

Landscape changes caused by the exploitation of granite quarries

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ABSTRACT: The exploitation of ornamental granite in the region of Pedras Salgadas (North of Portugal) has increased in the last ten years. The incorrect use of this resource has resulted in the expansion of the waste piles area, with severe environmental implications. Some guidelines for the solution of this problematic situation are presented in this paper, namely the use of small blocks in the production of artefacts which would reduce the impacts and improve the financial condition of quarry operators.

1 INTRODUCTION

Exploitation of natural resources affects the environment on its several components (Figueira et al., 1995). In the particular case of non-metallic resources, landscape changes play a major role, traduced by: a) large areas removed from their natural vegetation; b) significant changes in morphology, induced by resource withdrawal and waste accumulation.

Landscape changes are even more decisive when quarry exploitation is devoted to production of large blocks (used in the industry of ornamental rocks) because the percentage of extracted material that will be used as raw material is very minor; this percentage depends on many factors but, in general, approaches 10 to 30% (Sousa, 1995).

The wasted material is accumulated in large piles around the quarry site, with the known detrimental consequences to the outlook and important economical injuries to the operators which are not permitted to exploit the massif in its total extension.

1.1 Geographical location and geological setting

The area of Pedras Salgadas (North of Portugal) is situated in the Western part of the Trás-os-Montes province, at the post-tectonic (relative to phase F3 of the Hercynian orogeny) Vila Pouca de Aguiar massif where a homogeneous and leucocratic granite is exploited (Figure 1).

The mineralogical composition of this granite is characterised by quartz (25%), plagioclase (31.8%), K-feldspar (27.3%), biotite (4.4%) and muscovite (0.8%). The Pedras Salgadas granite, whose commercial name is White Silver (Moura et al., 1994), is one of the most important production poles of ornamental rock in Northern Portugal (Pires, 1992).

Regional faulting comprises three main families: N10°-30°E, N40°-50°W and N60°-80°E (Figure 2). The first is the most important because is parallel to a large scale fault, which is located 1000 m Eastwards of the studied area and has controlled the emplacement of the Vila Pouca massif.

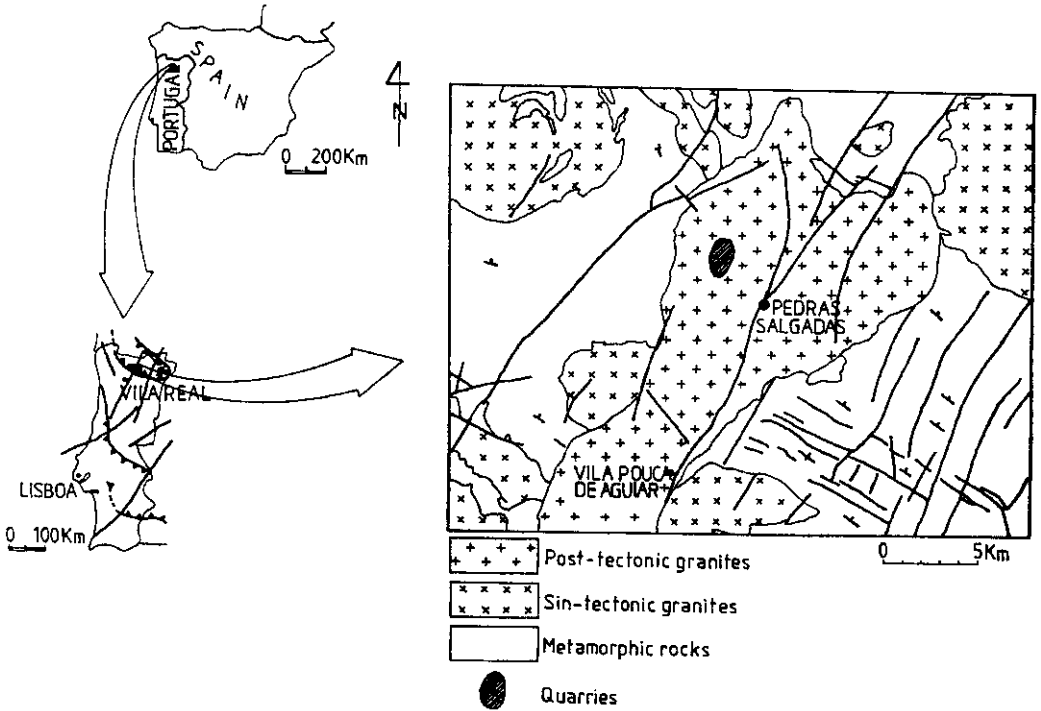


Figure 1 - Geographic location and geological setting.

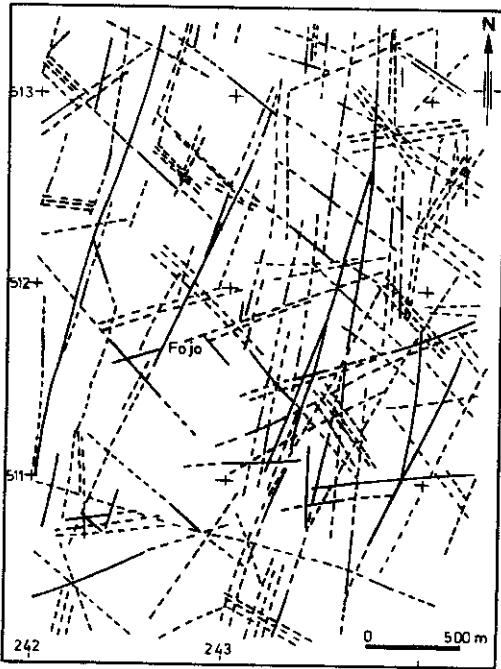


Figure 2 - Regional faulting in the studied area.

A detailed mapping of regional faults is of major importance for the selection of ideal quarry sites; quarries should be installed as far as possible from the regional faults, because: a) it has been demonstrated that the pattern of joints is closely related to them (Sousa, 1995; see also Figure 3); b) it has been observed that the joint density sharply increases in their vicinity.

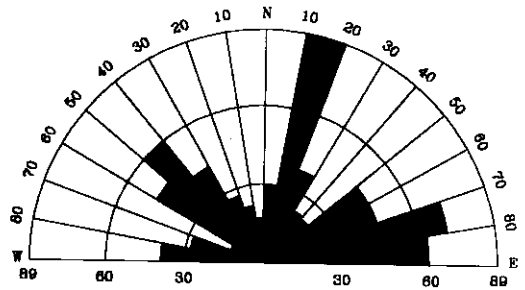


Figure 3 - Distribution of joint directions as observed at the quarries (number of joints per interval of direction).

1.2 Economic importance

The exploitation of granite has commenced in the early 60's. In those days, only small blocks were produced for the use in house building. The aesthetic characteristics and homogeneity of the Pedras Salgadas granite suite the requirements imposed by the industry of ornamental rock. The production of large blocks for transformation began in the 80's, increasing from that time on, and, as a consequence of this demand, the area occupied by new and remodelled old quarries has increased considerably (Sousa & Pires, 1994a). The average annual production of primary blocks for transformation is around 8000 m³, which corresponds to a value of 360000000 PTE (≈2400000 USD).

Quarry exploitation is crucial for the economy of Pedras Salgadas. This activity assures 250 working places, a very large number for a region of Portugal where is difficult (but important) to fix the population.

2 ENVIRONMENTAL IMPACTS

Environmental impacts resulting from quarry exploitation are essentially represented by heavy landscape changes caused by expansion of waste tips; we will come back to this subject later on.

Destruction of soil and vegetation is another consequence of quarry exploitation. In the area, soils are normally very thin (leptosols) and, unless they are previously stored (they never will), later reconstitution of natural vegetation will become very difficult.

Quarry exploitation frequently disrupts the natural flow of water table aquifers; after a certain depth, quarries work as outflow boundaries of these aquifers. The water that enters into the area that is being exploited has to be pumped out and normally is drained into near by streams and streamlets. Based on the average precipitation and evapotranspiration

in Pedras Salgadas (1000 and 500 mm, respectively) (Oliveira, 1995), one may estimate that 500000 m³ of waters are thrown out of quarries, either by natural out flow or by pumping. This water transports a considerably amount of inorganic materials (mainly silts and clays), engine oils and so forth.

2.1 Landscape changes

The area occupied by quarries started to grow up in the late 80's when selective production of large blocks for the industry of ornamental rock commenced. This partial use of the extracted rock resulted on the unruly increase of waste tips (Table 1 and Figure 4) that nowadays correspond to 50% of the area affected by the exploitations. Furthermore, the tips are located in places where the massif has good geological conditions for exploitation, which obviously limits the expansion of the quarry.

The dimension of blocks in waste piles has been measured (Figure 5). The largest blocks are suited for transformation into new products and (therefore) the volume of wasted blocks might be used as a criterion to distinguish between quarries

Table 1 - Approximated waste piles volume.

Quarry	Waste pile volume (m ³)
M	10 500
L	16 000
H	21 200
K	5 000
J	10 400
G	2 250
E	11 700
D	116 000
F	5 000
A	44 500
N	18 000
B	2 000
P	3 800
Total	266 350

where the improvement of small blocks is profitable from other quarries where only the larger blocks are valuable. Figure 6 shows the distribution of block volumes, drawn for two distinct situations: 1) quarries where some recovery of secondary blocks is done (SB); 2) quarries where no improvement is made (LB). It becomes clear from the SB and LB plots that transformation of small blocks is indeed the first step for the reduction of waste at the quarry sites.

3 SOLUTIONS

The most common problems associated with the rock exploitation in the area are summarised and connected to their most probable causes in figure 7; general problems affecting the rock industry in the European Community are described in Aguirre (1995). The lack of geological studies (to identify the regional faulting and then select the most favourable quarry places) and the insufficient technical advice are two major reasons for the low profits of granite quarries (Sousa e Pires, 1994b; Gomes, 1994). Other reasons are linked to the extraction process; in general, operators do not take to much advantage from the natural fracturation (Toyos, 1994; Tomašić, 1994) and, as a consequence, less blocks are extracted in much more time, with increased fuel costs and equipment deterioration.

3.1 Global exploitation

The main objective of quarry operators is the extraction of large blocks. Removal techniques and quarry organisation are exclusively determined by this aim and the areas suited for the production of small blocks are systematically rejected, although they ought to be selected as areas for production of artefacts.

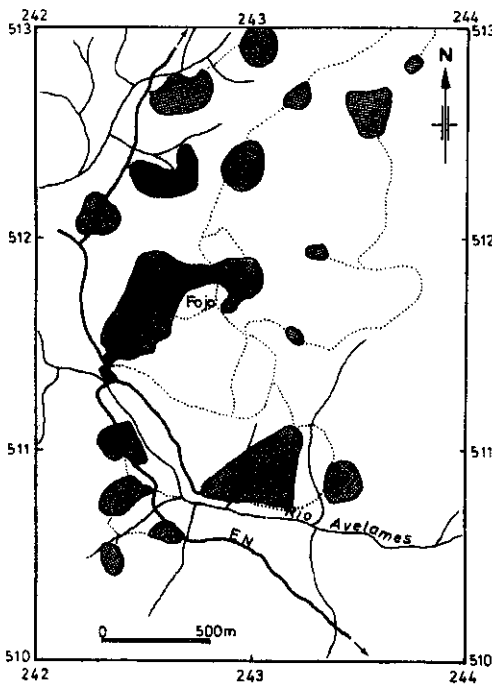


Figure 4 - Area affected by the quarries.

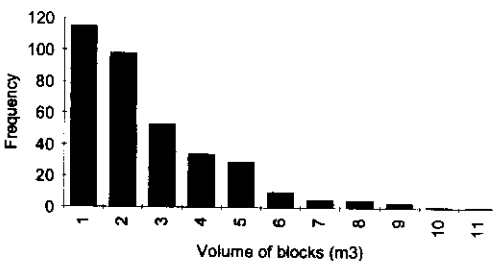


Figure 5- Volumes of the largest blocks measured in the waste piles.

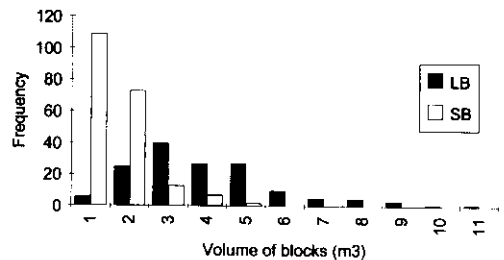


Figure 6 - Distribution of blocks in waste piles of quarries where small blocks are transformed into artefacts (SB) and in piles of quarries where no improvement of small blocks is made (quarries D, P, A and H - LB).

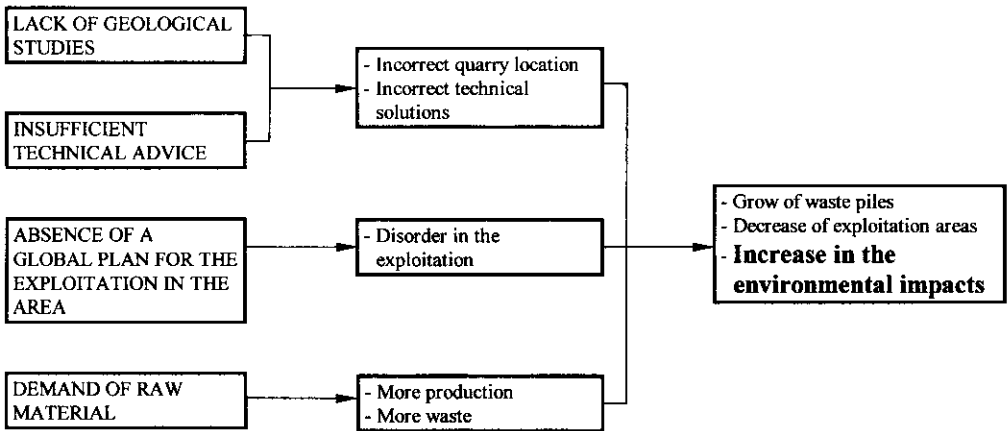


Figure 7 - Main exploitation problems in the area of Pedras Salgadas.

Three types of quarries have been used in a study of economical feasibility (Sousa & Pires, 1996); these quarries were chosen according to the products that were being exploited: blocks; paving-stone; both blocks and paving-stone. Based on the investments, profits, and the residual value of equipments, the Profitability Rate (PR) was calculated (the PR measures the annual return of invested capital - Barros, 1991) and the results are 4.38%, 8.26% e 13.85%. These results show that the most viable quarries are those where blocks, paving-stones and other products are exploited.

The effect on PR caused by variation on technical and/or economical parameters can be measured by Sensibility Analyses. In other words, sensibility analyses are able to identify which parameters are the most important in determining the economical viability of a quarry. In the following analysis, we produce variations on parameters one at each time, assuming that the others stay constant. However, parameters can (and do) vary simultaneously increasing or decreasing their effect over PR than if they were considered in separate.

The results of a sensibility analysis made for a quarry where the integral use of the extracted rock is performed are presented in figure 8. The most

important factors which determine the economical viability of the quarry are the increase in exploitation yields and selling prices and the decrease in operation costs; less important are the financial investments and the volume of extracted rock.

Residual materials, which do not have any economical value, should be transformed into aggregates at a common stonebreaker. Fortunately, this is already practiced by some operators, because they do not have a space at their quarry sites where they can deposit their final residues.

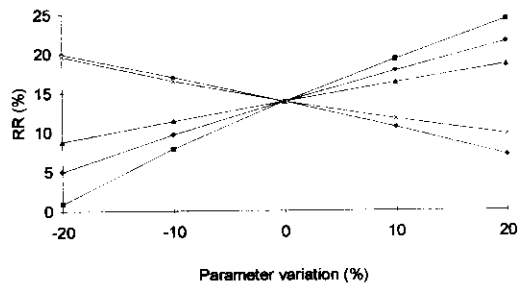


Figure 8 - Profitability Rates (RR) with parameters variation: ■ - price; ● - exploitation yield; ▲ - volume of extracted rock; × - financial investments; ◆ - exploitation costs.

3.2 Legislation

Legislation was created specifically for the Pedras Salgadas region to improve quarry exploitation and reduce the environmental impacts (law 766/94). This legislation is to be applied to new quarries, which are obligated to occupy an area of 50000 m² (or more) and satisfy several environmental requirements.

It seem unreasonable to us that only very large quarries will be able to open in future years: a) field rents will be much higher, resulting in major costs to operators. Consequently, reductions on investment are expected, which will affect non-profitable activities like environment protection; b) a very large area addressed to a quarry facilitates the growth of waste piles in places where the mass is poorer. If quarries are smaller, operators will have difficulties in managing their final residues and probably will take the opportunity of send them to the common stone breaker.

4 FINAL REMARKS

The transformation of the smallest blocks in to paving-stone appears to be the most important contribution for the reduction of environmental impacts and the economical improvement of granite quarries. All the material that is not able to be transformed into a commercial product should be sent to a common stonebreaker. This would free the quarry sites from their waste piles turning possible the environmental recovery.

Recent legislation tries to avoid that new quarries become into pollution sources. This should not mean that old quarries continue to accumulate their waste chaotically. All quarry operators should be forced to attain the zero-waste level around their quarries

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