

**GLOBALSTONE**  
c o n g r e s s 2 0 2 3

**7th EDITION**

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**MOSTEIRO DA BATALHA**  
BATALHA, PORTUGAL

**PROCEEDINGS**

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**18TH - 23RD OF JUNE 2023**

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**ASSIMAGRA**  
MINERAL RESOURCES OF PORTUGAL



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**UNIVERSIDADE  
DE ÉVORA**



# **GLOBAL STONE CONGRESS 2023 | BATALHA, JUNE 18 – 23**

<https://globalstone2023.stonebyportugal.com/>

**NEW CHALLENGES ON DIMENSION STONES, FROM PORTUGAL TO THE WORLD**

**Responsibility for the information and views set out in this  
publication lies entirely with the authors**

Luís Lopes, Marta Peres, Célia Marques (Organizers)

Edition: Departamento de Geociências da Escola de Ciências e  
Tecnologia da Universidade de Évora

Cover: Inês Ribeiro, Luís Lopes

Back cover: Luís Lopes

Graphic design and pagination: Luís Lopes

Publication date: June 2023

Support Type: eBook

I.S.B.N.: 978-972-778-327-4

**How to cite publications in this proceeding's eBook (example):**

N. Careddu, L. Pia, O. Pandolfi, N. Santoro, S. DüNDAR. 2023. Study for the Implementation of an Integrated Monitoring System in Marble Quarries. Proceedings of the VII Global Stone Congress, Batalha, Portugal, 18-23 June 2023. Luís Lopes, Marta Peres, Célia Marques (Eds.). Departamento de Geociências da Escola de Ciências e Tecnologia da Universidade de Évora, Portugal. pp. 30 – 35. ISBN: 978-972-778-327-4

# GLOBAL STONE CONGRESS 2023 | BATALHA, JUNE 18 - 23

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## EXOTIC STONES: A MILESTONE IN NATURAL STONE SECTOR

M.H.B.O. Frascá<sup>1\*</sup>, N.F. Castro<sup>2</sup>

(13) MHB Geological Services, [\\*mheloisa2@yahoo.com.br](mailto:mheloisa2@yahoo.com.br)

(14) Centre for Mineral Technology, CETEM/MCTI.

**Summary:** *The natural stones, commonly called exotic, comprise a special group characterized by unusual patterns and relatively rare geological occurrence. They are currently the flagship with the highest added value of Brazilian natural stone exports and are used domestically and internationally for the internal and external cladding, flooring and decoration of luxury buildings or residences. Its high price, in addition to the intrinsic exclusivity of almost all slabs, stems from the high costs of locating the deposits, mining exclusively with diamond wires, transport, processing, including several steps of reinforcement and resining, and finally, polishing. The development and use of all these state-of-the-art technologies, exposed in this article, make it possible to point to exotic rocks as a milestone in natural stones' production.*

**Key words:** *exotic stones, Brazil, pegmatites, quartzites, processing technologies*

### Introduction

Exotic, according to Merriam-Webster dictionary (2023), means either "strikingly, excitingly, or mysteriously different or unusual" or "introduced from another country: not native to the place where found". Exotic stones in Brazil seem to cover both definitions since they constitute a set of rare rocky materials and are currently the flagship of exports. Technically, they can be defined as rocks that usually have a differentiated aesthetic appearance and a relatively rare geological occurrence, whether of an igneous, metamorphic, or sedimentary nature.

The term started to be used by the natural stone sector around the 90s of the 20<sup>th</sup> century when it began the production and marketing of some very heterogeneous rocks in several aspects (granulometric, mineralogical, textural, and structural), namely the pegmatitic rocks, which are characterized by very large feldspar mega crystals. Frascá (2007) also called these "decorative stones" due to their typical low mechanical strength and limited production, and thus commonly used as interior cladding.

Gradually, other distinct rock types were introduced into the market thanks to the geological singularities of the Brazilian territory and technological developments that facilitated their extraction and processing. The "exotic" quartzites are the best example of top-ranked stones nowadays.

Although the innovations in the natural stone industry are extended throughout the sector, regarding exotic stones, pegmatites could be considered as "Phase 1" and quartzites as "Phase 2", in technological terms. Therefore, the first can be related to the new resin-bonding technologies in the 1990s and early 2000s, and the second to the additional advances in equipment and inputs for cutting and polishing, specifically new diamond tools and resins, together with CNC (computer numerical control) technologies.

The lack of sharing the provenances and technological properties, which seem to be predominantly linked to marketing strategies, is a relevant characteristic of these rocks. So, the primary objective of this paper is to gather the available information to contribute to a better knowledge of these stony materials.

### Brazilian and international market

Montani (2021) points Brazil as one of the main world stone producers, regarding chromatic diversification or the exclusive nature of a good proportion of the offered products, which seems to refer to exotic stones.

In 2020, Montani (2021) positioned Brazil as the fourth leading quarrying producer (circa 5% of world production), the fourth leading exporter of stone in quantity (circa 2,000 tons and 4% of global shares) as well as of processed stones (5,7%). China, India, and Turkey precede Brazil in almost all positions.

The export data provided by Centrorochas (2023) shows that a large part of the stone material currently exported refers to quartzite slabs, exotic silicate rocks, and massive quartzite blocks.

In terms of buyers, the USA is the major importer, predominantly of processed stone. In 2022, the USA, China, Italy, and Mexico, in that order, represented the leading destinations for Brazilian exports, with the USA responsible for 58% of revenues in this period (ABIROCHAS 2022). The same publication mentioned that the stones sold under the code 68.02.99.90 (massive quartzite slabs and exotic silicate stones) had an average price of US\$ 2,300/t, representing US\$ 356.6 million and 154,800 t of the material exported.

Regarding stone consumers, after China (33.1 %), India (8.2 %) and the USA (5.7 %), Brazil is an expressive consumer, using circa 3.3 % (56.4 mill m<sup>2</sup>) of the world stone produced, according to Montani (2021).

#### **Main rock types and technological properties**

As a result of the great geodiversity and the improvement of the geological knowledge of the Brazilian territory, together with the search for detailed information on the likely places of occurrence of the rare materials, it was possible to discover and diversify the range of options for Brazilian natural stones.

Figure 1 (a, b, c) shows some rough blocks to illustrate the huge diversity of patterns and geological nature exhibited by exotic stones. They may be pegmatitic, quartzitic and schistose rocks that, in addition to each type's characteristic mineralogy, quartz and feldspars, quartz and quartz and micaceous minerals, respectively, additionally contain a significant variety of subordinate and accessory minerals, making their petrographic classification very difficult in routine characterization studies.

Likewise, the structural, textural and granulometric heterogeneity also difficult an accurate determination of their technological properties.

Besides, although their properties may meet the requirements for application in flooring or wall covering, in addition to other decorative options, due to the very coarse grain size and the high degree of cracking or fracturing of some lithotypes, their mechanical strength and porosity/water absorption may be relatively lower or higher, respectively, than typical granites or quartzites.

Thus, studying an pegmatite exotic stone called Karnaval (from Borborema, in the northeast region of the state of Paraíba, and geologically associated with the Seridó Fold System), Pazeto et al. (2017) indicated two main petrographic factors contributing to its brittleness and lower flexural strength: (a) the extremely coarse grain size, configuring a high degree of discontinuities and poor mineral interlocking, and (b) the surfaces of weakness related to feldspar mega-crystals cleavage plans.

On the other side, wear abrasion and chemical attack resistance are high for most quartzites due to their high quartz content.

Zagôto et al. (2022) proposed a natural stones quality index based on the technological test results of 285 natural stones. The quartzite group (61 samples), in its natural state, showed the highest mechanical strength dispersion, which was attributed to the microcracking density.



Fig. 1. Examples of exotic stones: quartzitic rock (a), pegmatitic rock (b), and schistose rock (c).

Furthermore, characterization results of several quartzites from Ceará (Santos et al., 2017) showed that some may have low mechanical strength, but also low water absorption. In this case, Nunes (2018) found that some quartzites, even with a high density of microcracks, have most of them not connected, thus inhibiting the percolation of water. Consequently, reinforcing the blocks and slabs is of utmost importance.

### Occurrences

Singularity and differentiated geological aspects, such as structure, grain size and colour are the main requirements for a rock to be "exotic". Thus, they are mostly stone materials of restricted occurrence, with smaller reserves than traditional deposits of granites and marbles.

Another remarkable feature is the insufficient knowledge of the exact locations of exploitation, mainly aiming to avoid competition and maintain exclusivity.

Pegmatitic rocks and quartzites are the main stone types commercialized as exotic stones, followed by schists and some very rare igneous rocks (such as metamorphosed pillow lavas).

The leading producers of exotic stones are Minas Gerais, Paraíba, Rio Grande do Norte, Ceará and Bahia (ANM, 2023). Quartzite slabs and exotic silicate rocks from the states of Ceará and Espírito Santo, as well as massive

quartzite blocks from the state from Bahia and Minas Gerais, are the main exported items, according to Centrorochas (2023).

However, it is important to mention that the state of Espírito Santo has, by far, the largest processing park and is the largest Brazilian exporter of natural stone. On top of this, companies from that state also quarry and process natural stones in other states. This explains its presence in the statistics and not necessarily due to its significant occurrences of exotic stones.

Data available at the National Mining Agency (ANM, 2023) show more than 1,000 companies with licensed areas, explicitly registered to produce dimensioned quartzite, alone or with other substances. Half of the areas are for dimensioned quartzite alone. Though this does not mean they are effectively exploited, it clearly shows the market interest.

The mentioned exotic silicate stones, which include pegmatites and differentiated granites, are those whose provenance is most challenging to determine since they are late phases of granitic intrusions that can occur in the most distinct orogenic belts scattered through the Brazilian territory (Figure 2).

Thus, it is more difficult to identify the licensed areas for pegmatite natural stone as it is usually registered as granite.

Within the tectonic complexity of the Brazilian territory, there are several regions with a high concentration of pegmatites, called pegmatitic provinces, generally

named according to their geographic distribution. Dimension pegmatitic stones have been quarried in the Eastern and Northern provinces since the beginning of the 21<sup>st</sup> century (Beurlen, 2009; Pedrosa-Soares et al., 2009) from barren exposures of fresh rock, sometimes together with associated aplites and granites.

Several quarrying operations are carried out in the pegmatitic occurrences reported by Teixeira (2012) in the Seridó Belt, on the border of the states of Paraíba and Rio Grande do Norte, as well as in the northeast of the state of Minas Gerais, and some in other states of the country (i.e., Ceará and Goiás).

In the state of Minas Gerais, most of the countless pegmatites are Late Neoproterozoic intrusions of granitic residual melts (Pedrosa-Soares et al., 2009) of the Araçuai Folded Belt, related to Gondwana amalgamation.

As for quartzites, they have been used as building stones, in Minas Gerais, since the Portuguese colonization (Costa, 2015). The quartzite flagstones from the region of São Tomé das Letras, named 'Pedra São Tomé' and 'Pedra Mineira', have been exploited for several decades and domestically used and exported as rough slabs or setts for external paving. Geologically, they belong to the Andrelândia (Neoproterozoic) and Canastra (Mesoproterozoic) Groups, both in the Tocantins orogenic system, which lies between the Amazonian and São Francisco cratons (Hasui 2012). Some predominantly white quartzites, such as the commercial 'Montblanc', from the Espinhaço Supergroup (Paleo/Mesoproterozoic), are currently

exploited in the north-eastern part of Minas Gerais, as well as in the south of the State of Bahia.

Also, regarding well-known quartzites, the "exotic" blue quartzites (Frască; Castro, 2022), also in the Espinhaço Supergroup, have been mined since the 1960s close to the city of Oliveira dos Brejinhos, state of Bahia.

Thus, due to the tradition and presence of mining companies in these areas, the exploitation of other types of quartzites, included here as exotics, and occurring in these geological and geographic contexts, is expected. For instance, quartz stones with green-coloured fuchsite crystals are exploited close to emerald occurrences in northeast Bahia.

Bahia is also known for the diversity of coloured and banded quartzites: 77 of the 118 commercial varieties presented in the Atlas of Dimension Stones of Bahia (Iza et al., 2022) are quartzites.

Another important site for quartzite production is the state of Ceará where some well-known whitish beige quartzites, such as 'Perla Santana', 'Perla Venata', 'Taj-Mahal', 'Matira' and others, are being mined are being mined in the northwest of the state, in the Médio Coreaú folded region, belonging to the Borborema Orogenic System, which comprises diversified Precambrian lithotypes of different ages. They are pure quartzites, sometimes micaceous and ferruginous and fine- to medium-grained (Nunes, 2018), of the Neoproterozoic metasedimentary sequence of the Martinópole Group (Santos, 2004).

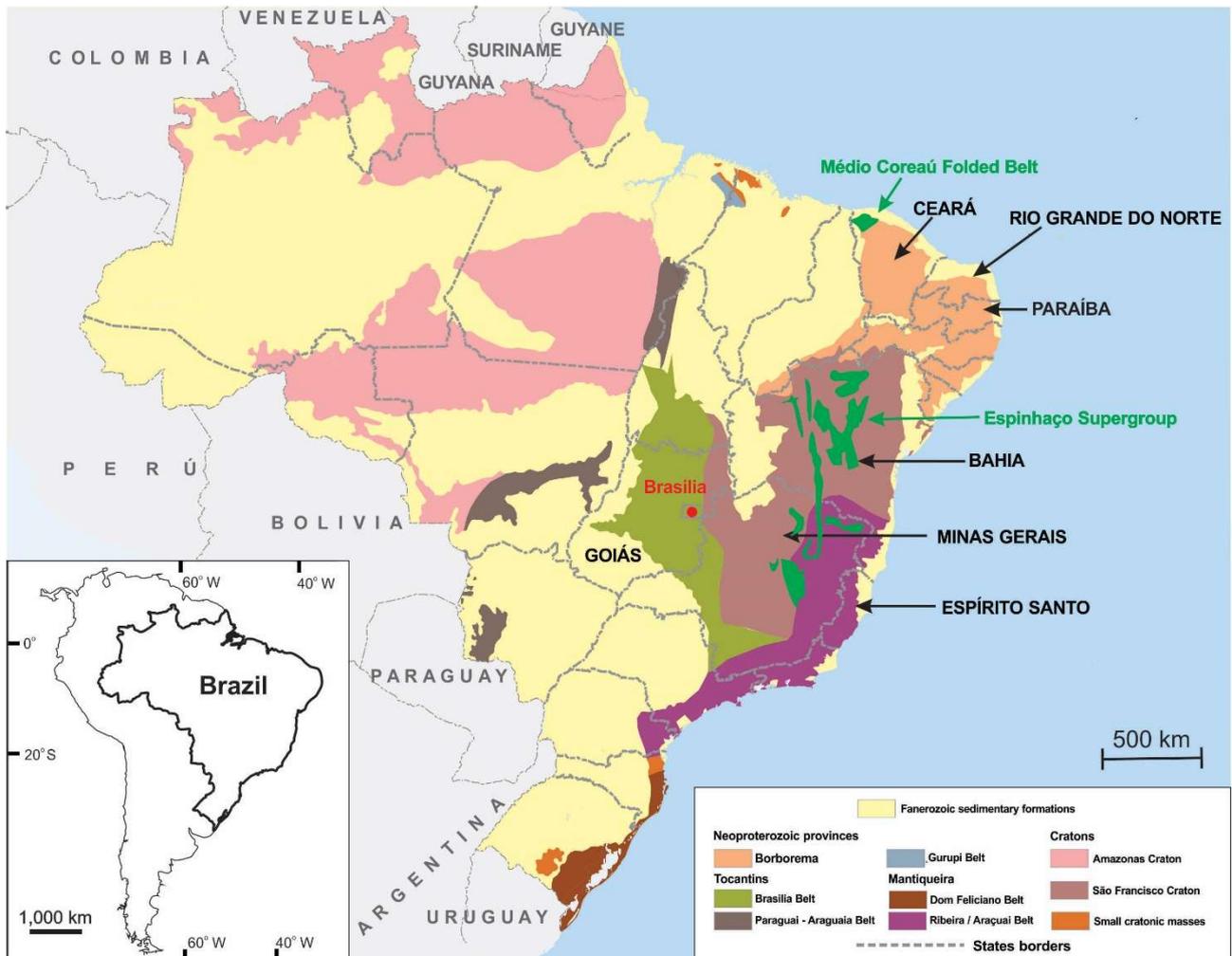


Fig. 2. Simplified map of Brazilian Geotectonic Provinces, with location of geological features and states mentioned in the text (Sources: Franz et al., 2014; Silva et al., 2014).

### Mining and processing technologies

The Brazilian stone industry has achieved a high technological level regarding the quarrying and processing of exotic stones during the last decades, partly due to the increasing production of exotic stones. European companies, most Italian, have been working together with stone producers to improve the cutting and resining of hard and heterogeneous stones, so Brazil is frequently considered a research laboratory for diamond wire and resin companies. Although the national industry has also developed and provided cutting equipment, tools, and chemical products, most of them are still imported.

Exotic stones are usually quarried in open pits with the medium-to-high benches method. Diamond wire is the only cutting technology. Primary cuts on benches of six to fifteen meters high and secondary cuts on the laid benches to produce the blocks are done by diamond

wire equipment, while drilling is used for auxiliary operations.

Most blocks are superficially reinforced on-site, or at least their corners (see Fig. 1 a, b), with a mixture of resin and mineral fillers over which a fiberglass mesh is fixed. More valuable stones can be reinforced twice in the quarry to allow their safe transportation, and sometimes, even the benches' wall is reinforced with the same system before laying them down to the quarry (Figure 3 a).

Production is slow, and costs are high as diamond wire, drilling rods and bits need more frequent replacement than in quarries of traditional silicate rocks, which are more homogeneous and can be quarried in high or ultra-high benches resulting in higher production rates. Moreover, especially regarding pegmatites, the more exotic patterns occur as several meters width veins inside the rock massif, requiring continuous and careful quarry planning and leading to a low recovery.

additionally, exotic materials, which have a high selling value, allow a profitable quarry production of small blocks for slabs or other products (i.e., furniture, artworks), beyond producing the market-demanded big blocks.

The quarried blocks go straightforward to exportation or to a processing facility to be cut into slabs and polished. The blocks can again be reinforced with resin, mineral filler and a fibreglass mesh and cut into slabs in multiwire saws (Figure 3 b, c). Before the multiwire cutting machines, a quartzite block took around ten days to be cut in a gang saw, while now, that task takes just several hours (Souza et al., 2012; Careddu; Cai, 2014).



Fig. 3. Exotic stones production: quartzite quarry showing benches and blocks reinforcement (a); pegmatite block being reinforced at the quarry (b); and a multiwire saw cutting a reinforced quartzite block (c).

The slabs polishing process involves the following sequence: the back of the slab reinforcing with fibreglass; restoring (filling of cavities with the same rocky material), when needed, and subsequent rubbing; slab resin impregnation; rough polishing; first resin coating; medium polishing; second resin coating; fine polishing; and inspection (Martins; Silveira, 2020). The slab drying and resin curing are done mainly by gas or electric ovens, but there are also microwave and UV systems. Almost all Brazilian companies have automatic polishing lines, and several have fully automatized production facilities, including robots and vacuum systems for resin application. (Figure 4).



Fig. 4. Exotic stones production: automatized processing plant (a); cavities for filling (b); robotized resining for fibreglass fastening (c); automatic resin coating (d).

Pazeto et al. (2020) conducted a study to determine the mechanical performance of the reinforcing process adopted by industry (netting) by testing specimens of Karnaval pegmatite reinforced with different thermoset resins and glass fibres. An important finding, in terms of costs, was that the post-curing process of the epoxy resin commonly applied in the industry proved to be more efficient in meeting a better mechanical performance than adding low-density fibreglass to the reinforcing procedure.

Resining has also experimented with a remarkable evolution in Brazil to achieve the best surface quality through less time-consuming application methodologies and cost savings (Martins; Silveira, 2020). Regarding the resins applied, some polyester-based systems are used for the blocks' reinforcement (Camargo et al., 2022), but most are epoxy resin-based systems. They require rigid health and safety measurements for their use, beyond being originated from a non-renewable source. Brazilian research has been studying natural resins to substitute them in the industry for several years, but epoxy resins are still the most commercialized (Dorigo et al., 2020; Silveira et al., 2020).

### Uses

Although the scarcity of information describing the final application of the several exotic stone types, the best indications are that interior decoration is their principal use, even in Brazil, mostly due to their high price and beauty.

Best examples are countertops, tables, bathrooms, swimming pool areas, gourmet kitchens and many others (Figure 5).



Fig. 5. Examples of uses of exotic stones: kitchen with 'Ornamental Granite' (a) and 'Perla Venata' (b); dining room with 'Quartz Blue' (c); bathroom with 'Taj Mahal' (d), and pool area with 'Yellow Bamboo' (e). Photos by Paulo Giafarov (a, c, e) and Liliane de Lucca (b, d).

## Conclusions

Exotic rocks are a particular group of natural stones characterized by special patterns and, in most cases, by their rare occurrence.

To the exotic stones high market price due to their aesthetic patterns, it must be added the high production costs for that, as it is used high tech cutting tools,

abrasives, and resins in a consumption much higher than for common natural stones.

Along with that are the mining operations, which generally involve the movement of large amounts of burden and rock massif to reach the desired product, often with several quarry fronts opened without success. Transportation costs are expensive because of the long distances to the processing or exporting facilities.

As for the final products' elaboration in Brazilian workshops, providing more technical information about the finished slabs properties would help improve the quality of natural stone applications and reduce costs.

The technical advances that currently allow the exploitation, processing, and use of rocky materials, unfeasible until the end of the last century, opened great market opportunities, especially concerning competitiveness against the ceramic industry.

The major bottleneck compared to ceramics, at least in Brazil, continues to be the proper dissemination of products' technical properties and consumer assistance.

**Acknowledgments:** The authors would like to express their acknowledge to Liliane de Lucca (Defruili Mármore) and Paulo Giafarov (DGG Stones) for the pictures.

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