



MARBLES FROM PORTUGAL

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Abstract

The "Estremoz marbles" were for decades the hallmark of Portuguese Dimension Stone. Mostly economic constraints associated with a lack of knowledge regarding the physical, chemical and mechanical properties of different rocks of prescribers, created a "fashion" that focuses primarily on the homogeneity of the material don't having in account its longevity. We note that there was no depletion of raw material; in fact almost every varieties of marble have enough reserves to sustain a mining activity for several hundred of years.

Geology and Mining Heritage

Despite its dimension, Portugal has mining units of ornamental rocks throughout its territory. In fact, the North its rich in igneous rocks, particularly granites (Fig. 1), while the microcrystalline sedimentary calcareous are concentrated in the Maciço Calcário Estremenho (Fig. 2). There are considerable reserves of limestone breccias in Algarve (S. Brás de Alportel – Tavira, southern Portugal) as well as nepheline syenite, unique in the World and explored in Serra de Monchique (Algarve). Schists have an extractive pole of considerable dimension in the area of Porto, registering also additional exploration in Alentejo, in Barrancos.

The marbles are exploited in the province of Alentejo, southern Portugal, between Sousel and Alandroal, were can be individualized the Estremoz anticline. This main symmetrical and elliptic geological structure, orientated NW-SE and measuring some 42x8 km (Fig. 3), is located within the greater Ossa Morena Zone geological unity in which Lower Palaeozoic marbles with ornamental interest outcrop over 27 km² (Moreira & Vintém, 1997).

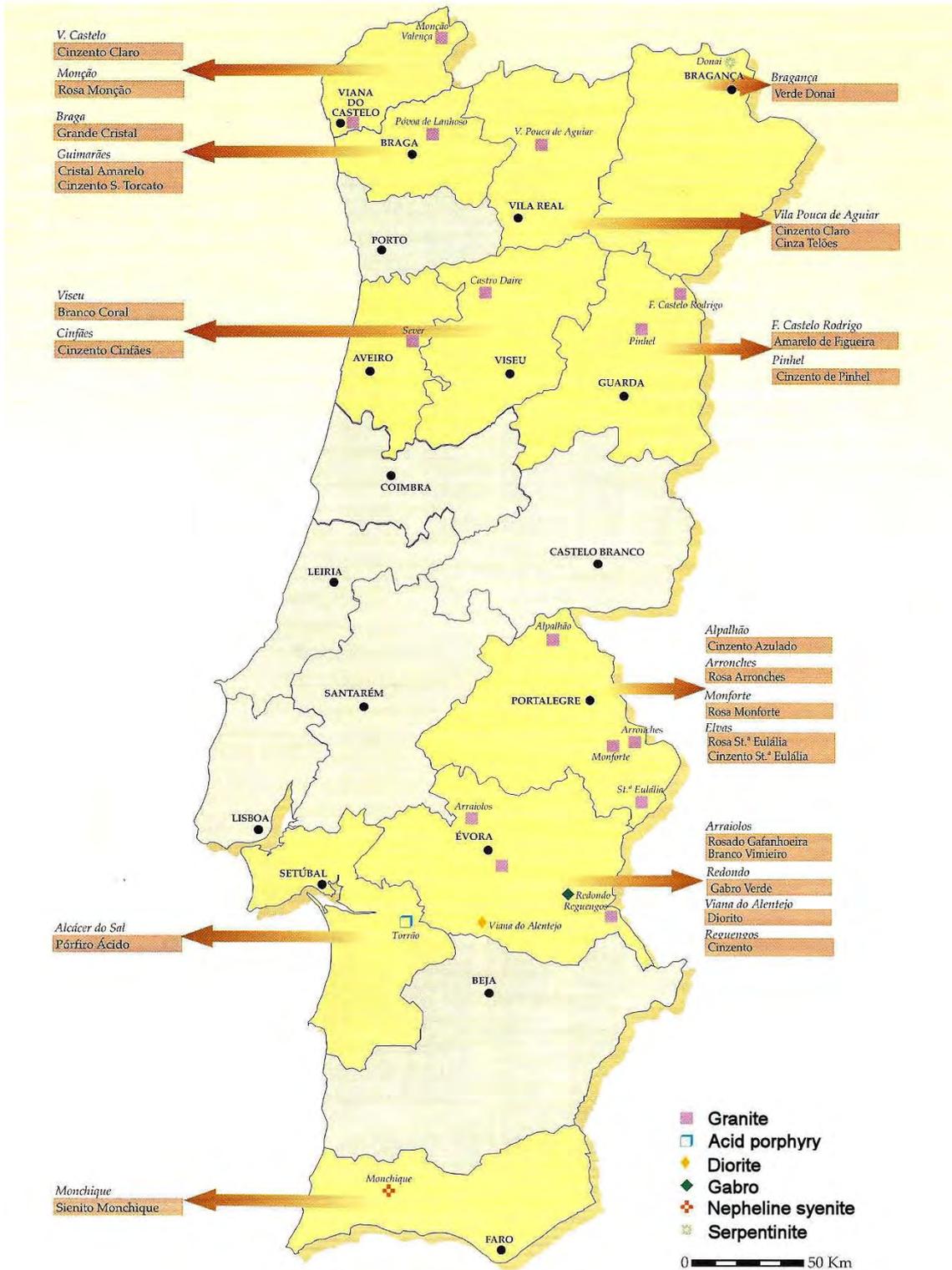


Fig. 1 – Siliceous Dimension Stones in Portugal (IGM, 1997).

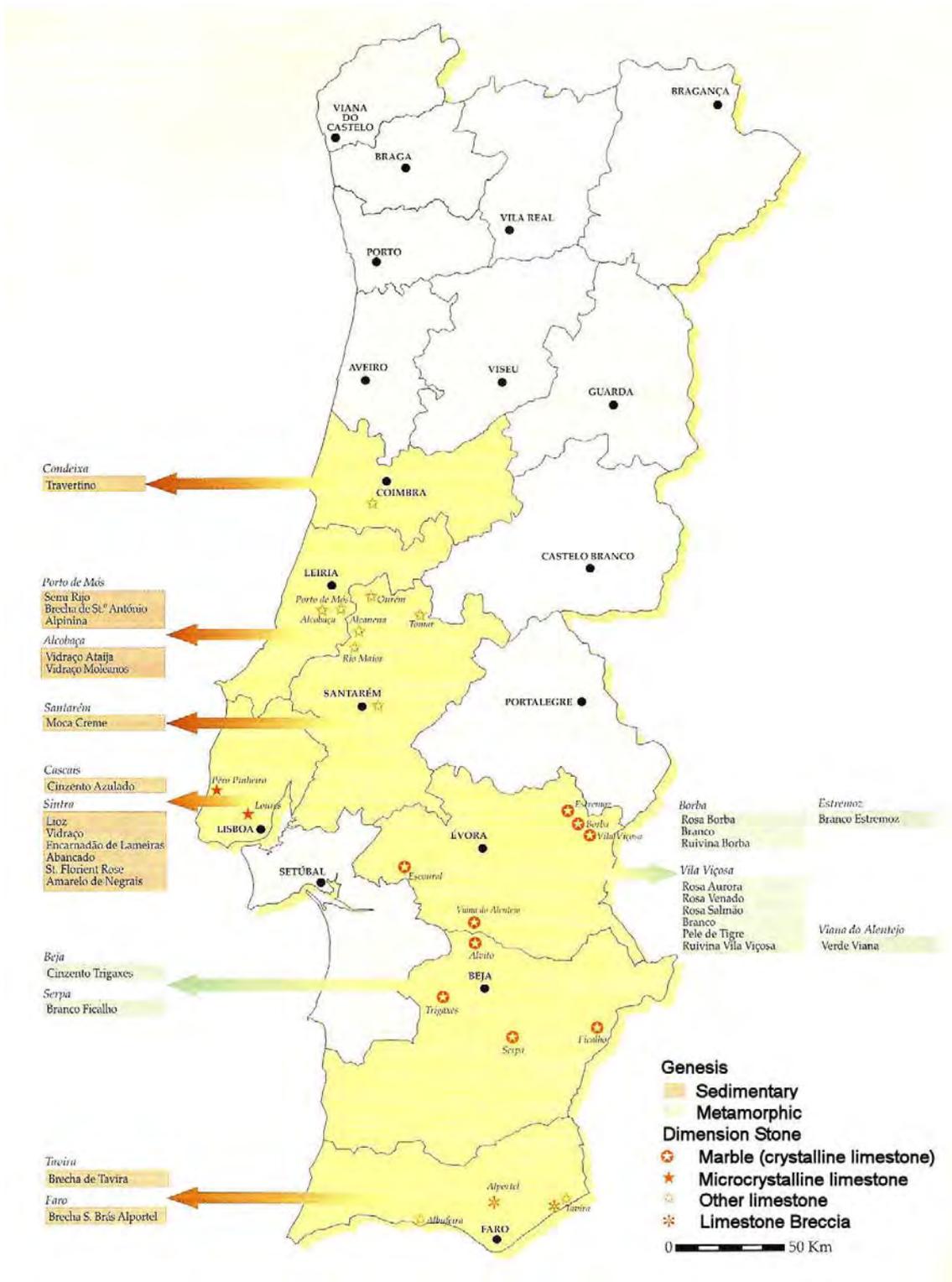


Fig. 2 – Carbonated Dimension Stones in Portugal (IGM, 1997).

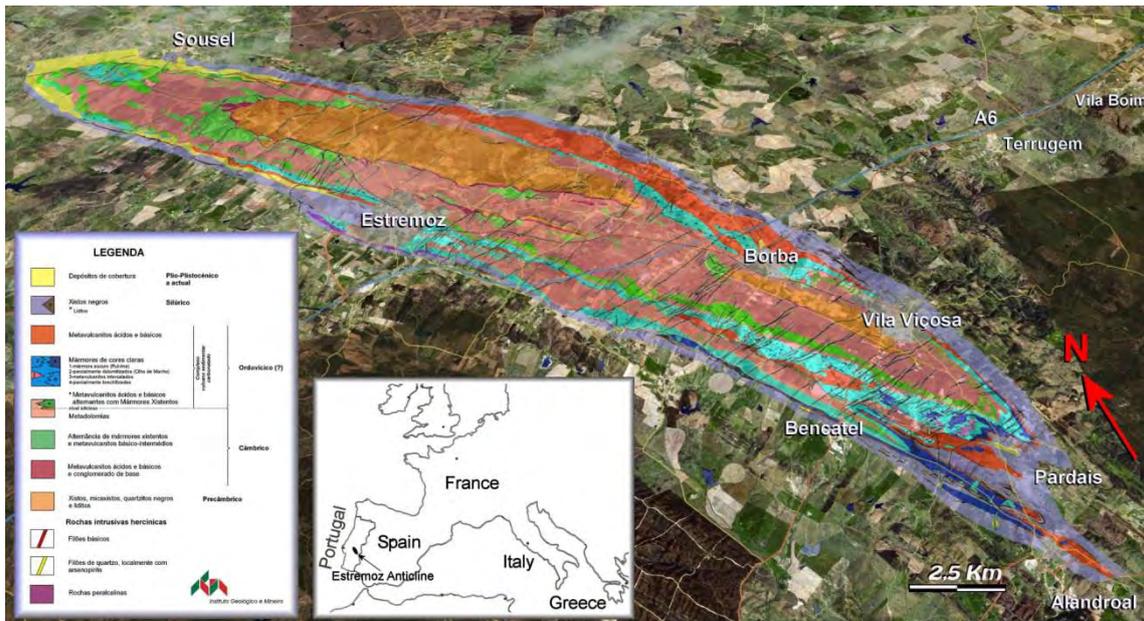


Fig. 3 – Geological map of the Estremoz anticline (Moreira, J., and Vintém, C., coords., 1997) superimposed the image of Google Earth. The marbles are shown in dark and light blue. Adapted from Lopes & Martins (2010).

The Estremoz anticline is the main centre for Portuguese marble exploitation and one of the most important internationally. A large number of quarries in the area greatly simplifies the access to the marbles and provide unique geological windows some of which reach some 150 m in depth. The marbles preserve the effects of the Variscan Orogeny and several structures preserved in the quarries originates beautiful aesthetic patterns that frequently are emphasized in the final applications of the marbles (Fig. 4).

Other Palaeozoic marbles, which are less relevant, also outcrop in Alentejo (Vila Verde de Ficalho, Trigaches, Serpa, Viana do Alentejo and Escoural) (Fig. 2). In every case, the marbles occur integrated in Volcano-Sedimentary Complexes. Although local variations, a similar lithostratigraphic sequence essentially made up of marbles, marble-schist, and intercalations of felsic and basic volcanic rocks is shown. The textural and mineralogical differences between the marbles in these locations are marked by the distinct position that they occupy within the Variscan Orogeny in Portugal (Lopes, 2003).

In the last decades, several exploration studies have been undertaken to valuate this resource (Gonçalves, 1972; Reynaud & Vintém, 1994; IGM, IST & UE, 2000; Vintém, *et al.*, 2003; Carvalho, 2008). Bearing in mind the interaction between mining and the environment, the application of methodologies that allow the proficient land use planning of this area have been studied, which will lead to an efficient global land management (Falé *et al.*, 2004; 2006).



Fig. 4 – This picture shows an example of geometric patterns obtained by polishing the Ruivina marble slabs in open book.

It is well known that these marbles have been quarried since antiquity as a valuable geological resource. The oldest evidence of recognition of its use dates back to the year of 370 BC. This archaeological find is represented by a tombstone ordered by the Carthaginian captain Maarbal in their trip from Faro to Elvas and was discovered by investigator Father Espanca in Terena (Alandroal) (Brito da Luz, 2005). Later, in the Roman Period, the marbles have been widely used as structural and decorative features of buildings that today are fabulous architectural monuments, e.g. the Roman Temple in Évora (Fig. 5), the Roman Theatre in Mérida (Spain) (Fig. 6), etc. In the Middle Ages marbles were used for the construction of palaces, castles and other buildings. From the 15th Century these marbles began to have a more prominent use, both nationally and internationally, having been transported by Portuguese explorers to Africa, India and Brazil. During the next few centuries, these marbles were searched for ornamental purposes and they appear inlaid with various polychromatic associations in several national and international monuments, e.g. Jerónimos Monastery (Portugal), Escorial Monastery (Spain), several monuments in Rome (Italy), Louvre and Versailles (France), 2003). In the 20th century, with the introduction of new exploitation and manufacturing technologies and especially in the 70's with the opening of the Portuguese economy to the exterior, the marble industry took a step forward and since then marble has been exported worldwide (Brilha *et al.*, 2005).



Fig. 5 – Roman Temple in Évora (Portugal). The granite columns have bases and capitals of white marble from Estremoz.



Fig. 6 – Detail of the Roman Theatre in Mérida (Spain). The columns were made of marble "Ruivina" found in the South-western limb of the anticline of Estremoz.

The marbles correspond just to a small part of the Estremoz anticline. Considering that only 30% of the 27 km² that the marbles occupy are explored, 10% from exploitation and explorations up to 100m depth, we obtain 220 million tonnes wick, taking into

account the maximum average annual exploration of 400.000 tons in the period between 2000 e 2002 (INE – Instituto Nacional de Estatística), allows us to point bookings for about 550 years. This value is calculated by default because we know that the deposit can reach over 400m in Fonte de Moura – Pardais (Vila Viçosa), and between Carrascal and Encostinha (Borba), where the finest marbles and of better quality are more than 280m depth. Currently there are only four quarries with about 100m depth. In other words, this means that we can say certainly that it will not be for lack of raw material that the marbles of Alentejo won't be able to assert themselves globally.

Business Associations

For many years the companies that developed their activities in the Municipalities of Estremoz, Borba and Vila Viçosa were characterized by family structures, with unskilled human resources, guided by intuitive methods of management. With the increasing of the national and international competition, companies gradually have come to organize themselves, investing in qualified personnel, in a considerable technological development, in the professional training and, due to that, in a more skilled labour, in a professional management embodied in well-defined lines of development, greater sensibility to environmental issues and in a more aggressive and planned marketing strategy.

Nowadays there are some initiatives and projects in order to promote and develop the sub-sector of ornamental rocks, particularly in Alentejo marbles, investing in safety campaigns, hygiene and health in work, as well as developing the concept of eco-efficient, environmental friendly enterprises and sustainable value methodology.

Witnessing the importance of Ornamental Rocks Sector in the Portuguese economy, it was governmentally recognized the “Cluster da Pedra Natural” and, following this, it was formed the Associação Valor Pedra whose mission is to “implement initiatives related to the Cluster das Pedras Naturais which aim for innovation, qualification and modernization of companies of the Sector and develop the cooperation between enterprises, business associations, technology center, I & D institutions, training centers and other entities of the Sector contributing to the dynamization of technology transfer processes to increase productivity, competitiveness and innovation in different economic activities – productive”.

This Association, physically situated in CEVALOR (Center for the Study and Appreciation of Rock Industries and Dimension Stones), integrates as founding partners, the very CEVALOR, industry associations like ANIET (National Association of Extractive and Manufacturing Industries) and ASSIMAGRA (Portuguese Association of Manufacturers of Marbles, Granites and Related Enterprises) industrial sector, public institutes such as LNEG (Laboratory National Energy and Geology), IGESPAR (Management Institute of Architectural and Archaeological Heritage) and universities (University of Évora, University of Trás-os-Montes and Alto Douro and the

Engineering Institute of Porto. Since its creation it has mobilized companies, universities and institutes for submitting projects with the aim of Promoting the Natural Portuguese Stone, Environmental Sustainability in Extractive Industry and the Development of New Technologies for the Competitiveness of Natural Stone.

At the moment two of the main projects are already approved and in progress and, as they include the participation of several companies and two Industry Associations (ASSIMAGRA and ANIET), the transfer of results to companies will be a reality.

These projects come against the inevitable development that companies in the region will have to suffer and pass necessarily through a process of modernization, where the concept of sustainability must always be present. There are several definitions of sustainability or sustainable development, being that one of the most quoted and somehow generalized, is the one published by the Brundtland Commission (World Commission on Environment and Development), in its report (Our Common Future).

Thus, according to this committee, sustainable development "is the one that satisfies present needs without compromising the possibility of future generations to satisfy their own needs" (Bonito, 2010). Therefore, the companies of the Sector should develop models in order to optimize the three indicators of sustainability: the environmental, economic and social aspects. In the environmental indicator it is crucial the control of the volume of waste produced, energy and water consumption, consumable materials, the optimization in the traffic of mobile equipment and the prevention of environmental accidents. In the economic indicator it is fundamental to quantifying the costs of the production process and the income generated, costs for facilities, collateral and environmental costs, not forgetting also possible costs involved shares I & D. Finally, in the social indicator it should be taken in consideration the promotion of direct and indirect employment, without neglecting a fundamental economic parameter which is the prevention of accidents.

Dimension Stones Productions

Despite a relentless global economic recession, slightly contradicted by the contribution of countries like China and India, both with an increasingly evident position in the landscape of world trade in ornamental rocks, Portugal, though it has been losing market share and the difficulty of remaining competitive with some Eastern countries, Turkey and Brazil, remains firmly in a prominent position in terms of production of dimension stones (Table 1) thanks to the quality shown by the stone material and the national adaptation business.

On the weight of the national market of Dimension Stone, marble from Estremoz, Borba and Vila Viçosa for many years were positioned in the top position in regards to extraction, processing and export, however, progressively, it has been losing ground to other ornamental rocks, specifically, the sedimentary limestone of the Maciço Calcário Estremenho, with strong development thanks to the Chinese market and also to the

clusters which have gradually been gaining market and are now a reality on the production of kitchen worktops.

Table 1 – Dimension Stone Worldwide Production (t)

Países	2003	2004	2005	2006	2007
China	18 600 000	20 600 000	21 000 000	21 500 000	22 000 000
Índia	14 221 000	15 528 000	17 367 000	19 000 000	21 500 000
Irão	10 000 000	10 400 000	10 493 000	11 045 000	11 100 000
Itália	10 810 623	10 883 849	10 658 758	10 554 903	10 048 221
Turquia	6 200 000	7 725 000	8 250 000	9 400 000	9 500 000
Espanha	7 625 000	7 830 000	7 987 000	8 100 000	8 000 000
Brasil	6 000 000	6 400 000	6 900 000	7 500 000	7 500 000
Egipto	1 950 000	2 200 000	2 800 000	3 300 000	3 500 000
Portugal	2 792 545	2 950 190	2 948 732	3 122 358	3 178 840*
Grécia	2 100 000	2 100 000	2 100 000	2 200 000	2 100 000
USA	1 340 000	1 460 000	1 360 000	1 330 000	1 500 000
França	1 231 500	1 189 020	1 200 480	1 214 600	1 200 000
Polónia	800 000	1 100 000	1 100 000	1 100 000	1 100 000

After: Internazionale Marmi e Macchine Carrara Spa (2007) and *DGEG (2008)

Currently, the marble from Estremoz, belonging to the sub-sector of Dimension Stones and integrated into the Natural Stone Sector, is extracted and processed for near 6% of the total number of companies in the country generating a volume of employment of 12.22% , also in relation to the national total, surpassed only by large areas of Lisbon and Porto (Martins, 2009).

Despite the global crisis, the statistics have shown a slight increase in the production of Portuguese Dimension Stones with an evolution of 2 792 545 t in 2003 to 3 178 840 t in 2007 (Table 1).

Analyzing the different types of production in Portugal it is clear that the limestones have shown an increasing importance and are the ones that main contribute to the value of national production (Fig. 7).

In the other hand, although marbles show a downward trend, its value will practically remain reflecting the quality of these materials.

This observation is confirmed by the fact that, for example, in 2007 limestone production (629,941 t) was approximately three times the production of marble (240,200 t) and yet, its value (€47,840,000) only adds 27% compared to marble (€ 37,743,000). Similar analysis could be made regarding granites, here with differences more pronounced. In fact the production values are still the higher (798,990 t) and the economic value is practically identical (€38,162,000) (Fig. 8).

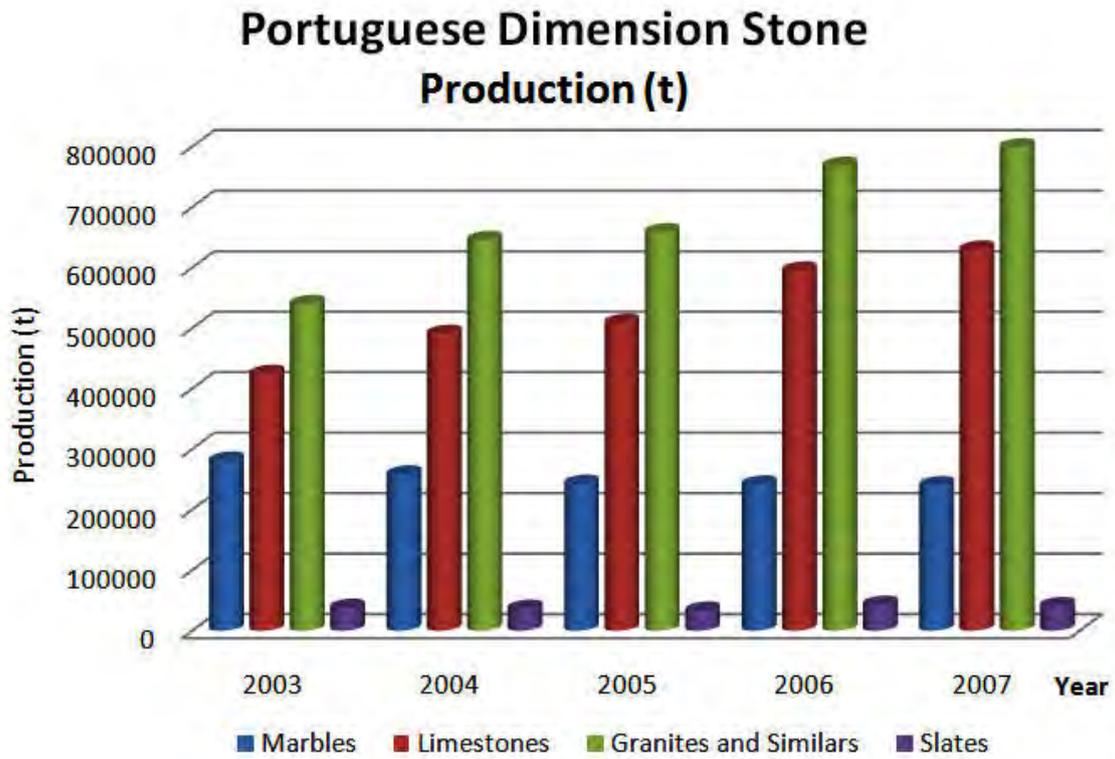


Fig. 7 – Portuguese Dimension Stones production – 2003 and 2007, after DGEG (2008).

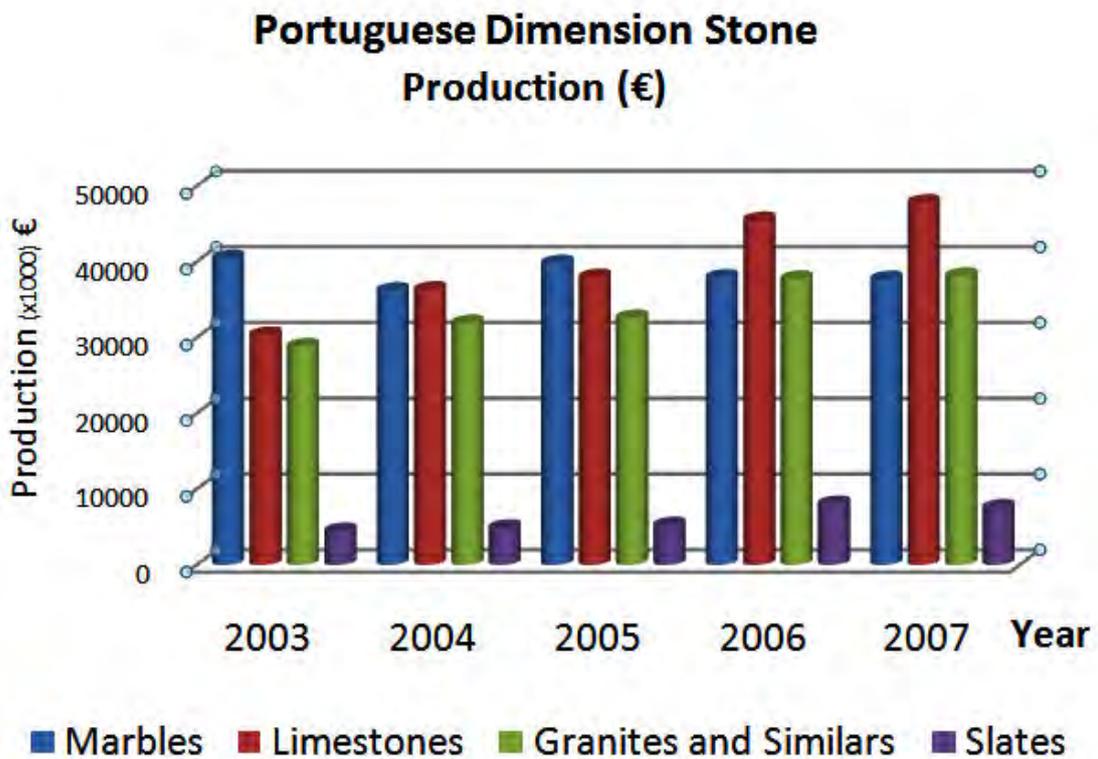


Fig. 8 – Portuguese Dimension Stones values – 2003 and 2007, after DGEG (2008).

The numbers are quite elucidative of the importance that, at present day, the extraction of marble and limestone have in Portugal.

We want to emphasize that these values are only related to the production of raw material and not to the value added by processing and implementation of the same. Different materials require different processing according to the finishing and the subsequent application.

Dimension Stones Characteristics

The excellence of the marbles of Alentejo makes them very versatile, allowing its use on decks, coverings of interior and exterior (outdoors and indoors) and decoration of interior (fireplaces, floors, tables, staircases, kitchen countertops, etc.).

They are also often used in urban furniture such as benches, garden tables and fountains, in funerary art, as masonry in engineering works, as structural elements in buildings and for paving of sidewalks and roads.

Its workability and variety of colors makes them the first choice of stones for sculptors who, throughout the ages have produced artworks great refinement and high aesthetic value.

The high quality, fine to medium-grained, “Estremoz marbles” show excellent mechanical-physical properties as well as aesthetic beauty, which is attested by the prices they fetch and also by the large volumes of rock quarried, places Portugal at the forefront of world marble production. Colours vary from white, cream, pink, grey or black and streaks with any combination of these colours are possible (e.g. white with pink streaks). The types of pink marble are internationally coveted because of their quality and beauty and locally, high-quality, white or cream-coloured blocks are also used in statue manufacture (Fig. 9).



Fig. 9 – This picture shows some of the most well known types of Portuguese Marbles.

Analyzing the values related to physical properties and carbonated composition of various Portuguese marbles and some from Turkey, Italy, Greece, China and Brazil (Table 2), it appears that Portuguese marbles from the zone of Estremoz - Borba - Vila Viçosa present values perfectly framed with the values revealed by the other marbles. Regarding the compression breaking load before and after freezing, the values are relatively similar, with the exception of the values presented by the "Bianco Carrara Unito C" from Italy, "Imperial Pink" from Brazil and "Salome" from Turkey with very high values for these kinds of dimension stone. For values of bending strength, the Portuguese marbles exhibit very favorable results

The remaining parameters have values within the expected carbonate rocks, possessing Portuguese marble optimal characteristics for applications in interior and exterior, funerary art and creation of furniture.

Land planning and other activities in Estremoz Marble Region

The areas of intense mining activity, strongly dynamizing of the economies of the regions where they develop, inevitably mischaracterize the environment, transforming it in most cases permanently. When the activity ceases or slows down it is essential to find solutions to its reactivation. It is here that imagination and acquired knowledge during the activity are fundamental, so that they can take advantage of the legacy left by the industry.

Until the end of 2010, the Project Rumys, "Rutas Minerales de Iberoamérica y Ordenamiento Territorial: un Factor Integral para el Desarrollo Sostenible de la Sociedad", developed by CYTED (Cooperação "Ciencia y Tecnología de la Región Iberoamericana"), in different fields, from basic research to technological development and innovation, it appeared the need to create mechanisms to minimize the negative impacts left by mining companies in Latin American societies and monetize mining heritage and its mineral wealth, covering aspects as diverse as geology, mining, tourism, historical patrimony, gastronomy and Society.

On each route, the Project Rumys compiled an historical inventory of the production and enhancement of cultural heritage and geomining, showing its relationship with the Society and, in two books, published the results of that inventory and predicted what was the social impact expected in order to promote regional development (Falé *et al.*, 2008, 2009).

To continue the work developed in the project RUMYS, it was tendered, through the Entidade Regional de Turismo do Alentejo, S.A., the project "Promotion of Tourism Industry." Regardless of its approval there is the commitment between the University of Évora, the Direção Geral de Energia e Geologia e a Câmara Municipal de Vila Viçosa to implement the Route of Marble, as it had initially been proposed with the agreement of the Industrialists, being its opening scheduled for the next International Exhibition of Alentejo Marble (FIMAL) to be carried out next October.

Table 2 – Physical properties and carbonated composition of Portuguese and foreign marbles.

Ministério da Indústria e Energia, Direcção Geral de Geologia e Minas (1992) and <http://www.stoneexpozone.com/>

Portuguese Marbles											
Type	Localization	Compression Breaking Load kg/cm ²	Compression Breaking Load after Freezing Test kg/cm ²	Bending Strength kg/cm ²	Volumetric Weight kg/m ³	Water Absorption at N.P. Conditions %	Apparent Porosity %	Thermal Linear Expansion Coefficient 10 ⁻⁶ per °C	Abrasion Test mm	Impact test: minimum fall height cm	Carbonate Composition
Branco Estatuária	Vila Viçosa, Pardais, Lagoa	788	895	208	2709	0,08	0,23	9,9	2,8	65-70	98% calcite 54% CaO 43% CO ₂
Branco	Vila Viçosa, Bencatel, Vigária	967	933	208	2713	0,07	0,17	12,6	2,1	45-50	99% calcite 55% CaO 44% CO ₂
Branco Rosado	Estremoz, Sta. Maria, Cerca de Sto. António	970	950	243	2718	0,07	0,20	7,3	2,0	50	94% Calcite 55% CaO 44% CO ₂
Crème Venado	Borba, S. Tiago de Rio de Moinhos, Herdade do Mouro	990	863	238	2713	0,05	0,15	11,1	2,6	60	99% Calcite 54% CaO 43% CO ₂
Rosa Aurora	Vila Viçosa, Bencatel, Santos	872	950	179	2717	0,06	0,16	7,3	3,7	50-55	99% Calcite 54% CaO 43% CO ₂
Ruivina Escuro	Borba, S. Tiago de Rio de Moinhos, Ruivina	930	952	270	2715	0,05	0,14	5,4	2,6	45-50	99% Calcite 55% CaO 43% CO ₂
Ruivina da Fonte da Moura	Vila Viçosa, Pardais, Fonte da Moura	863	977	256	2703	0,10	0,28	14,8	2,0	55	95% Calcite 54% CaO 43% CO ₂
Worldwide Marbles											
Afyon Tiger Skin	Turkey	648	447	65	2710	0,1	0,2		6,66		99,6% CaO
Afyon White	Turkey	701	590	151	2730	0,1	0,2		0,51		95,2% CaO
Bianco Carrara Unito C	Italy	1209	1181	174	2688	1,6		7,2	4,72	73,8	55% CaO 44% CO ₂
Calacatta Bianco	Italy	844	959		2674	1,5		10,3		71	
Greek Cipolino	Greece	965		155	2705	0,11			8,55		57% CaO 43% CO ₂
Imperial Pink	Brazil	1199	1182	184	2732	0,06	0,17	8	3,31	46	96% calcite
Mystique Dark	China	833		83,8	2693	0,08					
Salome	Turkey	1019	1019	174	2730	0,1	0,4		0,37		78,9% CaO
Thassos Saliara Snow White vein	Greece	971		185	2880	0,68			0,35		45,9% CO ₂ 33,8% CaO 19,9% MgO
Villa Gray	China	898		75,6	2820	0,17					

This route, located in the Estremoz Anticline, promotes the tourism industry which passes necessarily by the simultaneous and integrated development of various aspects such as tourism, scientific, industrial, cultural and sporting activities.

The proposal presented consists in the involvement of companies with potential for the development of industrial tourism by the elaboration of a plan of tourist visits. Thus, it is a great opportunity for the visitor to know the city's economic potential, as well as the valorization of the brand of the companies involved in the project, the generation of new business and touristic promotion of the city.

The integration between the industrial and services sectors involving the process of industrial production in the itineraries of visits to the city, is characterized as a viable form of local tourism development, since the collaborators of the participating companies in the project start to fill the role of main actor of the process (Falé, *et al.*, 2009).

Besides Marble Routes, the region has singular conditions and astonishing scenarios to the practice of adventurous tourism and to the realization of radical sports like “offroad” events, competitions of “BTT”, “Trial Bike” e “Motor Trial”.

The first edition of the Challenge Trophy event which happened in May 2010, in the Counties of Sousel, Estremoz, Borba, Vila Viçosa and Alandroal counted with one hundred athletes and last for two days where the participants had to realize several orienteering and obstacle competitions, taking advantage of the fact that some quarries with interrupted mining works present technical and safety conditions for its realization (Fig. 10).



Fig. 10 – Activities during the VIII Challenge Trophy in a quarry located in the Southwest limb of the Estremoz anticline, Vila Viçosa.

Certain quarries have high quality acoustic conditions allowing the realization of cultural events, such as concerts. One example of that is the “Ópera vai aos Mármore”, which includes the realization of an opera in a quarry that will be a great production with national and international projection.

Therefore, the reutilization of inoperative quarries close to the urban centres, can be reconverted in art and leisure places. These can be done with low funding projects, involving some superficial modeling, screen planting trees, building of infrastructures and adaption of the land for appropriate use and security.

Concluding Remarks

It should be noted that the values achieved by the production of carbonate rocks in Portugal are particularly due to the rising production of calcareous sedimentary rocks, in detriment of the marbles production that in recent years have been falling.

The stagnation of national prices and the fall of the stone in the decorative global landscape is due to, in one hand by the substitution of top of the range types by others manifestly inferior as well as regarding the quality of the rock, either in the use of the automatic computerized production series of standard parts cheaper than processing more complex and elaborate pieces and on the other hand due to the international competition pressure, i.e. the low bid prices, especially China and India, but also Turkey and Brazil (Martins, 2009).

The marble has life and is temperamental, changes color and texture with the daylight, humidity and weather. It also ages! Its diversity makes it unique and can show truly abstract paintings. Their traces show up winding convoluted and strong personality, imposing itself in the eyes of the beholder. The diversity of colors makes it irreverent. Nevertheless it is be presented constant, reflecting the constancy of color appearance, determined by the conditions that prevailed in its genesis.

Those who work the marble, first they have to know it well and become familiar. Only then they will be able to shape it wisely. It is not easy to tame a rebellious nature but, there are those who have done it so masterfully, like Michelangelo, Bernini, among other geniuses of the sculpture. Armed with art and skills they possessed the ability to give life to stone. Also today there are wonderful sculptors (Fig. 11) but they have technology to help them to facilitate their work.

The marble is not just for carving. Its application as a raw material for construction has also been done for millennia, since early man discovered the potential of this noble material. The art of giving more value to the marble, or other type of dimension stones, requires more than just technical training. Sensitivity is needed since the extraction step, through all the stages included in the processing until the proper application of work (Fig. 12).



Fig. 11_– Detail of a sculpture by César Valério, Vila Viçosa, Portugal.



Fig. 10-12_– Spectacular example of white marble applied on a staircase of a private home.

Only then we can take advantage of a raw material of exceptional beauty, otherwise the final result could be disastrous both from a technical standpoint as well as from an aesthetic point of view.

One last note to the great work done by Antonio Manuel Esteves Henriques, who for 30 years through his magazine “Rochas & Equipamentos”, Seminars and Conferences, Publication of Books and many other activities, boosted the Dimension Stone Portuguese Sector and promoted it all over the World, whom we want to pay our sincere tribute.

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