Sustainable exploitation of ornamental limestones in Maciço Calcário Estremenho, Portugal

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Abstract

The Maciço Calcário Estremenho, in Portugal, is a limestone massif where an intense extraction activity of limestone blocks for ornamental purposes takes place in five main quarry clusters. A large extent of this massif, including the exploitation centers, is covered by the Natura 2000 Network PTCON0015 site, which simultaneously corresponds to the Portuguese Natural Park of Serras de Aire e Candeeiros.

As a result of the restrictive measures imposed by the regulations for the protection of nature, conflicts with the extractive industry have persisted for decades.

The present case-study demonstrates that through the dialogue between the extractive industry and the public entities responsible for nature conservation and spatial planning, it is possible to find compatibility solutions that consider the territory's aptitude for the exploitation of mineral deposits and the need to preserve relevant environmental values.

For that purpose, an unprecedented partnership between the environmental authority and an association representative of the extractive sector carried out detailed geological and environmental studies that resulted in a land-use planning proposal for each of the quarrying areas. These proposals make it possible to reconcile extraction with the protection of outstanding biological values and geological heritage.

Keywords

Ornamental Stones, Quarrying, Environment, Compatibility; Land-use planning

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Introduction

Nature alone determines the formation and location of mineral deposits. Hence, extraction of mineral resources can only take place where these deposits occur and, therefore, their sustainable supply to society depends on the land-use planning accessibility conditions, the technical and economic feasibility of extraction, and applicable jurisdiction.

Regardless of whether or not a given resource is deemed essential for society, public concern about the negative effects that the extraction operations might have on the environment and particularly the landscape (e.g., Eser & Luloff, 2003; Mouflis et al., 2008), can ultimately inhibit their development to production (Badera, 2014; Badera & Kocoń, 2015). When the mineral resources are in areas designated for nature conservation the relevance of these issues increases. As a matter of fact, the implementation of many natural parks is based on the existing knowledge about their wildlife values, frequently disregarding the geological support for them. Moreover, the value of the existing or possibly existing mineral deposits in these areas is also overlooked, which in most cases leads to their sterilization. This is because there is a generalized idea that quarrying is incompatible with environmentally protected areas, such as natural parks and Natura 2000 sites, which is contrary to the position of the European Commission on this matter (European Commission & Environment, 2012). Therefore, to ensure access to mineral resources in these areas it is necessary to find solutions to reconcile the mining activity with the protection of relevant environmental values.

In this article we present a case study about the sustainable production of ornamental limestone blocks in a Natura 2000 Network site located in Portugal. It reports the methodology adopted by a project aimed at ensuring the integration of quarrying areas in land-use planning and their management considering the nature conservation needs, inherent to the Natura 2000 Network site.

This Natura 2000 Network site corresponds to a Portuguese natural park (PNSAC – Parque Natural das Serras de Aire e Candeeiros), located in the Maciço Calcário Estremenho (MCE), which is a Jurassic limestone massif, about 150 km north of Portugal's capital city, Lisbon (Fig. 1), being among the most important sites producing ornamental limestones on the globe. Recent data from the Portuguese mining authority point to a production of 1 million tons per annum, corresponding to an income of around 60 million euros.

Background

The MCE's limestone potential as a resource for construction and ornamental stone production has been known for a long time and these limestones have been intermittently exploited for centuries, namely for monuments that are now World Heritage sites (monasteries of Alcobaça and Batalha, Fig. 2). However, the extraction activity from an industrialized and intensive viewpoint

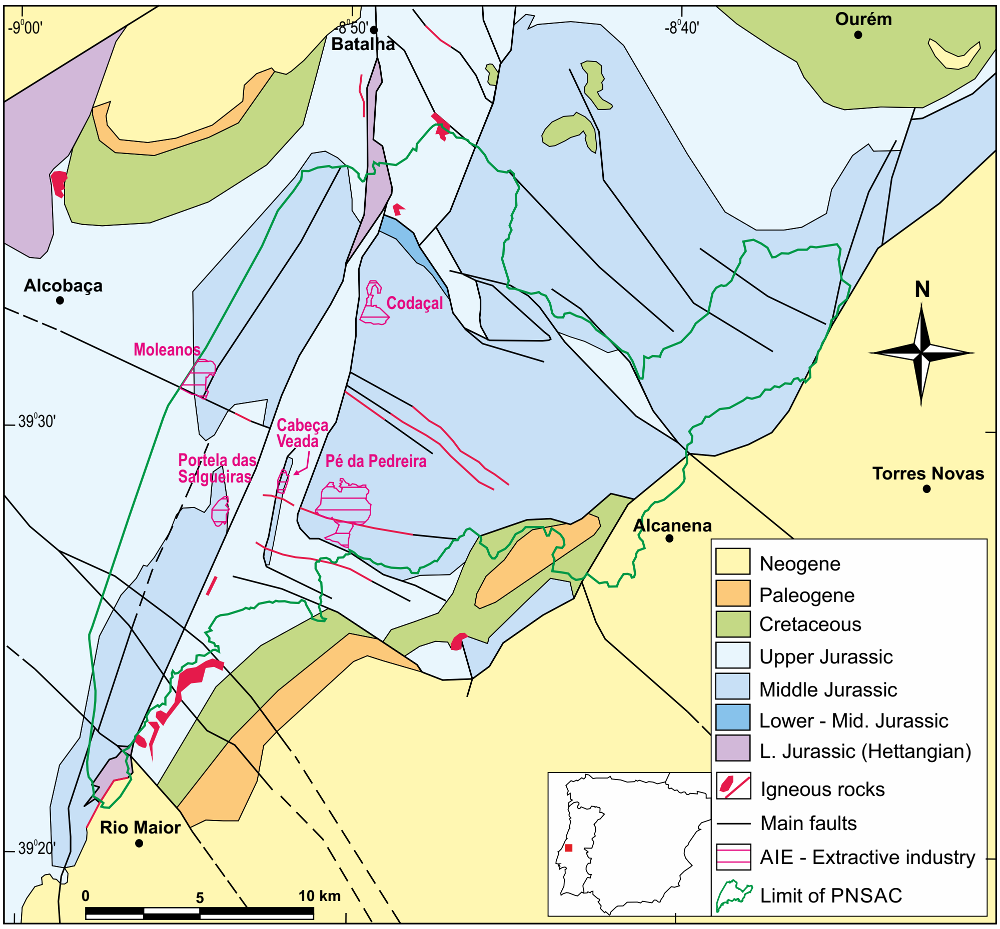

Fig. 1 Simplified geological map of MCE with location of the Natural Park of Serras de Aire and Candeeiros and its quarrying areas

Fig. 2 The monasteries of Batalha (left) and Alcobaça (right). The Monastery of Batalha was erected in commemoration of the 1385 Battle of Aljubarrota and took over a century to build (1386-1517). The Monastery of Alcobaça is a Roman Catholic monastic complex established in 1153 by the first Portuguese king, Afonso Henriques. It is one of the first buildings associated with the Cistercian Order in Portugal and was built between 1178 and 1223. Both monasteries are UNESCO World Heritage sites

Fig. 3 Large limestone blocks produced in Pé da Pedreira. These quarries are equipped with the most modern technological equipment and skilled workers, giving them the hability to produce large quantities of blocks

is relatively recent, having settled since the 1970s. In the middle of the following decade, the activity went into full development, specifically concerning the exploitation of ornamental limestone, due to the combination of a period of economic expansion with technological advances in the extractive sector (Fig. 3).

At that time, in 1979, the PNSAC was implemented, partially covering the MCE area and most of the quarrying sites. Its main objective was to protect the natural characteristics related to the karst morphology and associated wildlife, of which cave-dwelling fauna stands out, and the groundwater drainage network. The existence of specific habitats led, later on, in 2008, to its integration into the Natura 2000 Network (Site PTCON0015 - Serras de Aire e Candeeiros).

The PNSAC's first land-use plan and respective regulation (Portaria 21/1988) did not properly consider the other land-use activities already settled there, namely the extraction of or-

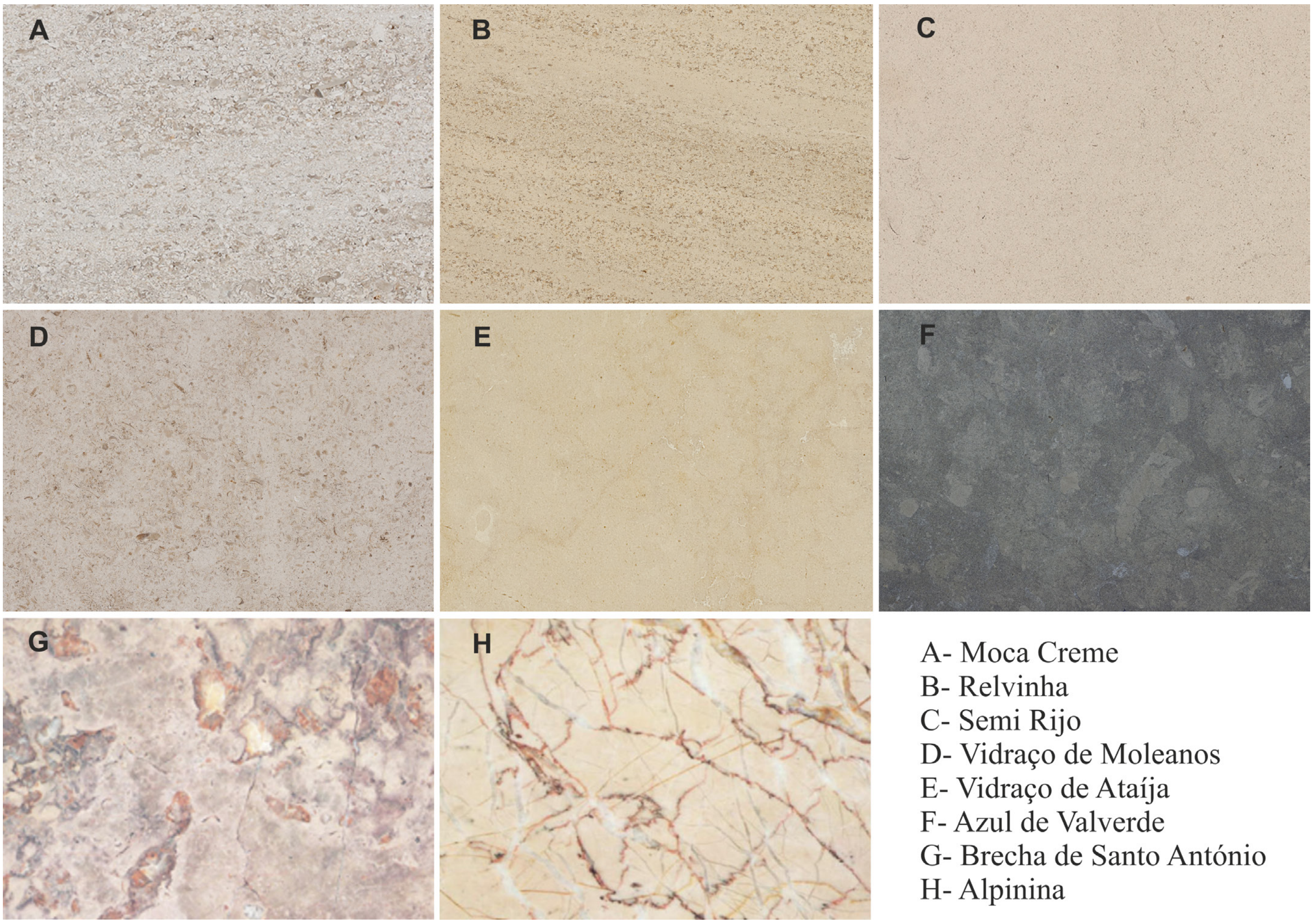

Fig 4 Main ornamental varieties produced in MCE. These are mainly exported to the Chinese market, where they are highly appreciated for building cladding. Since the beginning of the century, the Chinese market has been responsible for purchasing about 90% of production

namental stones. Consequently, several conflicts arose between the extractive sector and the environmental authorities: on one hand, the growing market demand for MCE's ornamental stones (Fig. 4) and the natural desire for economic growth in the industry, on the other, the need to enforce the objectives of nature conservation according to the PNSAC's regulation (Fig. 5).

These conflicts lasted for more than ten years. They only began to decline with the approval of a new PNSAC's land-use plan in 2010 specifying areas for the development of the extractive activity in the five main quarrying sites (Fig. 1), namely, the Cabeça Veada, Codaçal, Moleanos, Pé da Pedreira, and Portela das Salgueiras areas ((Resolução do Conselho de Ministros 57/2010). According to this new plan, these five areas designated for quarrying, formally named Areas for Specific Interventions (AIE), should be subjected to detailed municipal land-use plans aiming to implement compliance measures between the resources rational management and the environmental values protection. It also states that these areas should be the target of integrated exploitation projects, that is, a single mining project covering all quarries in each AIE.

To meet these demands, a project called Sustainable Exploitation of Resources in the Maciço Calcário Estremenho was implemented. It was carried out in the period 2011–2014 through an unprecedented partnership between ASSIMAGRA, the industry association of mining and quarrying (https://www.assimagra.pt/) and ICNF, the Portuguese Nature Conservation Authority (https://www.icnf.pt/). This partnership involved the close cooperation of the Portuguese Mining Authority (DGEG), the Portuguese Geological Survey (LNEG), the municipalities (Alcobaça, Porto de Mós, Rio Maior, and Santarém), a technological center (CEVALOR), and two private consulting companies for engineering and environmental studies (Visa Consultores, Lda., https://visaconsultores.pt/en-2/, and Biodesign, Lda., https://www.biodesign.pt/). The project had a financing support of 30% by the quarrying companies operating in the MCE.

A comprehensive methodological approach

This project had as assumptions that the use and valorization of the ornamental stone resources, along with the MCE's natural heritage, may be important elements of economic improvement for the region, contributing to a better acceptance, and

Fig 5 Examples of PNSAC's natural heritage subjected to protection measures

not the mere tolerance of the extractive industry. In this way, besides being a factor of economic development, this industry will also materialize as a factor of identity and self-esteem for the local population, matching to the current expectations of environmental and social welfare preservation. Aiming to foster the environmental performance of the quarrying activity through its efficiency increase, and the reduction of its impacts, the following key aspects were considered: the definition of strategies for the mining sector's sustainable development; the creation of geological and environmental background information regarding the integrated planning of the quarrying areas; the qualitative and quantitative characterization of the hydrogeological conditions of the MCE aquifer and its monitoring, aiming at assessing its vulnerability regarding the extractive industry; the inventory, characterization, and a management proposal of the vast geological and mining heritage encompassing the ornamental stones, aiming at their joint valorization as identity marks of the region; a Communication and Awareness Program to enhance the extractive activity alongside the conservation of the natural heritage; the definition and implementation of a panel of sustainability indicators to quantify and monitor the extractive activity's environmental, economic, and social performance in the MCE.

Most of these key aspects were considered in the project main outputs, which consisted of a land-use and environmental planning proposal for each of the quarrying areas, together with integrated quarrying projects and respective Environmental Impact Assessment studies, and a general plan for waste management.

In Portugal, detailed land-use and environmental planning at municipal level in rural areas is designated as Intervention Plans in Rural Areas (PIER). The PIER for each quarrying area resulted from a comprehensive approach that followed the various steps depicted in Fig. 6. It was a transparent process, frequently monitored by all the entities involved.

To achieve a land-use planning proposal for each one of the five AIE, the methodological scheme presented in Fig. 7 was followed. Two main stages stand out: characterization and diag-

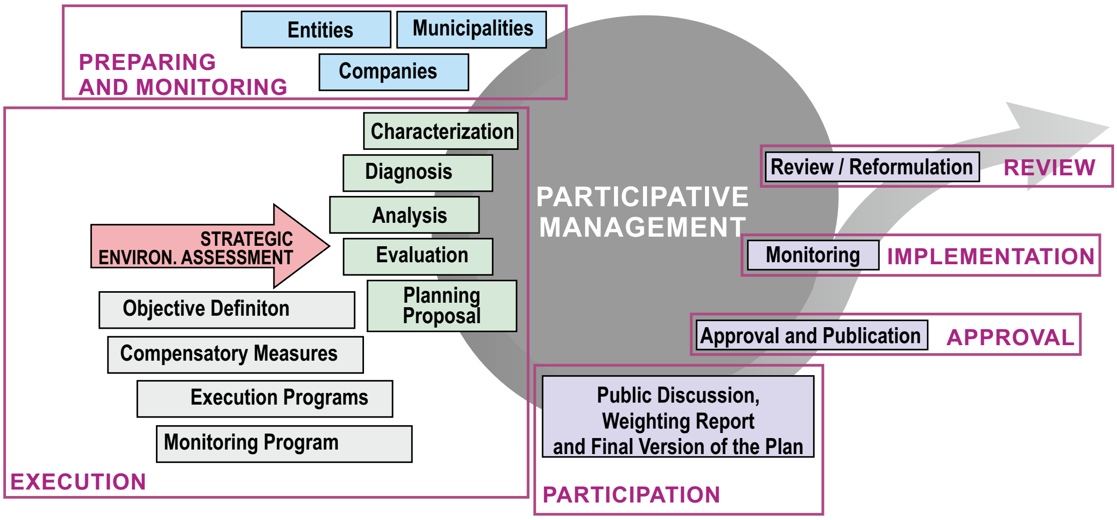

Fig 6 The various steps considered for the preparation of the PIER proposal for each of the considered areas

nosis, and concretization of the planning proposal itself. Characterization and diagnosis studies were carried out at three levels:

1. analysis of the land-use planning tools in force for each AIE to guarantee compatibility and compliance with the higher-level tools (e.g., the Sectoral Plan for Natura 2000 Network) and support a proposal for alterations to the current environmental protection regime;
2. public easements and restrictions to identify their consequences and the necessary administrative procedures;
3. biophysical characterization aiming to create a zoning, which enlightens the compromise between the exploitation of resources, ecological values, and environmental sensitivity.

The characterization and diagnosis studies, particularly the geological and environmental ones, were the basis for all the subsequent evaluation and decision-making process steps.

Evaluation methodology and results

After all the data had been acquired and analyzed, the evaluation process started. From here on, this paper focuses on the process itself and the achieved results, notably those concerning geological, environmental (particularly those of a biological nature), and geological heritage data. For the case of the studied AIE, these are the most relevant.

Geological evaluation

The studies involved the geological characterization of the outcropping rocks and their mapping at 1:2000 scale (the scale legally required for the elaboration of the PIER), drilling with continuous core recovery (validating and complementing the geological interpretations), and a general fracturing survey. These studies allowed the mapping of the most favorable areas for the extraction of large blocks of limestone, within each AIE (Fig. 8).

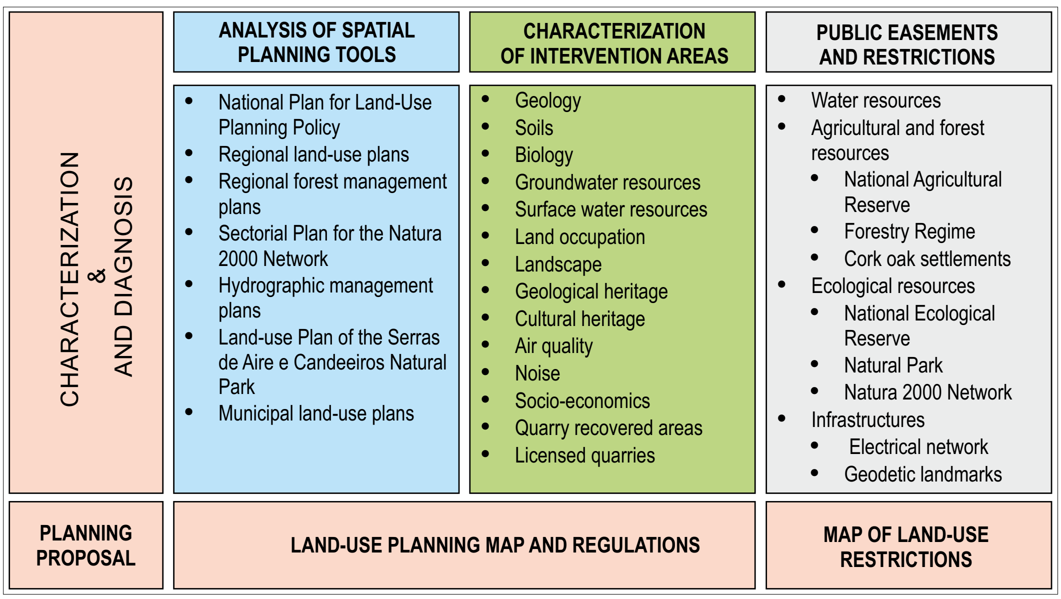

Fig 7 Information components obtained for the preparation of a rural land-use planning proposal for the each AIE

Environmental evaluation

The environmental studies included the characterization of soils, biology, climate, surface and groundwater resources, landscape, air quality and noise. However, the greatest emphasis was on biological characterization and mapping of the flora species holding conservation value, habitats recognized from the vegetation units and flora species, ecologically relevant wildlife species, and biotopes retrieved from the mapping of habitats and soil use.

The mapped areas corresponding to these four ecological components were then subjected to distinct valorization processes: one for the valorization of the habitats / flora components, and other for the biotopes / wildlife components. This allowed obtaining distinct valorization zoning maps of flora and wildlife values. Finally, their aggregation led to a biological rating map for each AIE (Fig. 9), in which the natural heritage value is reflected in an ecological relevance variable ranging between Outstanding and Low, yielding the results presented in Table 1.

Geological heritage evaluation

Geological heritage at MCE encompasses geological, mining, and geomorphological sites of interest. Their inventory was not restricted to each AIE because the relevance of each site cannot be taken individually, but in the context of the entire MCE. As an example, the occurrence of a particularly interesting outcrop within an AIE is not relevant if that type of outcrop is very common in the MCE.

The characterization and evaluation of heritage sites was based on templates specifically developed for the PNSAC, according to a geoconservation methodology developed by Brilha (2005, 2006) and Brilha et al. (2010).

Each site was ranked quantitatively considering its scientific value, vulnerability, and potential use, enabling the establishment of geoconservation priorities. Moreover, to reconcile the extraction of ornamental stones with the conservation of these geosites, they were systematized in three classes of qualitative value: outstanding value, high, and medium/low.

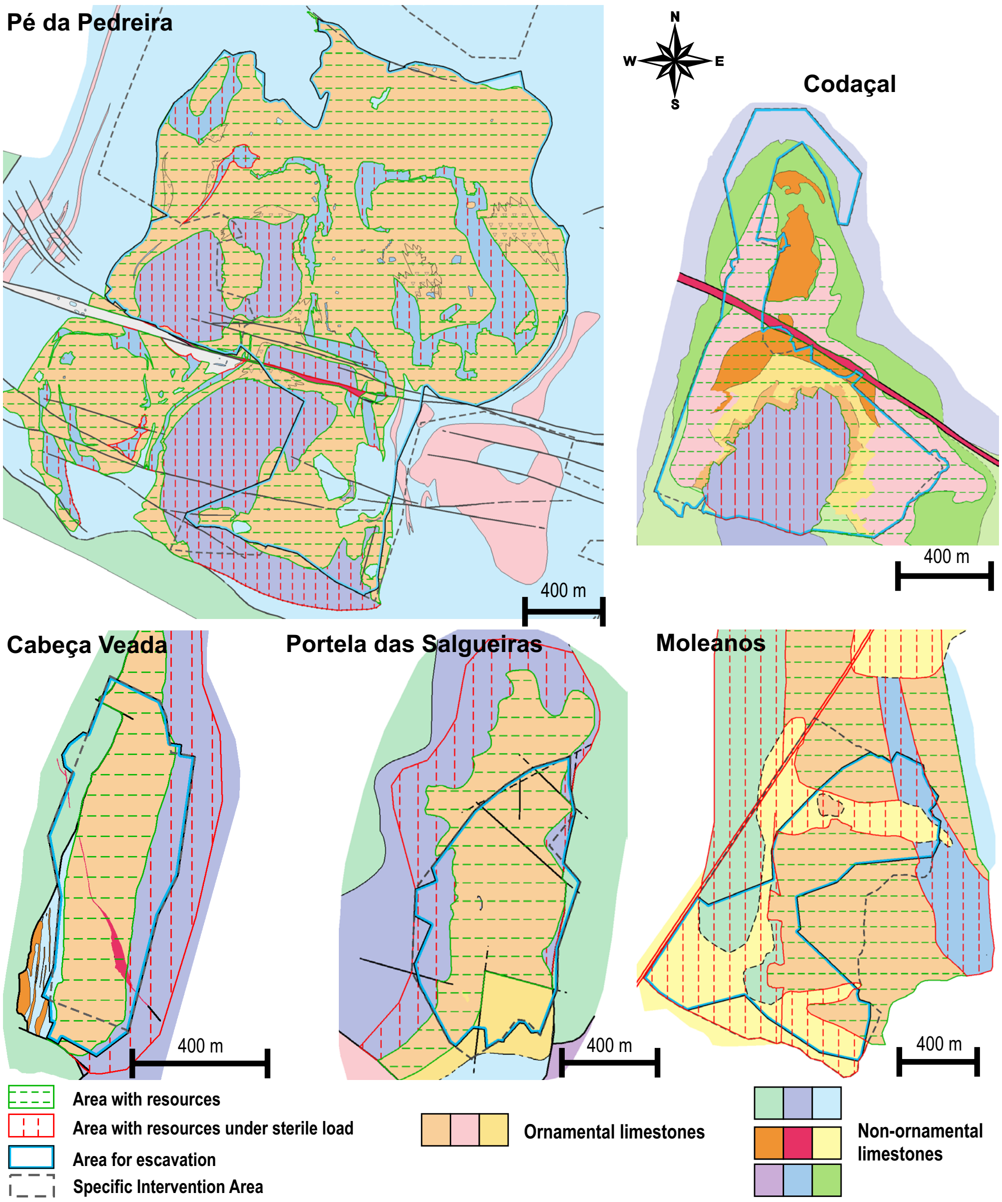

Fig 8 Simplified geological maps showing the areas suitable for the production of ornamental stones

Relevant geosites only were found in two of the studied AIE, namely in Codaçal and Pé da Pedreira. They correspond to geomorphological values, such as karstic cavities (caves and shafts), dolines, and well-developed limestone pavements.

Case study results – a land-use planning proposal

The land-use planning strategy was to make land-use compatible with the conditions and adequacies of each AIE, in a sustainable perspective of anthropic activities and their relationship with natural values.

The characterization study and the geological evaluation of each AIE showed, as expected, their suitability for the extraction of ornamental limestone blocks. On the other hand, studies on the characterization and evaluation of natural (biological) values showed the presence of ecologically relevant areas, sometimes with an outstanding character. In addition, there are geological heritage occurrences that are important for the PNSAC's conservation objectives.

These three circumstances were considered critical decision factors for the land-use planning proposal, but a fourth factor needed to be considered: Recovered Areas, that is, old quarries that were the object of environmental recovery actions, and for which the PNSAC regulation provides for its preservation. In this respect it is important to note that some of the areas still have ornamental stone resources.

The systematization and management of data was carried out in a geographic information system, which allowed the establishment of a dynamic interaction between the different subjects by means of the intersection of the different information levels.

Given this set of determining factors for the planning model of each AIE, the fundamental question arises of deciding how to weight each of them. Three different scenarios were considered: prioritizing the geological suitability for producing limestone blocks, that is, a scenario aimed at maximizing the extraction activity; prioritizing the existing natural resources, i.e., where the values of outstanding and high ecological relevance outweigh the benefits of the quarrying activity; considering the compatibility between the quarrying activity and the results of the biological resources valuation, which should be achieved with the establishment of compensatory measures, in line with the so-called biodiversity offsets and tradeoffs commonly carried out for large scale development projects (e.g., Gordon et al., 2011; Brownlie, King & Treweek, 2013).

In the PNSAC land-use planning context, the decision clearly fell on the third scenario, as it advocates for a land-use model that imposes the valorization of the AIEs by granting their use to an activity that generates significant impacts, but also imposes the need to minimize and compensate them through corrective or balancing measures.

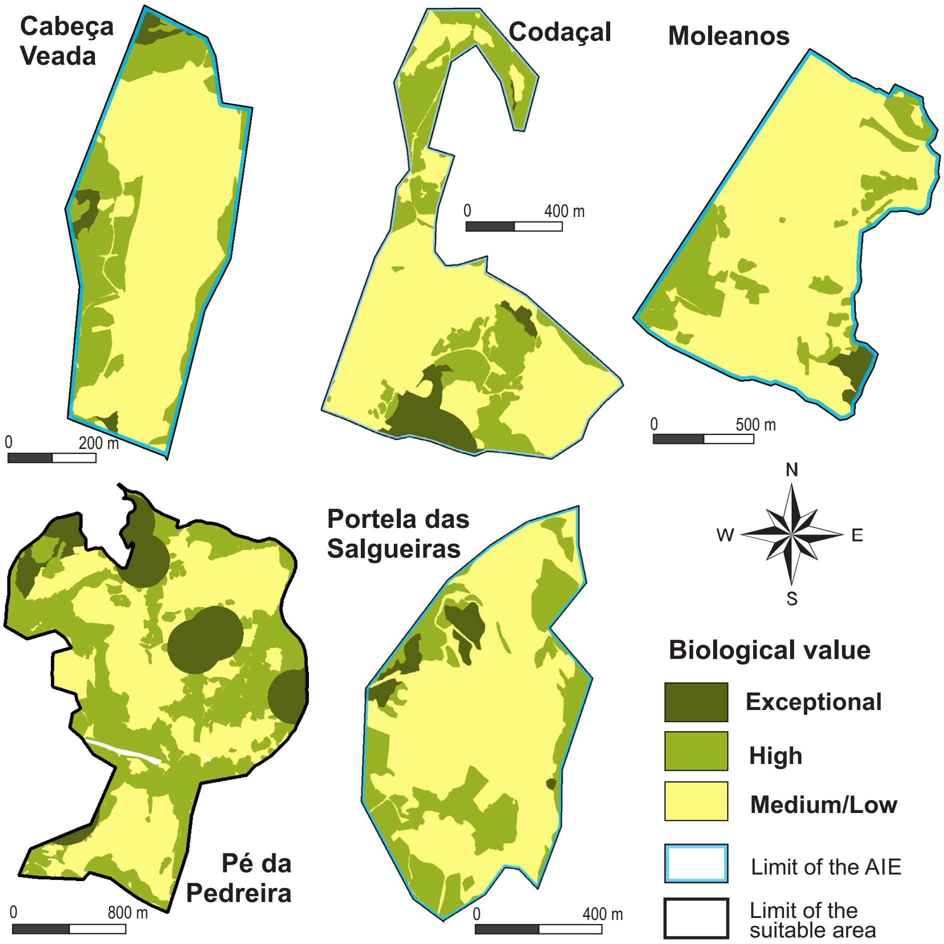

Fig 9 Biological classification maps for each AIE

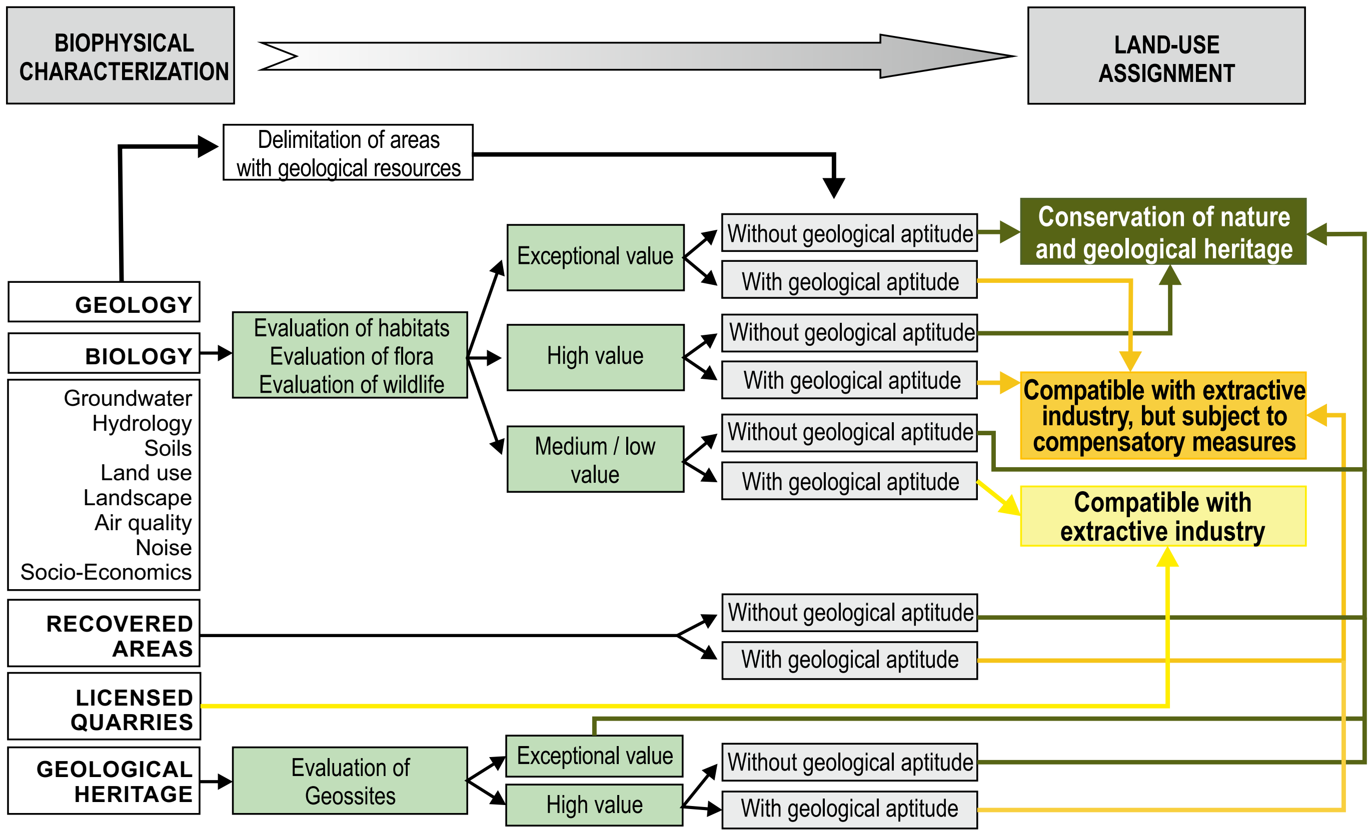

Fig 10 Methodological diagram used for the land-use planning of the Specific Intervention Areas

Table 1 – *Components and characterization of the ecological relevance classification.*

ecological relevance	habitats / flora	biotopes / wildlife
outstanding	areas of limestone slabs and limestone slopes habitats and the areas occupied by relevant flora species	priority places for the shelter and nesting of species with great conservation concern in the context of the PNSAC (mostly, punctual rock cavities, so it was considered a protection buffer with 200 m in diameter)
high	areas occupied by the most frequent natural habitats in the AIE, provided they have a high spatial expression and include priority habitats of the Natura2000 network	areas occupied by the most valued biotopes, i.e., meadows, shrub-thickets, and rocky environments biotopes
medium	areas with median coverage percentages of natural habitats that have wide expression in the PNSAC	the remaining biotopes or the previous ones, when they present a very small spatial expression
low	artificial areas (quarrying-related landforms).	

With these assumptions, the land-use assignment in each AIE followed the methodology presented in the diagram shown in Fig. 10, resulting in maps that correspond to land-use planning proposals (Fig. 11). They need to include the areas corresponding to easements and restrictions of public utility (e.g., roads, power lines) to become formally considered in the municipal land-use planning procedure as a PIER.

In each one of these maps, the areas indicated for nature and geological heritage conservation correspond to those where there are no ornamental stone resources. Exceptions are geosites with an outstanding value, which should be preserved, regardless of the existence of ornamental stone resources.

Regarding areas where identified resources coincide with values of outstanding or high ecological relevance, geosites without exceptional relevance, and recovered areas, those areas were classified as compatible with the extractive industry, provided that it was subject to compensatory measures. These are to be decided on a case-by-case basis, according to proposals to be submitted by the quarry owners to PNSAC or vice versa.

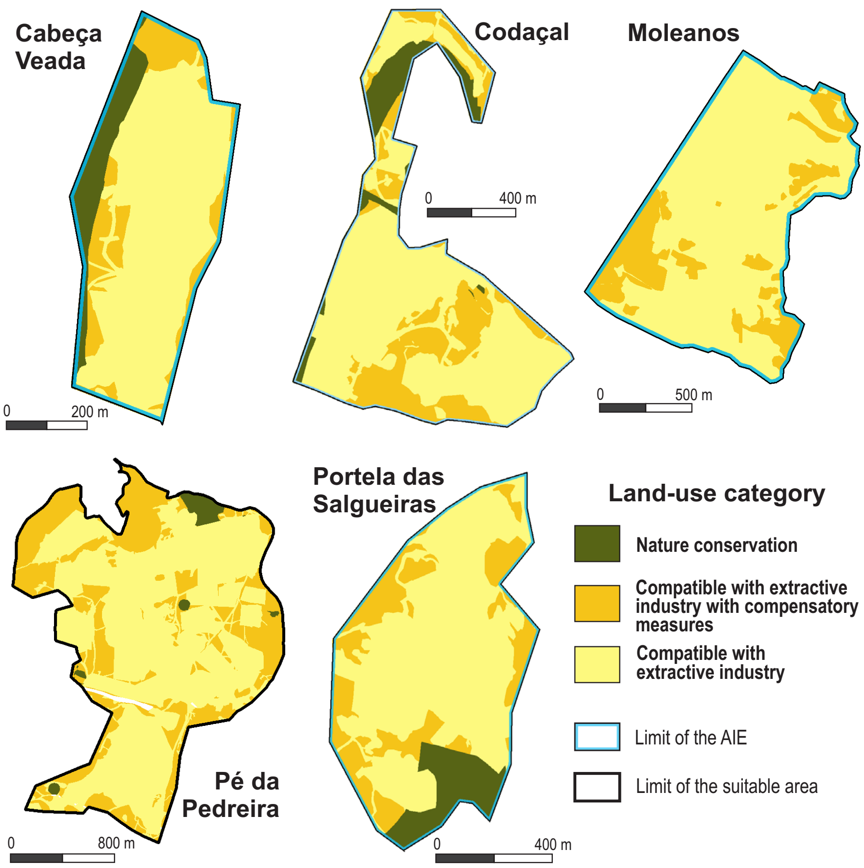

Fig 11 Land-use planning proposal for each Specific Intervention Area (AIE)

As for the areas indicated as compatible with the extractive industry, they match to areas whose ecological relevance is medium or low, and to the areas previously licensed for exploration.

Conclusions

The actions undertaken had the main objective of contributing to increase the competitiveness of the ornamental stone industry in a context of valorization of both the raw material and the environmental values specific to the MCE. For this purpose, the project was developed according to a methodological process based on a strategy of making the rational exploitation of resources compatible with the conservation of natural values.

A fundamental component of that process was the development of a land-use planning model to be applied to each of the AIEs, which was based on the identification of the critical decision factors, namely the existence of ornamental stone resources, outstanding and high biological values, relevant geological heritage and recovered quarries. In essence, this model advocates the allocation to nature conservation all the areas without interesting mineral resources. The remaining areas are compatible with the quarrying activity, but if outstanding or high relevance ecological values occur, environmental offsets should be implemented. Maps corresponding to land-use planning proposals are the spatial expression of the proposed model for each of the studied areas.

The key to the success of this case study was the development of a partnership between the association representing the extractive industry and the Portuguese environmental authority. Protocols for direct collaboration with national and local authorities responsible for the management of geological resources and spatial planning were implemented, as well as with quarry owners, to guarantee part of the financial contribution.

It is expected that this operating model can be replicated in other regions, namely those where there is a need to value mineral resources and increase the competitiveness of the mining industry in a sustainable way, both from a social and environmental point of view. In particular, the present planning methodology can be a reference for other situations, with the necessary adaptations. Effectively, it shows a way to make the mining activity and the conservation of natural assets compatible in the context of land-use planning, even when the areas are subjected to environmental protection regimes, such as natural parks and the Natura 2000 Network.

Declarations

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

All data presented in the text of the article are fully available without restriction from authors upon request.

Authors' contributions

Jorge Carvalho conceived, designed, and carried out the research and conclusions. Jorge Carvalho and José Vitor Lisboa drafted the manuscript.

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