studies focused on this theme, the work HIDRARCHY+ in the Veneto territory (Northern Italy) is particularly sensitive to climate changes. The quarries located in this area became reservoirs to mitigate the variations of the hydric system. On the one hand, they are storage areas for the dry season and the drought periods, and on the other hand, they represent the buffering and infiltration structures against flooding (Figure 8a) [61]. The realised recovery interventions in this perspective were rather rare until now.

Concerning flood problems, there were two significant projects made in the Chicago area: Henry Palmisano Park and Chicago’s Calumet Deep Tunnel in the Thornton Quarry. The first is a recreational park conceived in a multifunctional and adaptive manner; this park also serves as a buffer in flooding situations [62]. The space is capable of containing 5.56 million gallons of water using bioswales, wetland cells, and a retention pond, and it saves 10.5 million gallons of potable water by using native prairie plants, which requires no irrigation (Figure 8b).

The second work was conceived within one of the biggest quarries in the world, transformed in a stormwater detention structure. It is linked, through channels systems and tunnels, to the south

metropolitan area of Chicago and the suburb of Cook County (Figure 8c). Apart from reducing stormwater flooding and damage, and removing occasional sewage infested overflows from Chicago's streets, the Thornton Quarry project is also for the benefit of much of Chicago's remaining waterways, the city's stream, rivers, and lakes, through diverting sewage tainted water. In a city in which the Illinois Environment Protection Agency believes sewage overflow to be the "water quality issue of today", this is a massive boost [63]. The quarry will be the largest control reservoir to prevent floods, with an estimated capacity of 7.9 million gallons. Finally, Atlanta's Westside Park, in the former Bellwood Quarry, can also be cited. This represents one of the greatest examples (still in progress) of a water reserve container to avoid drought, and it is part of the new program of hydric supply for Atlanta city. The pit will also be part of integrating a large recreational park (Figure 8d).

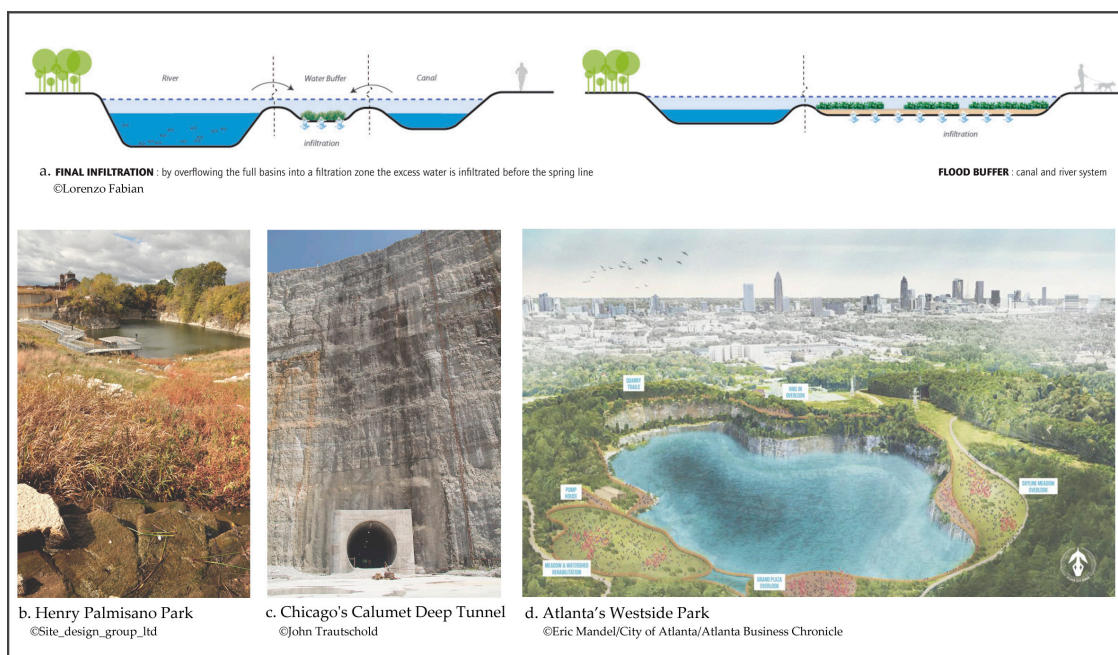


Figure 8. Selected projects related to environmental control.

5.3. Microclimate

The extraction sites normally constitute components of discontinuity in the landscape. This disconnection is the consequence of multiple factors, from morphological to vegetational. The physical elements considerably affect the microclimate conditions of the examined area and its surroundings. For instance, rock landscapes, without vegetation, provoke a conspicuous enhancement of the temperature, and a terraced system significantly increases the sunny surface exposure of a quarry. Therefore, the most relevant features of a place, as aforementioned, are related not only to the shape of the ground, but also to the superficial structure, its composition, colour, and the presence or absence of flora and water. These critical characteristics influence the local meteorological processes and, consequently, the vocation of the transformation of the area, for instance, to the possibilities connected to agriculture fields or the creation of habitats and shelters for native species.

It appears pertinent, at this point, to refer the case of the ancient archaeological site known as "the sacred valley of Moray" in Peru, where unusual Inca ruins exist on an upland of 3500 m of altitude (Figure 9a,b). They arise, morphologically, as huge circular terraced depressions, in which the space between them has a deep of 30 m. The more probable use of these depressions was that of quarries and, successively, as a massive open-cast agronomic laboratory, due to the singular features of the site. In this respect, their orientation relative to the sun and wind generates a consistent disparity of temperature of about 15 degrees C° from the upper to the lower part. This vast thermal variation was used by the Inca

to naturally investigate the effects of diverse climate conditions on their cultivation [4]. This notable open-air laboratory offers a glimpse of the science developed by this civilisation, now disappeared [64].

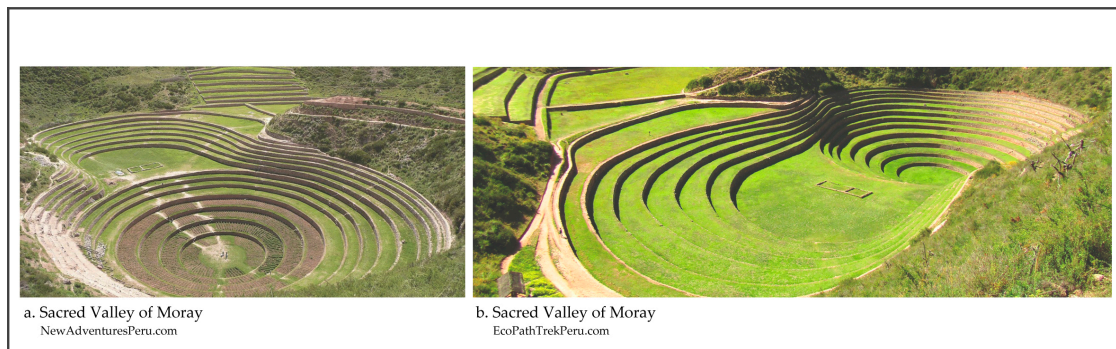


Figure 9. A selected project related to microclimate conditions.

5.4. Biodiversity and Geodiversity

Based on the previous considerations, we found that the places altered by natural disturbances presented great potential from the ecological point of view and also represented real "containers" of rare biodiversity [65]. Many geological faults become ecological corridors and spaces of connectivity, shelter and biological transit, ensuring the survival of particular biomes. This finding suggests that the modified areas, through the extractive activity, can generate other repositories of biodiversity. If adequately planned, the open cast quarries can contribute to the creation of new habitats for flora and wildlife [66].

Regarding this specific vision, numerous environmental studies conducted in France and Germany have demonstrated that some rare protected species find refuge in the ancient extraction sites. Part of the cited research, concerning 35 French stone quarries, highlights the presence of new species within these former industrial pits, such as birds, amphibians, and reptiles, including rare and endangered species. Thus, if there are certain context conditions, the protection of biodiversity can be considered meaningful [4]. Two significant projects that promote this conception are the Brick Pit Ring in Australia and Zanderij Crailoo in Holland.

The Brick Pit Ring is the last material evidence of a vast working industry at Homebush Bay, in Sydney. It is archetypal and primitive, raw, deprived, and transformed. The Brick Pit is first a place of exceptional human effort, now arrested, and it is a portrait of the altered land through use. Equally, this is a place of adaptation where new sustainable technologies replaced a leftover industry, as well as a refuge for the rare and endangered species, such as the green and golden bell frog. The architects, Durbach Block, have valorised this place, conceiving a large recreational aerial walkway, with a circular shape, which serves for outdoors exhibitions and as an observatory of the mentioned species.

The Ring Walk, located twenty meters above the brick pit floor, gives the area an original urban connection and presence within the Sydney Olympic Park. A simple ordering structure, this circular walkway facilitates access to the pit, recognising the fragility of the environment and the pure form. The consistent level of the ring also expresses the diverse depths of the excavation. The Ring Walk allows for both a 10-min walk and a longer layered experience, through wide and shaded sections of the platform. The exterior surface is a colorful screen, an exhibition of mesh and glass panels. The ring, thanks to the presence of an audio guide, provides visitors with different perspectives on the history of the place and its use as a wildlife refuge. The steel structure is a slender and delicate intervention within the massive roughness of the pit and it appears to tip toe across this fragile spot (Figure 10a) [35].

Zanderij Crailoo is, today, a natural reserve, developed close to the Dutch railway. This area of 65 hectares originally represented the perfect place to extract sand. The industrial site was converted, after its exploitation, in a multifunctional area having an ecological overpass next to the railroad. This green corridor, 800 m long and 50 m wide, provides safe passage of the wildlife from side to side

of the reserve, bisected by major roadways (Figure 10b). Rather than to try their luck with the traffic, native populations of deer, wild boar, and the endangered European badger can wander across on one of these designated wildlife bridges that was planted to simulate the surrounding environments [67]. Therefore, structures like Natuurbrug Zanderij Crailloo are exciting examples of the union between conservation efforts and architectural innovation [68].

The concept of biodiversity, jointly with the notion of geodiversity, forms the natural diversity of a precise area. The term "geodiversity" describes the range of geological, geomorphological, pedological, and hydrological features of a place [69]. The extraction activity is closely linked to the physical characteristics of the minerals from mining. Quarries provide many of the most valuable geological exposures and are, therefore, a vital resource for geological education, training, and research. The utilisation of this resource, at the discretion of quarry operators, may range from the involvement of schools and local communities in discovering and understanding their local, natural heritage, to more detailed scientific research and the conservation or recording of relevant geological evidence [70].

In this respect, excavation reveals sedimentary layers that would otherwise be unnoticed. Excavation can also show rare situations, attractive for scientific, educational, and scenographic value. The various elements, in some cases, can present peculiar geomorphological qualities, such as the shape, the colour, the process of sedimentation, geological discordances, layer relations, and fossils. Considerable dinosaur tracks, for instance, have been discovered in a quarry in South Tytherington, in England. For this purpose, the geomorphological components heavily affected the definition of an extractive landscape and, as such, they are part of the local heritage. A remarkable number of projects have recently persevered the objective of valorising and preserving the geodiversity peculiarities. Several of these projects provided only actions of protection of the relevant parts, improving the safety and accessibility and establishing educational and informational paths dedicated to the geodiversity.

Volcano Croscat, in Garrotxa (Spain), is one of many examples that singularly interprets this notion. The natural park of La Garrotxa Volcanic Zone is an area of magnificent geological, botanical, faunistic, and landscape value and, despite the presence of human activity, its natural environment has been well-preserved. This protected area includes about 50 stored volcanic cones, which manifests a wide variety of Strombolian and phreatomagmatic volcanic outputs. The volcanic activity, combined with the humid climate aspects of this space, gave rise to fertile soils and, consequently, a vast range of biodiversity. Since its declaration as a natural park in 1982, it has become a famous attraction for local and foreign tourism.

The recovery methodology of the quarry overthrows the negative thought of "hurt", on the contrary, it has emphasised the potentialities instead of being "healed". In this way, the enormous cut in the hill, made by the extractive industry, has been conceived as an educational activity, thanks to its geological exceptionality. This damage permits the observation of the interior geological structure of the volcanic cone, as if it was a section of a drawing (Figure 10c). La Garrotxa Volcanic Zone is a fitting case study to investigate the impact and sustainability of geo-tourism on preserved volcanic land, as it has allowed the transmutation of a poorly known territory into one of the most famous and most visited geo-sites of the Catalonia community.

The protection of this volcanic area symbolised the end of quarrying actions that significantly destroyed most of its volcanoes, but also produced a chance to increase the zone for tourism. Geo-tourism is a growing business of our society, a sustainable type of tourism based on an interdisciplinary combination of the tourism between industry and the maintenance of the geological heritage. In parallel, this improves the economic and social expansion of local communities. La Garrotxa Volcanic Park proved that using geo-conservation as a means for sustainable tourism is a beneficial strategy. If well managed, this strategy can bring economic and social gains to the area, not only in tourism but also in the global image of the territory [71].

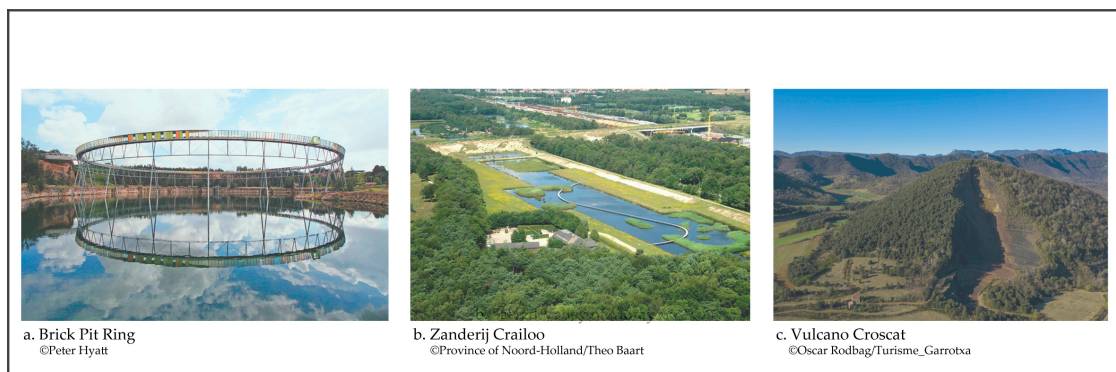


Figure 10. Selected projects related to biodiversity and geodiversity aspects.

6. Conclusions

This article focused on human activities that have strongly influenced our environment. The present work discussed the extraction industry, which mirrors the activity that has caused, and still causes, changes in the land. As the paper has shown, after the exploitation, it is important to transform these industrial and abandoned places to something with architectural and environmental value. Numerous and notable typologies of recovery exist, but in this work, we mainly promoted those belonging to the architectural field, analysing the subsequent environmental implications. Through regeneration strategies, the previously devastated industrial territory acquires a new aspect, function, and meaning.

Quarry spaces become the location of various architectonic scenarios, and, according to the typology of the excavation and its main features, they incorporate a wide range of structures and uses. Quarries have been transformed into large public parks, botanic gardens, natural areas of considerable environmental value, auditoriums, tourism buildings, infrastructures, shopping malls, cemeteries, and many other leisure areas. In addition to conferring a new life to the "dead" territory, this aspect affects the economy of the place where the quarries are located and the policy of land consumption.

Most of the time, the extraction of material from quarries involves discarding a considerable amount of it. This quantity is abandoned at the side of the pit and accumulated in piles of rejected material. Due to their vast dimensions, the waste heaps are considered to be destructive elements of the landscape that cannot be demolished or stored elsewhere due to economic factors. Not including these accumulations of wastes in the process of regeneration of a quarry represents a significant disadvantage. On the contrary, they could be integrated into any typology of recovery to complete the process and respect the theory of the circular economy.

In this regard, it is necessary to underline that this literature review article is only a minor part of the broader research focused on innovative strategies of quarry rehabilitation. The future directions of the current investigation suggest replacing not only the former industrial pits, but also the gigantic heaps of remains located at their side, linking the two components [28]. This study is also concerned with the Anticlinal of Estremoz, in Portugal, consisting of an area of 280 km² formed by approximately 200 marble quarries, each of which is flanked by an enormous pile of wastes (about 15 m high). These giant mounds of remains symbolise a distinct sense to requalify the devastated landscape and to reuse the rest in situ [72]. They are the principal factors to promote tourism in the place, through the addition of new structures between, above, and inside them. These interventions will be connected to the inactive quarries and they will be incorporated into the surrounding landscape.

Based on these innovations, the current review, through the conception of the matrix of schemes related to the different and existing recovery typologies of a quarry and their discussions (previously illustrated), constitutes only the starting point on which to add, in future publications, new methodologies of rehabilitation, never before experienced. In this way, our research aspires to

produce new issues for future investigations (in both the scientific and practical sector) related to the inclusion of the discarded material in the recovery interventions of a quarry.

Author Contributions: Conceptualization, K.T., methodology, K.T. and M.A.; investigation, K.T.; writing—original draft preparation, K.T.; writing—review and editing, K.T., M.A. and J.C.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by FCT—Fundação para a Ciência e a Tecnologia, grant number SFRH/BD/133777/2017.

Conflicts of Interest: The authors declare no conflict of interest.

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