The integration and reclamation of quarries

António Pliz
University of Évora
Department of Landscape, Environment and Planning-
University of Évora
Évora, Portugal
antonio.pliz@gmail.com

Rute Sousa Matos
University of Évora
Art and Art History Investigation Centre (CHAIA) -
University of Évora
Évora, Portugal
rsm@uevora.pt

***Abstract* - The reclamation of quarries can be characterized as a process of local intervention within the context of visual management, landscape conservation and landscape valuation.**

Through the process of reclamation, not only is it necessary to engage it with the existing legal framework, it requires an understanding of the landscape context, which allows a detailed assessment of the potential visual impacts and further to propose mitigation measures.

In order to make a right assessment of the landscape vulnerabilities, the article presents a methodology of analysis and interpretation of the landscape's main components, as well a structural landscape characterization and description concerning the visual impact assessment caused by the quarries. The goal of this method is to provide information about the visual dimension of the landscape in order to propose the most suitable options of rehabilitation and integration of the quarries on a specific landscape.

Keywords-Landscape; Reclamatiom; Quarries; Integration

I. Introduction

This work emerges from the need to create a suitable methodology of landscape reclamation applied to quarries, with the intention to approach the reclamation plans to the local reality and to the principles established by the European Landscape Convention, mainly those concerning the "Landscape quality objective", the "Landscape protection" and the "Landscape management" [6].

It is very important to predict and assess the degree of alteration introduced in the landscape caused by the quarrying activity. It will make it possible to understand the vulnerabilities of the landscape by assessing its visual sensitiveness to changes, and to propose mitigation measures that will combine the development of the quarrying activity as an economic activity with several environmental issues in order to restore progressively the natural values inherent to the landscape character.

Therefore, it developed a methodology with several criteria of analysis and assessment including a thorough description of the existing landscape components such as, the topography, the vegetation, the water, and the anthropic elements, which provide an assessment of the potential visual effects on them as on their combination caused by the presence of the quarries. Based on the compiled information concerning the landscape components, the next step is to assess the capacity of visual absorption of the landscape to changes, to understand the effects of the presence of quarries in the visual quality, and to assess the visual sensitivity of the landscape. This will ensure and provide an important contribution to the landscape visual quality management throughout the process of reclamation of ecosystems and habitats of flora and fauna.

The path to achieve the reclamation goals was developed under a complex and deep landscape study, which is now presented in short. The study describes the most important components and their combination that compose the landscape structure.

The approach concerning the structural organization of the landscape and the awareness of how the landscape mosaic is organized, allows for a more accurate assessment of the visual absorption capacity, the visual quality, and the visual sensitivity of the landscape. The landscape reclamation plans, the relation with numerous options of reclamation measures, alongside with the knowledge of the main impacts and the possibilities at all levels of potential land uses, will enhance the possibilities of ecosystems rehabilitation and potential recreational land uses.

The importance of this methodology allows design teams to assess relevant information concerning the landscape qualities and weaknesses, which will help to define the best reclamation measures in order to propose the most suitable mitigation measures and achieve the best integration of the quarries in the landscape.

It is important to mention that this methodology was already applied to practical cases such as, a quarry of industrial granite and a quarry of ornamental granite. Its success and efficiency is currently being tested.

II. Methodology

The work method involves 4 work phases, which describe the process of analysis and landscape characterization. This process settles on the physical dimension of the landscape.

Phase 1 corresponds to an understanding and characterization of the landscape structure by describing the existing matrix, patches and corridors. The landscape structure approach is based on the description of the main landscape components (geomorphology, vegetation, water and anthropic elements). Specific maps back the elements and the structural characterization such as slope maps, hypsometry maps, stream and ridge maps, aspect maps, land use maps, landscape units and subunits maps.

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Based on phase 1, phase 2 consists of the characterization and assessment of the landscape visual absorption capacity (VAC) [8] [14], visual quality (VQ) [1] and visual sensitivity (VS) [11]. The assessment of the VAC is articulated with the characterization of the zones of visual influence (ZVI) [11], once it is necessary to know what areas are visible or not only by using topographic information. This will allow landscape architects to define and assess the visual absorption capacity (VAC) [8] of the landscape, where it is possible to identify the most sensitive areas from where a quarry can be seen.

The visual quality (VQ) is assessed by using mixed methods, which are composed of the direct and the indirect methods. The direct methods are related with the direct observation of the landscape, which is included in a process of perception of the landscape on its vertical dimension, horizontal dimension and distance, allowing the human brain to receive a set of information concerning depth, color discrimination, etc. [15]. This method is also related with the preference for certain types of landscapes. The preference for some types of landscapes is determined by the need to understand and explore them, which depends on coherence, legibility, complexity and mystery [12]. The direct methods are very subjective and depend on the observers background, motivations, culture, geographic origin, etc. [17].

The indirect methods are related with the decomposition of the landscape components (landforms, water, vegetation and anthropic elements) in order to assess the visual quality of each one of them, based on the direct observation.

The assessment of the visual quality of each landscape patch, corridor and matrix is done by using math calculations with the Geographic Information Systems (GIS), in which several criteria concerning the topography visual quality, the vegetation visual quality, the water visual quality**,** and the anthropic elements visual quality are introduced with different values.

After crossing the VAC map with the VQ map it is possible to assess and identify the overall landscape visual sensitivity (VS) [7] through the visual sensitivity map.

Phase 3 (visibility analysis) begins with the definition of the most sensitive visibility points. This analysis provides an understanding of the degree of exposure from a key point [11] towards a development according to the visual sensitivity map. In addition**,** the cross between the sensitivity maps and the main locations where people stand and move, called “sensitive receptors” [11], will identify the most “sensitive points” from where the visibility is higher. The “sensitive points” correspond to a specific location from where it is possible to gaze a quarry. The “sensitive receptors” [11] correspond to locations or areas of flux and movement of people such as paths, roads, highways, etc. and standing areas such as resting areas, housing areas, touristic developments, archeological sites, monuments, etc.

Phase 4 corresponds to the sensitive points and the sensitive receptor’s analysis. This analysis uncovers the most exposed observers, the locations with higher visual sensitivity and their potential of visibility. The sensitivity concerns the locations of observation or “sensitive receptors”, where the observation points are located. These points are ranked accordingly with a higher or lower number of users.

The outcome of the process of analysis and assessment of the landscape, allows us to understand the types of impacts caused by the quarry and the potential land uses, in order to design the Landscape Reclamation Plan.

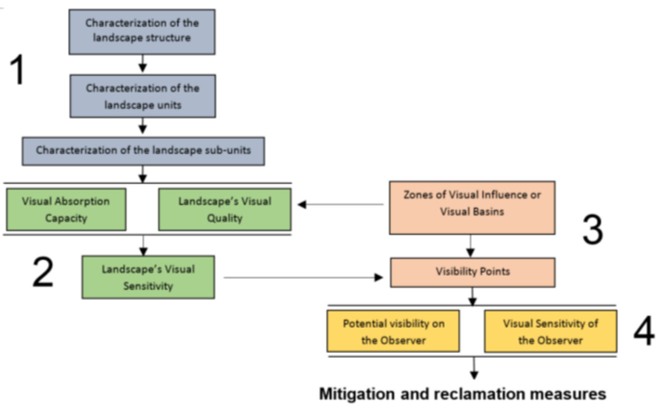

Figure 1 – Chart of methodology

III. Analysis and Characterization of the Landscape Structure

To understand the landscape structure it is important to know which components and elements compose it, as well as the setting that defines its structure in a deeper analysis of the landscape [7].

Aside from the different designations of the landscape elements from author to author, the classic theories of landscape ecology defines them as biotopes or ecotopes, which vary on the scale of approach as long as they present homogeneity in their interior.

On the course of the landscape element concept, introduce the matrix, patch and corridor system, as way to classify several landscape elements [9]. While the patches form the mosaic, the corridors form a web and the outcome of their combination results in a certain landscape pattern [7].

In this work, the identification of the landscape elements is based on the aerial photography and on the land use map (COS2007). From the crossing of both of those maps it is possible to recognize the patterns which will define the landscape subunits. The landscape elements can be big rock formations, streams and their margin vegetation formations, hedges, forests, groves, agriculture areas, built settings, urban areas, roads, ponds, etc. which will endow the landscape with intrinsic visual qualities [4] “Fig. 2”.

Figure 2 – Example of a three-dimensional terrain model with the topography and the existing vegetation

The landscape structure consists on the spatial relation between distinct ecosystems or the landscape elements [13].

That can be translated on the distribution of energy, materials and species considering their dimension, form, number, type and configuration of the ecosystems, that results on a particular configuration of the land use, vegetation, building presence and water presence, which are the landscape components, providing a specific character [7] "Fig. 3". The geomorphology supports and shapes those elements.

The structural analysis not only allows us to understand the landscape, relatively to its composition and organization, but to understand its vulnerabilities towards the modifications caused by the quarries. It makes necessary to adapt the mitigation solutions according with the degree of modification introduced in the landscape.

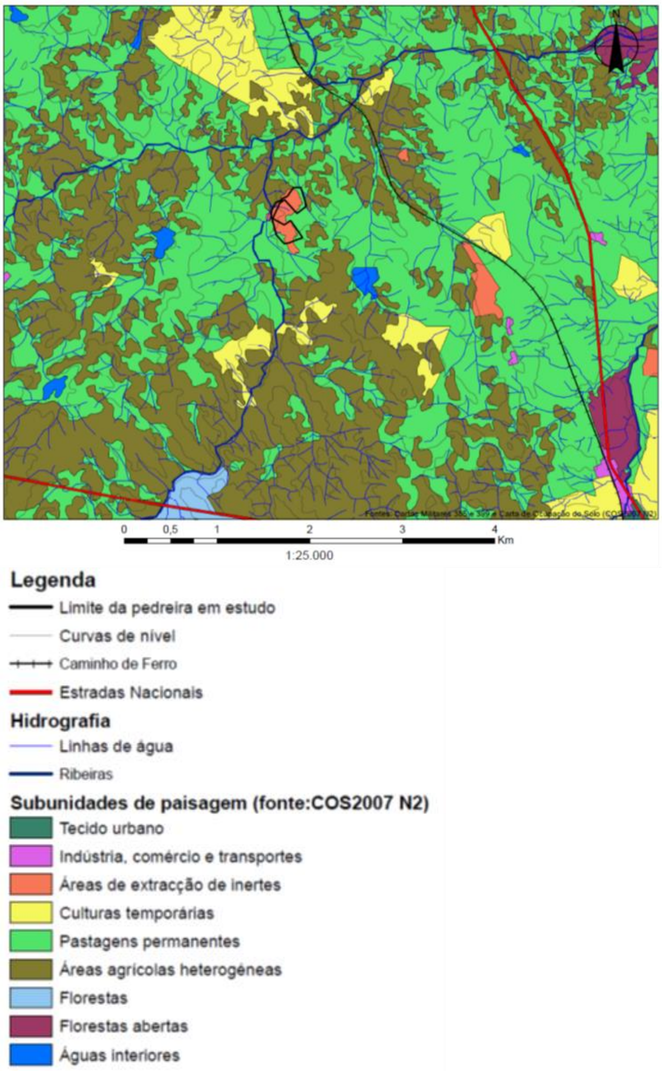

Figure 3 – Example of the Landscape Synthesis Chart, with the landscape sub-units.

IV. Analysis and Visual Characterization of the Landscape

In order to do the landscape visual analysis and characterization one must determine the study of the visual influence zones[a], the visual absorption capacity[b] "Fig. 4", the visual quality[c] "Fig. 5"., the visual sensitivity of the landscape[d] and the visibility points.[e]

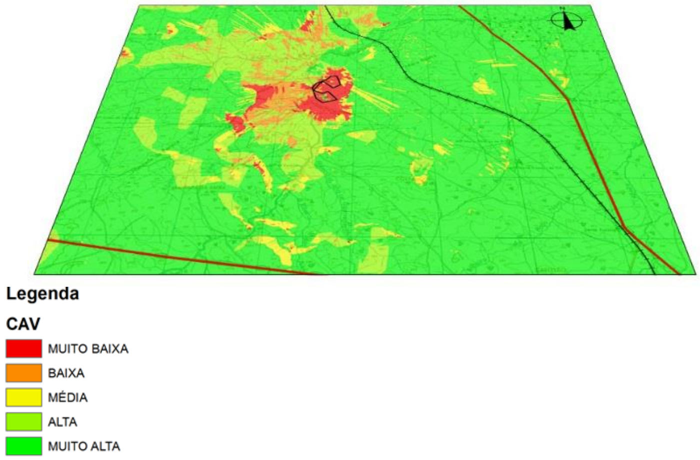

Figure 4 –Visual Absorption Capacity (VAC) map.

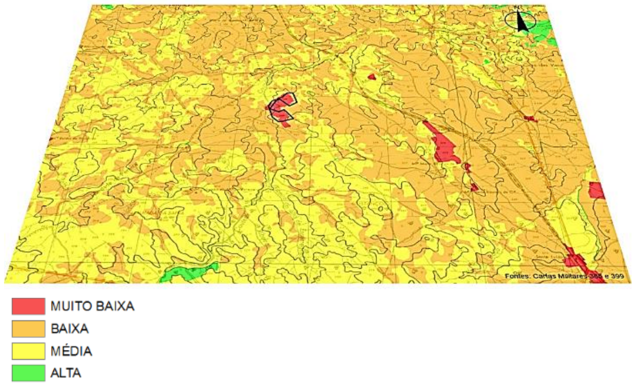

Figure 5 –Visual Quality (VQ) map.

[a] This concept is present on the "Guidelines for Landscape and Visual Impact Assessment" and it allows the identification of the most visible areas towards the source of the visual disturbance.

[b] The visual absorption capacity allows to assess how a landscape can bare a certain visual change and how it influences the landscape visual sensitivity caused by human action. *In* Canter, 1996.

[c] The visual quality is done at the landscape components level, considering the organization of the natural and the artificial elements. The visual quality can be interpreted in terms of its "appearance" as the visible expression of the geomorphology, vegetation, soil use and humanization. It results from the interaction of the natural, the historic, the cultural, the economic and the political processes [10].

[d] The visual sensitivity is achieved by crossing the degree in which a particular kind of landscape is able to absorb a change, with the visual quality of the land use and its inherent patterns, landscape scale, opening/closing of views, distribution of visual receptors and the landscape value [2].

[e] The landscape visual sensitivity comes from the need to know and assess the potential effects of the proposed change in the landscape, in order to identify the most visually exposed points towards the visual impact source. From the assessment of the landscape visual sensitivity, it is possible to define the best mitigation strategies, in order to get a reduction of the level of the quarries visual impact.

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This phase of the visual analysis it is accomplished with the visual framing of the quarries in the landscape, by assessing the potential effects on the quality and sensitivity of the landscape. By knowing the most sensitive areas it is possible to propose and design the best solutions of reclamation. These solutions should combine the mitigation of several impacts[f] related to the characteristics of the quarries and therefore to define a strategy concerning the preferred land use[g]. The intention is to implement the general conditions for the ecosystems to regenerate. The final goal is to restore the natural vegetation, the surface drainage, the shape of the terrain, which will have positive implications on the visual quality of the landscape.

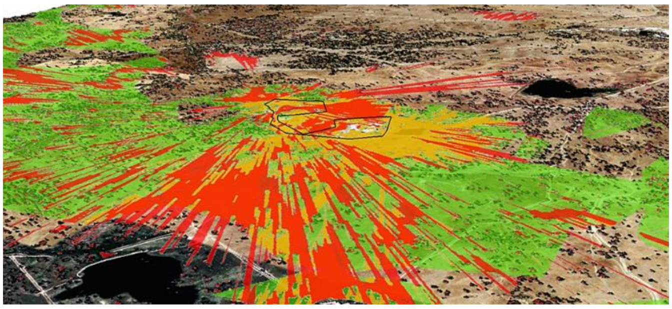

Figure 6 – Representation of the Visibility Zones. The green zones correspond to the Zones of Visual Influence (ZVI). The red zones correspond to the visible areas from the top of a 12m height pile of waste. The yellow zones correspond to the visible areas at ground level from the property perimeter.

V. Reclamation Plans

The reclamation plans are general divided into 3 phases. The first phase corresponds to the construction or preparation phase, which includes the location of the supporting structures as the equipment directly related with the quarrying activity. This phase is also highlighted by the deforestation and the removal of the top soil. It is common to propose safety measures for people such as fences and specific measure of protection of the top soil layer, mostly with grasses.

The second phase corresponds to the phase of exploitation. This phase marks the beginning and evolution of the extraction operations, where normally, are proposed several visual impact mitigation actions like ditches to control surface water runoff and vegetation screens “Fig. 7”.

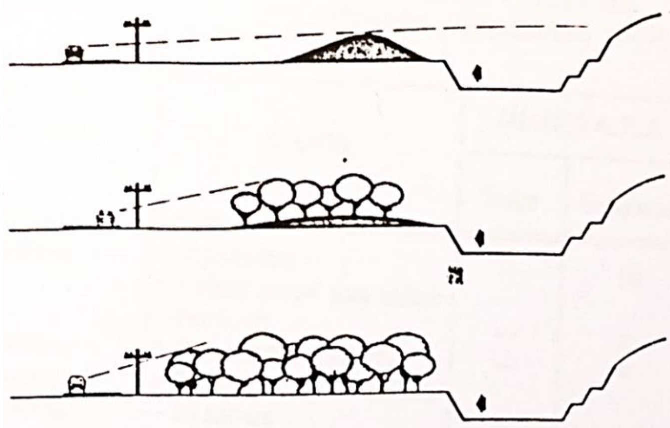

Figure 7 – Types of Visual Barriers.

The last phase is the reclamation phase, which can be done simultaneously with the phase of deactivation. This phase marks the end of the exploitation and the execution of measures such as the reinsert of the topography and top soil, the installation of the vegetation and the removal of the quarrying equipment. In this phase it is fundamental to equate the main reclamation measures, usually supported by good practice manuals. The support on specific types of manuals concerning reclamation of quarries is due to the lack of references of executed reclamation projects “Fig 8”.

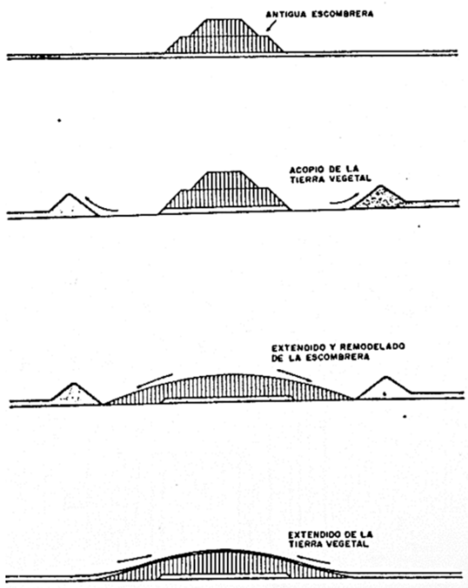

Figure 8 – Example of heap reclamation.

Apart of the existence of several phases, it does not mean that they should occur in different periods, the different phases could occur simultaneously. This method of progressive reclamation [3] will allow a more effective reclamation and faster results. Under several aspects, this strategy of reclamation is the most indicated because it allows the reclamation of the quarry as the exploitation process advances. “Fig. 9”.

[f] From the several negative impacts caused by “open sky” quarries, the visual effects is one of the most sensitive that depends on the exploitation area [5]. The visual changes usually cause changes at the level of the basic visual elements (shape, line, color and texture) regarding the existing landscape. [16]

[g] Urban and industrial uses; intensive recreational use; landfill, agricultural and forestry; intensive recreational and pedagogic use; nature conservation and ecological refuges. [3].

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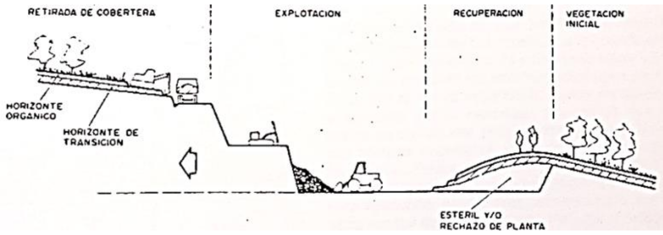

Figure 9 – Example of the progressive reclamation method.

Figure 10 – Visual simulation of the reclamation plan.

Besides the legal modifications and the higher requirements by the governmental authorities, the number of executed reclamation plans in Portugal is still very low. Considering the final reclamation budget, under the Portuguese laws the stone companies have to pay a fee on behalf of the Portuguese state.

If the stone companies stop their works or abandon the quarry, these fees will provide the financial means to proceed with the reclamation of the quarries. It is a fact that until now and considering the universe of quarries throughout the country, the government has reclaimed a very small number of quarries.

VI. Conclusions

The method that was summarized in this article has been applied in two cases.

The first case concerns the reopening of an industrial granite quarry and the second is the reclamation of an ornamental granite quarry.

Figure 11 – Reclamation Master Plan.

The first case "Fig. 11" it is a demonstration of the use of the method that was completely followed starting with an exhaustive analysis of the landscape concerning its structure, characterization of the landscape units and subunits, landscape visual analysis and assessment. This analysis helped to frame the reclamation plan, which is divided in two phases. The execution of the first phase was proposed for the first three years of quarrying by adopting minimization measures of visual impact through the strengthening and reinforcement of vegetation screens. The second phase was proposed for the quarry lifetime by removing the existing waste pile, the implementation of a drainage system to capture the runoff water, the plantation of several kinds of riparian trees and shrubs near the closest stream and the seeding of a mixture of grassesh of a few areas outside the property, damaged by the quarry. This strategy aims to promote the biodiversity as well to restore ecosystems, such has the flora and the fauna, which were absent by the presence of the quarry [3].

After the end of the quarrying works, it is proposed the minimum fill. The final form of the exploitation hole, which in this case has the shape of a well, will become a water reservoir filled with rainwater. The final lagoon will be accomplished with the accumulation of runoff and rainwater during the rainiest months.

The vertical walls of the quarry are five meters high each and they will be prepared to receive the trees and the shrubs in order to integrate the site within the "green structure".

This plan was developed in 2014 and the phase 1 is in progress. The plantation of the vegetation screens and the mitigation of the visual impacts caused by the opening of the exploitation is in progress and their implementation is under monitoring. The second phase will begin next year where a grinding unit will be assembled at the property to transform the

[h] Generally based on good practices manuals e.g. "Manual de Restauración de Terrenos y Evaluación de Impactos Ambientales en Minería" of IGME in Spain. IGME, 2004.

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materials from the existing waste pile. The process is running as expected and therefore the heritage value, the ecological value, the cultural value and the identity of the landscape is being preserved.

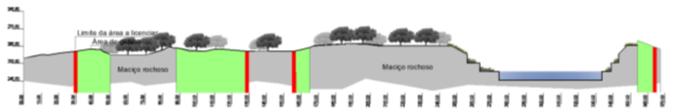

Figure 12 – Profile of the Proposed Reclamation.

The second case “Fig.13” concerns an ornamental granite quarry where the reclamation works started on the year of 2013 and finished in the year of 2014.

The method of assessing visual impacts and the reclamation process was the same as in the previous example.

This quarry had a very short period of exploitation due to the quality of the granite. The excess of fractures and the lack of visual aesthetics of the granite turned impossible to keep exploiting the stone.

Figure 13 – Master plan of the Reclamation plan for the second example.

The company decided then to close the quarry and proceed with the reclamation plan.

This quarry had two separated piles of debris, which were the two biggest sources of negative visual impacts from outside the property. The two main spots affected by its presence were two country houses that were located in the vicinity.

In order to eliminate the negative visual impacts, the reclamation plan proposed to remove the two piles of waste into the exploitation hole.

The vegetation plan was inspired on the existing vegetation patterns and distributions across the property and its surroundings. The plantations were done mainly with *Quercus suber*, once it was the predominant species in the site.

The figures “14 and 15” show the process of filling and the final landforms.

Figure 14 – View of the initial conditions on November 2013

Figure 15 – View of the final landform on April 2014

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