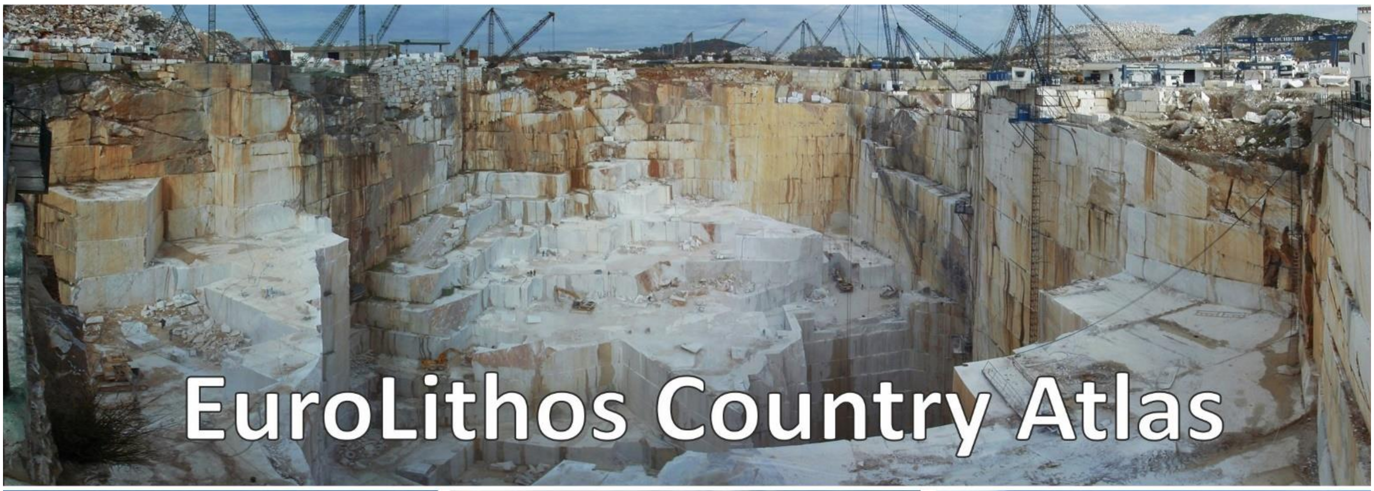
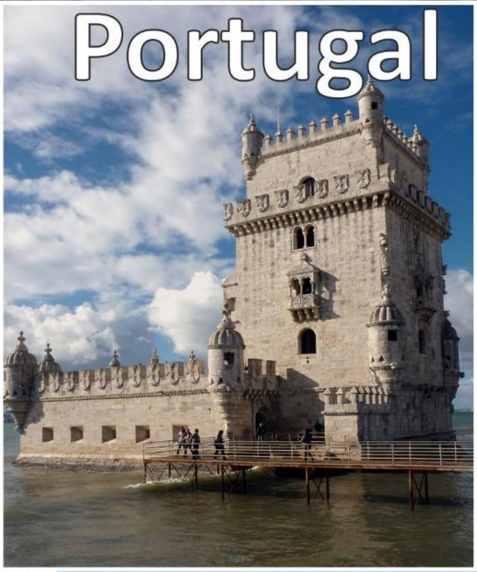
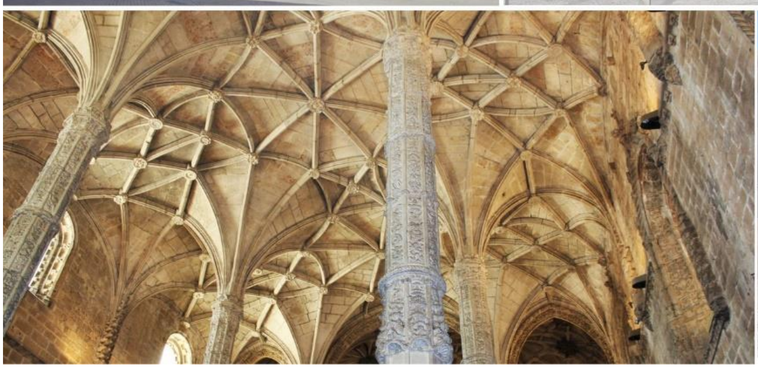
EUROLITHOS European Ornamental Stone Resources



EuroLithos Country Atlas

Portugal





EuroLithos Atlas

Ornamental stone resources in Portugal

Thematic focus: Country

Responsible partner: LNEG

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Year: 2021

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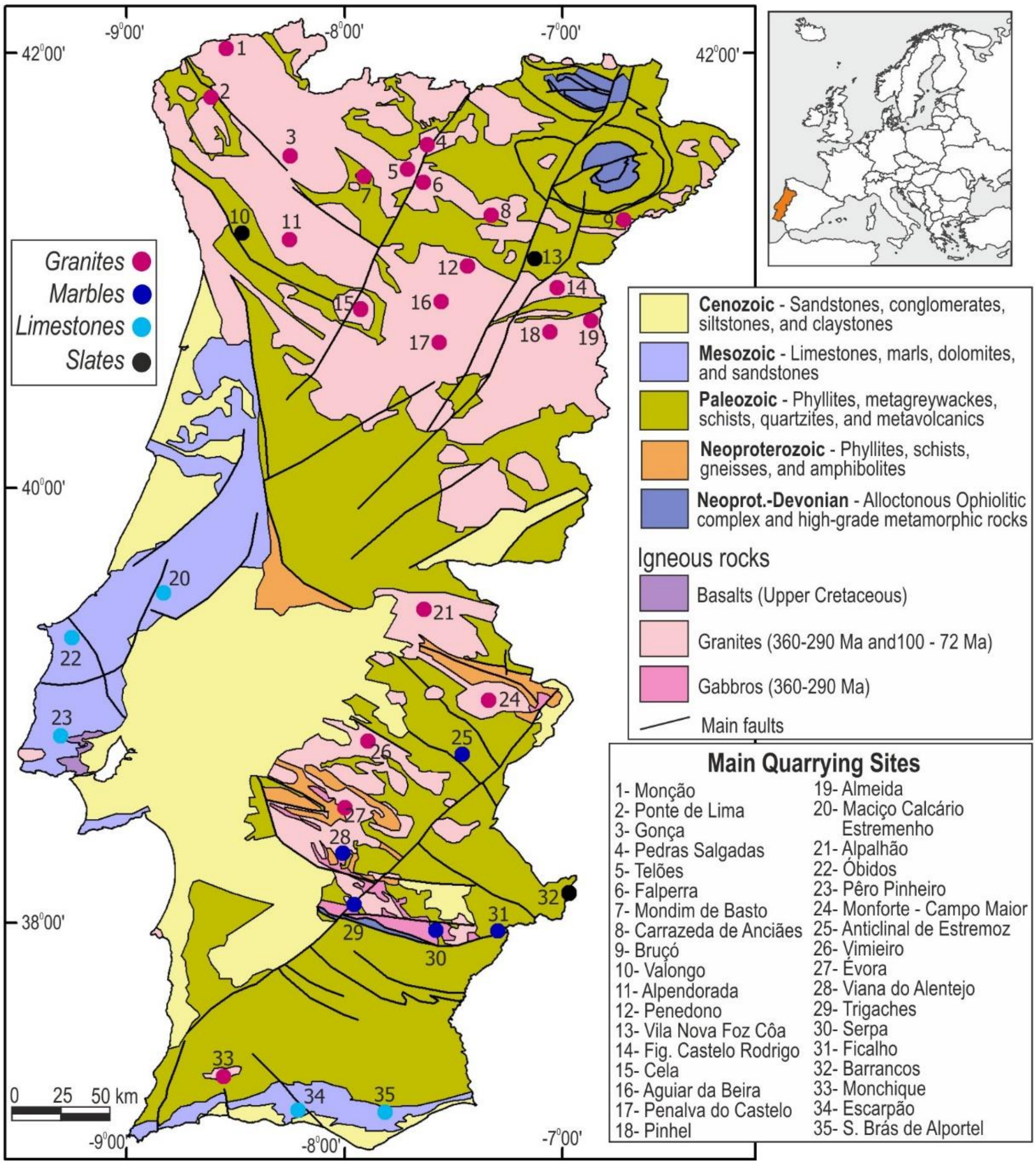
Geology of Portugal

Mainland Portugal is subdivided into the so-called Iberian Massif, the western and southern Meso-Cenozoic borders, and the basins of the Tagus and Sado Rivers. The Iberian Massif integrates Neoproterozoic and Paleozoic metamorphic (flysch-type metasedimentary sequences, quartzites, metavolcanics and marbles) and igneous plutonic rocks. The Meso-Cenozoic borders are mainly composed of clayey siliciclastic sediments, marls and limestones. In the Cenozoic Tagus and Sado basins, sandstones, conglomerates, and argillites predominate, being mostly of Pliocene age.



The Iberian Massif, particularly affected by the Variscan Orogeny, consists of four tectono-stratigraphic units. The Central Iberian Zone corresponds to the central and northern regions where Paleozoic metassediments are extensively intruded by granitic rocks. An ophiolitic complex and high-grade metamorphic rocks integrate the Galicia-Trás os Montes Zone in the north-eastern region. The Ossa Morena Zone, in the central-south region, comprises Neoproterozoic to Paleozoic metassediments, as well as gabbro and granitic intrusions. The southern region of the Iberian Massif makes up the South Portuguese Zone: a low-grade metamorphic sequence of flysch-type sediments with important VMS deposits.

Ornamental stone resources in Portugal

Portugal has a great diversity of ornamental stones distributed by the granite, marble, limestone and slate commercial groups. Quarrying of granite takes place in tardi-tectonic variscan plutons in the northern and central regions of Portugal mainland. Portuguese ornamental granites are fine to coarse grained, having colours ranging from dark grey to pink and yellow, the latter corresponding to weathered granites. The most important quarrying sites are located in the north of Portugal: *Monção* (light-pink granite, coarse grain), *Pedras Salgadas* (light-grey biotitic granite, fine to medium grain), *Falperra* (yellowish granite, fine to medium grain), and *Alpendorada* (grey granite, medium grained). Still, it is worth noting that a few granitic stones are also quarried at the south of Portugal, particularly a variety extracted in the Algarve region that corresponds to a medium to coarse grained syenite having a grey background colour, but with reddish-brown punctuations due to the presence of nepheline.

Most of the Portuguese limestones are quarried at the *Maciço Calcário Estremenho*, a morphostructural unit of the Lusitanian Basin. They are fine to coarse grain limestones (grainstones and rudstones) having light beige colour. Depending on how the blocks are cut to obtain the slabs, these may present a textural pattern marked by sedimentary laminations or not. In the Pero Pinheiro region, near Lisbon, limestones with a high heritage value are exploited. They are reef limestones in which the presence of large fossils of Rudists and the white, yellow or red colour gives them particular aesthetics characteristics.

The variscan *Estremoz* Anticline, eastwards of Lisbon, is the most important mining district of marbles in Portugal. Quarrying takes places in dozens of quarries grouped in five main exploitation centres. Predominantly, these fine to medium grain marbles have a white or pink colour, with shade variations, but dark grey varieties also occur. They have a wide variety of textures, with narrow stripes of darker colours being common. The marbles exploited at *Viana do Alentejo* and *Serpa* are also worth noting due to their greenish colour and coarse grain, and those from *Trigaches*, which have grey colour and very coarse grain.

Concerning slates, there are only a few quarrying sites. The most important ones are located in *Valongo*, where the extraction takes place underground, and *Vila Nova de Foz Côa*.

Ornamental stone production

Quarrying ornamental stones has a long tradition in Portugal and, despite the increased competition, Portugal is one of the most important worldwide producers and exporters. The extraction of ornamental stones occurs all over the country, but the main production centres are located in the northern region, where granites are extracted, and in specific places of the central region of the country, where limestones and marbles are quarried, respectively in the *Maciço Calcário Estremenho* and Estremoz Anticline.

Total production of ornamental stones in Portugal for the year of 2019 reached 3.6 million tons, broken down as follows: granites 2 261 553 t, limestones 1 127 233 t, marbles 165 535 t, and slates 61974 t. About 62% of this total was exported, but unevenly distributed accordin to the type of stone. Only 28% of the total production of granites was exported, meaning that the production was largely absorbed by the domestic market. On the contrary, of the total production of limestones and marbles together, 85% was exported, mainly to China. Provisional data for 2020 production are similar, meaning that COVID-19 pandemic did not affect production. However, exports decreased by 19%.

Use of ornamental stone and heritage values

Ornamental stones have been exploited in Portugal at least since the occupation of the Iberian Peninsula by the Roman Empire, particularly the marbles of the Estremoz Anticline, which can be found in ancient Roman buildings, epigraphs or sculptures in Portugal and abroad. The Roman temple of Évora and the Roman Theatre of Mérida (Spain) are iconic examples of the use of marble from the Estremoz Anticline during this period. Other stones have been used in antiquity, as a Roman quarry in the region to the north of Lisbon testifies. Limestones of the Lioz variety were extracte and used for the construction of buildings in *Olisipo* (the Roman city of Lisbon). These same variety was the main building material used for the reconstruction of Lisbon after the big earthquake of 1755 and it is still used today, not as a structural construction material, but for wall and floor cladding. In the granitic regions of Portugal, there are also testimonies of the use of granite since the Roman Empire, but the main current testimonies date from the period between the 9th and 13th centuries, during which several castles and other types of fortifications were built.

Descriptions of ornamental stone resources

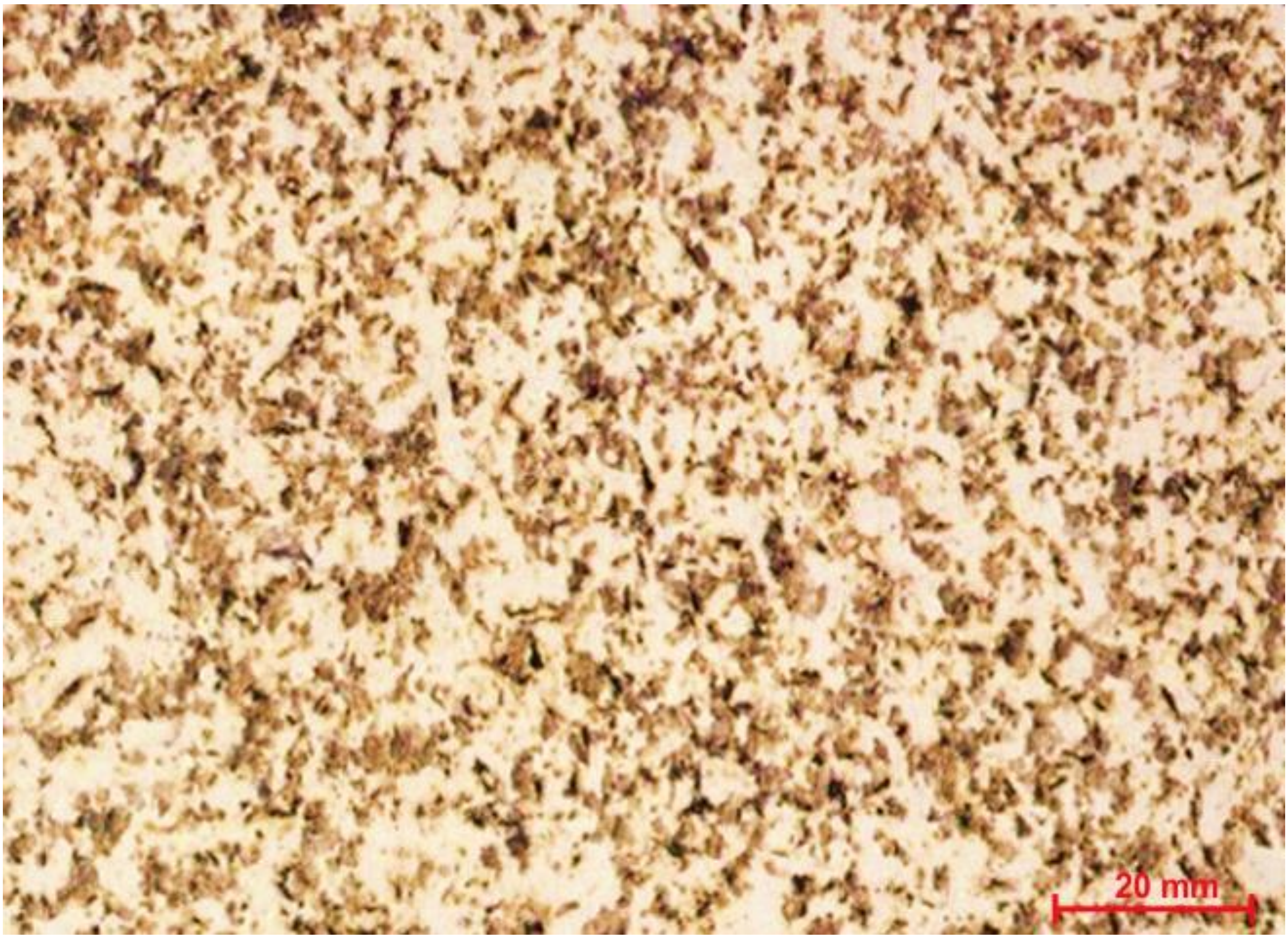
Portugal produces more than a hundred varieties of ornamental stones, distributed by the commercial granite, limestone, marble and slate groups. Some of the most important Portuguese ornamental stones are described below in the order shown in Table 1.

Stone name	**Commodity**	**Lithology**
Amarelo Vila Real	Commercial Granite	Monzogranite
Cinzento Alpendorada		Monzogranite
Pedras Salgadas		Monzogranite
Amarelo de Negrais	Commercial Limestone	Limestone
Creme de Fátima		Limestone
Lioz		Limestone
Moca Creme		Limestone
Moca Creme Fino		Limestone
Moleanos		Limestone
Semi Rijo do Codaçal		Limestone
Branco Estremoz	Commercial Marble	Calcitic marble
Branco Venado Estremoz		Calcitic marble
Creme Estremoz		Calcitic marble
Rosa Portugal		Calcitic marble
Ruivina		Calcitic marble

Commercial Granites

Amarelo Vila Real

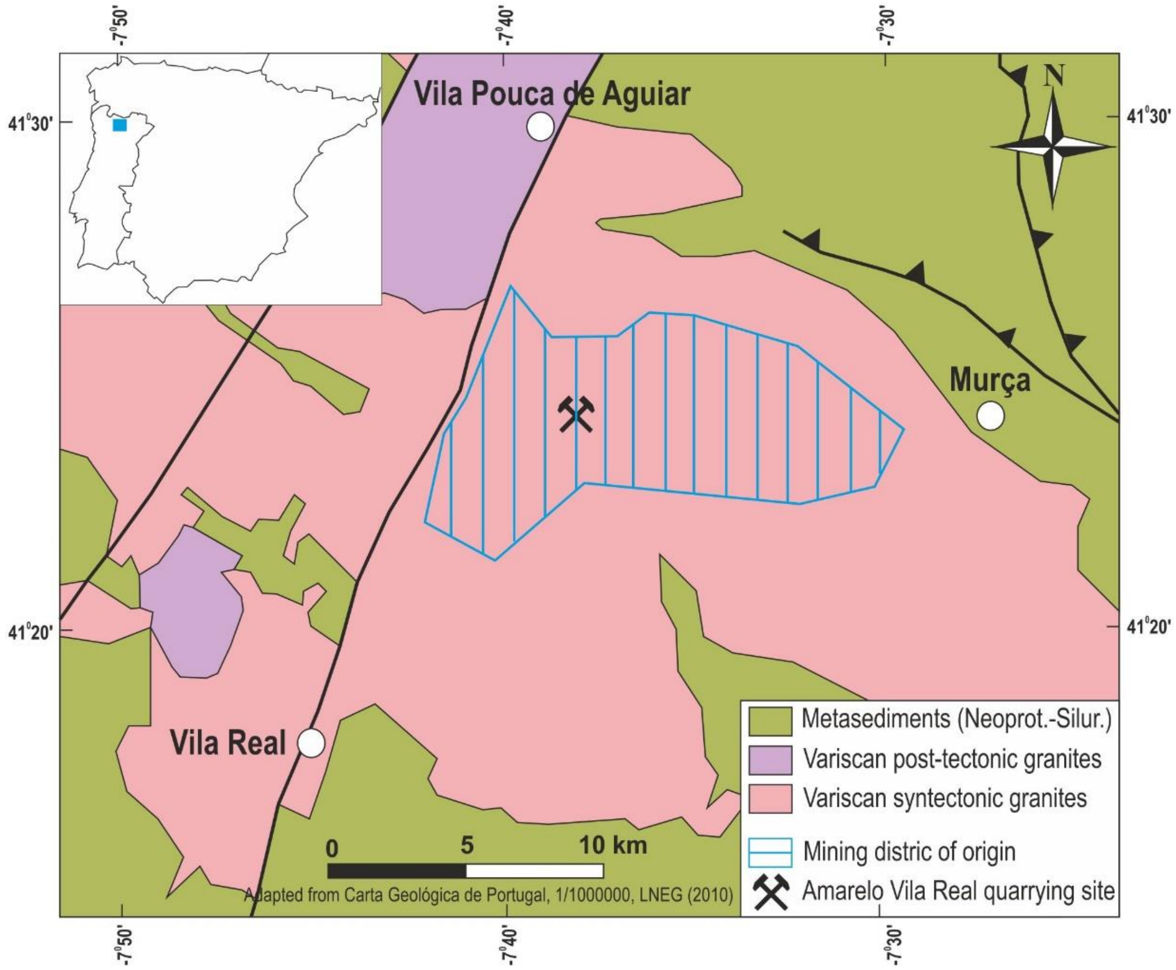
Amarelo Real



Light yellow to brownish yellow two-mica granite. Medium to coarse grain with porphyroid tendency and incipient foliation.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Village
Commercial granite	Monzogranite	Yellow	Portugal	Vila Real	Vila Real	S. Tomé do Castelo, Pinhão Cel

Geological setting



Geology:
The granitic massif of Vila Real is part of a larger granitic body striking WNW-ESE that was formed during the last stages of the Variscan Orogeny. The yellowish shades of the Amarelo de Vila Real ornamental variety is the result of a slight meteoric alteration of the most superficial levels of the Vila Real Granite.

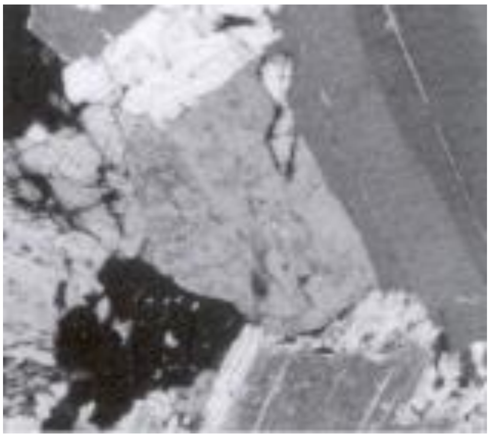
Production:
Because only the superficial levels of the Vila Real Granite show a yellowish colour, the quarrying of the Amarelo de Vila Real occupies large areas. Large granite boulders are also exploited.
Production is conditioned by the colour variations, which, in turn, depend on the proximity to fractures. Therefore, large blocks are difficult to obtain.

Geological age: Carboniferous
Geological unit: Maciço Granítico de Vila Real

Application, use and heritage

The Amarelo de Vila Real is suitable for application in interior or exterior sheltered areas, particularly for wall cladding. it is also used in the form of cubes for road paving

Petrography



Thin section parallel to the preferred orientation plane, when applied.

Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Granite with inequigranular hypidiomorphic texture, showing slight porphyroid tendency and moderate or clear feldspar weathering.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Microcline (%)	Quartz (%)	Plagioclase (%)	Muscovite (%)	Biotite (%)
~32	~27	~26	~11	~3
Chlorite, zircon, apatite, rutile, ilmenite and other opaque minerals (%)				
~1				

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2590	2.0	0.8	81	8.9

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	10.4 (C_1)	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	78	25	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
—	—	0.3	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
honed	82	77	6	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
73.59	14.67	1.11	0.02	< 0.20	0.46	3.32	4.91	0.36	0.15	—	1.18

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
< 5	6	—	<5	< 7	< 6	74	13
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
32	—	111	26	—	425	—	10
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 7	8	< 5	< 8	< 6	15	57	22
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
—	—	—	< 6	25	—	—	—
Tl	**Hf**						
—	< 5						

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements and of the trace elements: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:		
Commercial directory:		
Scientific publication:	Engineering Geology	http://dx.doi.org/10.1016/j.enggeo.2017.01.030
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7780-0
Other publication:		

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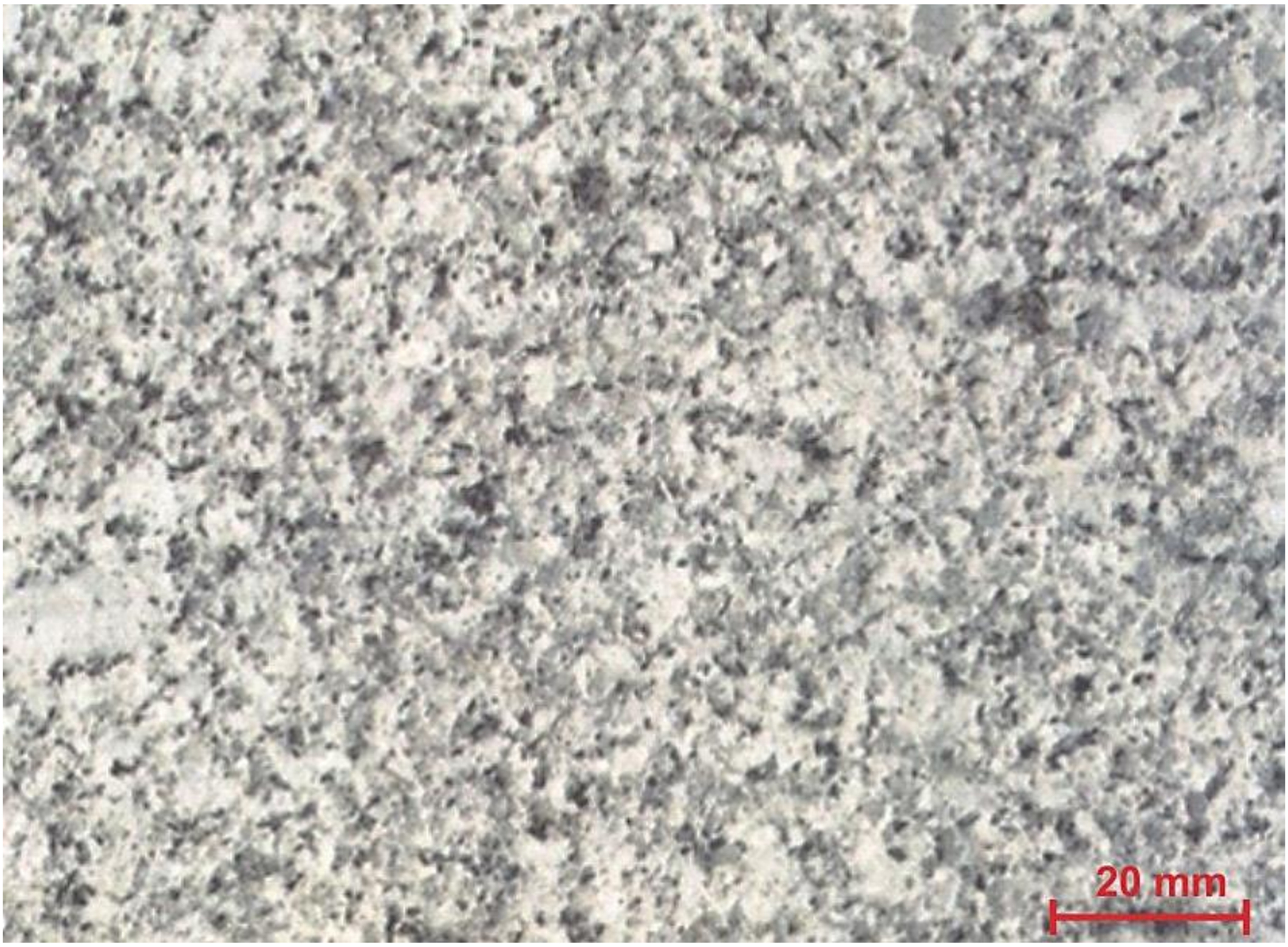
Cinzento Alpendorada

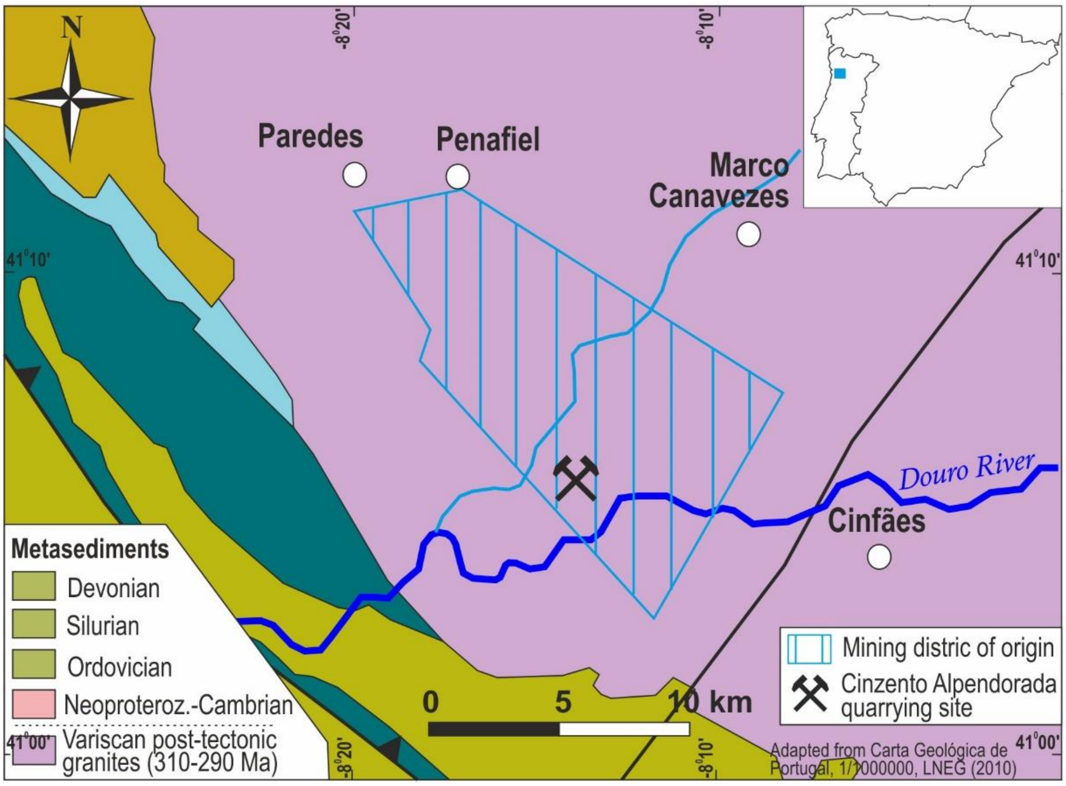
Azul Alpendorada, Cinzento Claro



Two-mica granite, medium to coarse grained, with a bluish grey coloration and very slight porphyroid tendency due to the occurrence of sparse megacrystals of plagioclase and potassium feldspar.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Village
Commercial granite	Monzogranite	Grey	Portugal	Porto	Marco de Canaveses	Alpendorada e Matos

Geological setting



Geology:
Quarrying of Cinzento Alpendorada takes place on the southwestern edge of a large late to post-tectonic calc-alkaline granite massif, which has an NW-SE orientation, extending from the region of Viana do Castelo to the proximities of Castro Daire

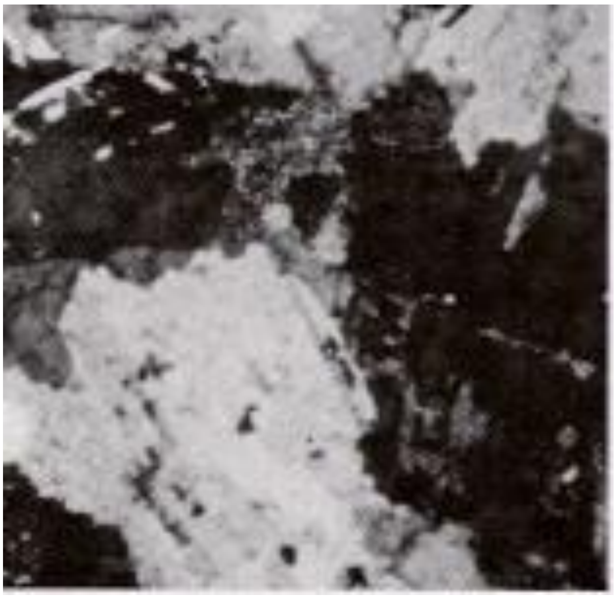
Production:

Geological age: Carboniferous
Geological unit:

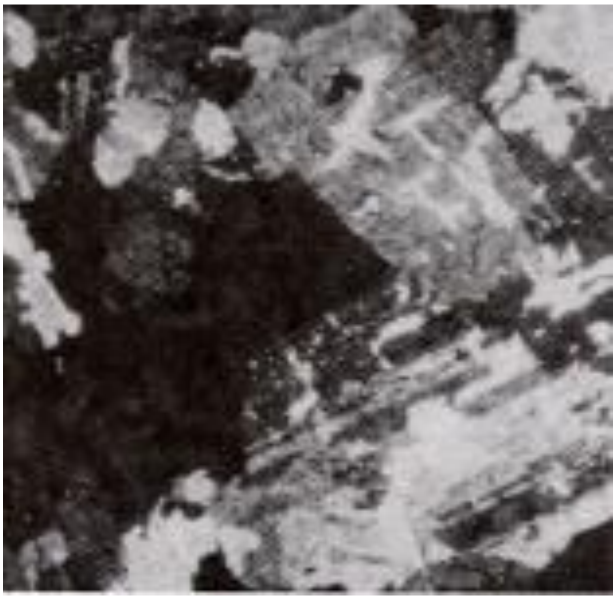
Application, use and heritage

Description:

Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Granite with a granular hypoidiomorphic texture, medium to coarse grained, characterized by the coexistence of crystals with anhedral, subhedral and euhedral morphology. The modal mineralogical composition of the studied stone, projected in the QAP diagram of nomenclature of plutonic stone, allowed to classify it as a monzogranite.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Plagioclase (oligoclase) (%)	Quartz (%)	Potassium feldspar (microcline and pertite microcline) (%)	Muscovite I (of primary origin) (%)	Biotite (%)	Muscovite II (resulting from post-magmatic alteration of feldspars) (%)
~31.2	~30.2	~26.3	~5.1	~4.1	~2.3
Apatite, zircon, monazite, andalusite, chlorite, rutile, calcite and opaque minerals (ilmenite) (%)					
~0.8					

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2650	0.5	0.2	218	15.9

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
15.2	48	212	48	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, 6mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
19.0	—	—	—	3100	28.5

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
sawn	74	54	6	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
72.90	14.60	1.76	0.03	0.38	0.87	2.89	4.92	0.32	0.27	—	0.84

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
10	9	—	< 5	< 7	< 6	66	< 6
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
110	—	290	28	—	348	—	8.53
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 7	11	15.0	—	1.65	16.2	100	12
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
—	—	—	< 6	23	—	—	—
Tl	**Hf**						
—	2.45						

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
23.1	50.5	6.05	22.6	4.36	0.43	3.39	0.53
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		
2.40	0.36	0.79	0.09	0.65	0.07		

Methods applied:
Determination of the main elements: X-Ray Fluorescence.
Determination of trace elements (except for U, Th, Ta, Nb and Hf): X-Ray Fluorescence.
Determination of U, Th, Ta, Nb, Hf and REE elements: Inductive plasma mass spectrometry.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
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Other publication:		

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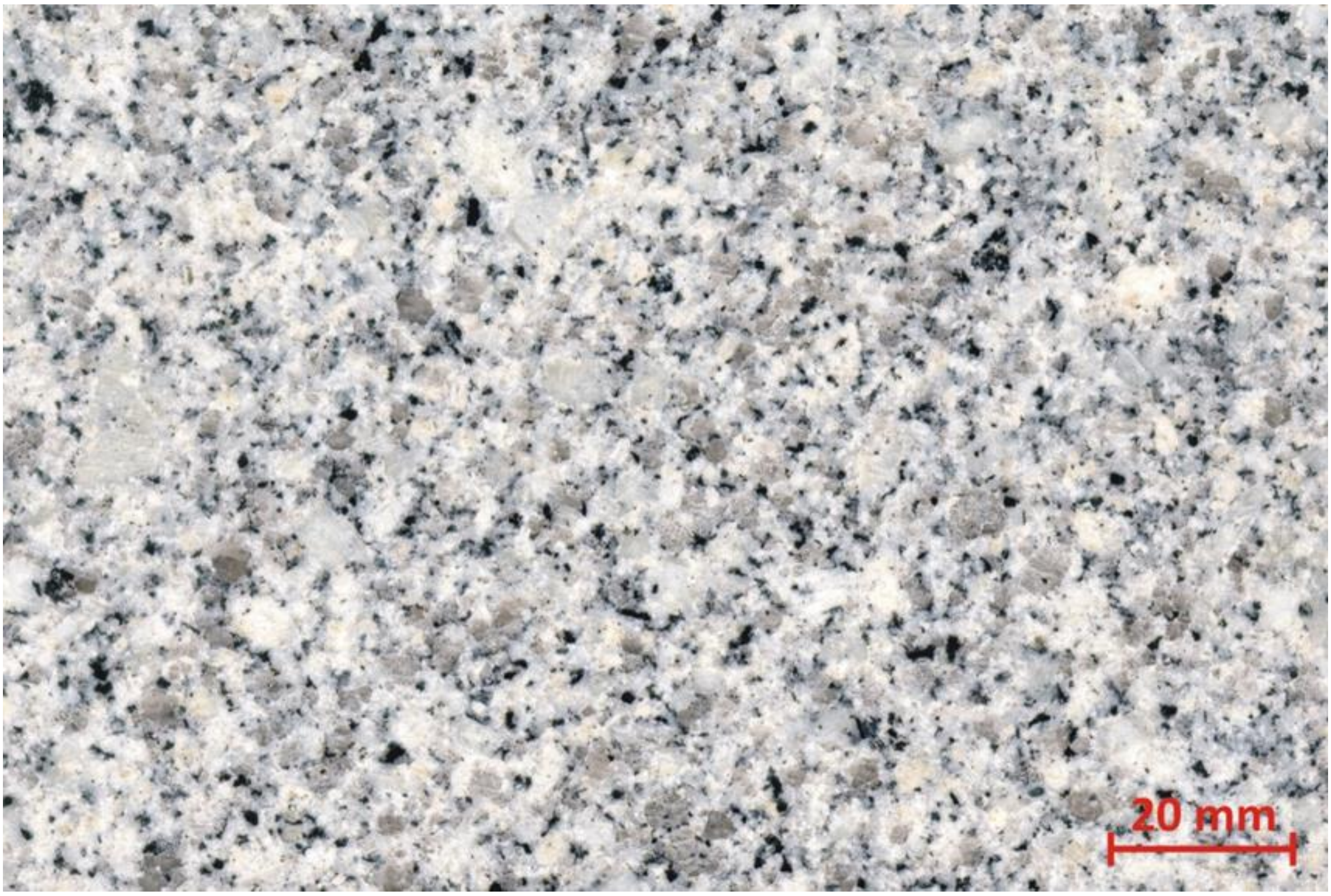
Pedras Salgadas

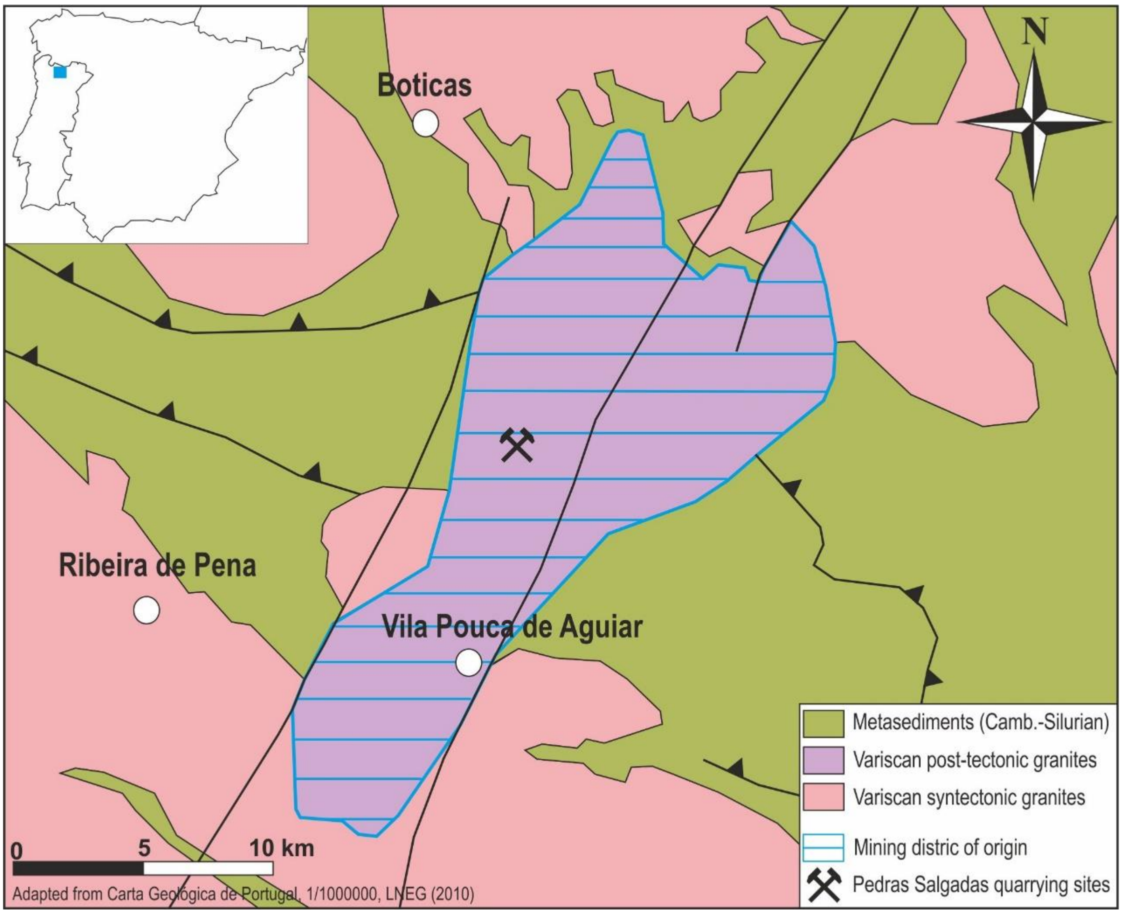
Cinzento claro de Pedras Salgadas



Short description:
Light-grey fine to medium grained biotitic granite, with disperse small K-feldspar megacrystals

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Village
Commercial granite	Monzogranite	Light-grey	Portugal	Vila Real	Vila Pouca de Aguiar	Bragado

Geological setting



Geology:
The granite massif of Vila Pouca de Aguiar outcrops parallel to the NNE-SSW Régua-Verin Fault, which controlled its installation after the main events of the variscan orogeny during the Paleozoic. It is a post-tectonic massif of granites with biotite and calcium plagioclase. It integrates two granitic bodies with porphyritic texture: one is medium to coarse grained and the other is fine to medium grained, the latter being the source of the Pedras Salgadas ornamental stone, which presents quite homogeneous characteristics.
The Pedras Salgadas granite, which presents quite homogeneous characteristics, is extracted in several neighboring quarries in the parish of Bragado, municipality of Vila Pouca de Aguiar. Three main fracturing systems affect the Pedras Salgadas granitic body, and consequently the production yield: N10-30E (parallel to the main faults, being the one that most conditions exploitation), N40-50W and N60-80E

Production:
The Pedras Salgadas granite is extracted in several neighboring quarries in the parish of Bragado, municipality of Vila Pouca de Aguiar. Three main fracturing systems affect the Pedras Salgadas granitic body, and consequently the production yield: N10-30E (parallel to the main faults, being the one that most conditions exploitation), N40-50W and N60-80E

Geological age: Permian
Geological unit: Granitic massif of Vila Pouca de Aguiar

Application, use and heritage

The extraction of Pedras Salgadas granite began in the early 1960s by hand-made means. The small produced pieces were mainly used for paving streets and building small houses. Extraction of large blocks only started after de 1980s with the introduction of modern machinery.
It is a stone used mainly for domestic consumption in cladding, building and street pavements, staircases and kitchen tops. More recently, it is being widely applied as large pieces for urban furniture

Steven Lek, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

Description:
In addition to other stones, the Pedras Salgadas granite was used for the exterior cladding of the European Parliament.

Petrography

Description:
Photomicrograph of thin section (15x; transmitted natural light).
Medium grain monzogranite with microcline, oligoclase, quartz and biotite as essential minerals. Light bluish-grey color, granular hypidiomorphic texture with porphyroid tendency.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Oligoclase (%)	K-feldspar (%)	Quartz (%)	Biotite (%)	Muscovite (%)	Chlorite (%)
36.4	28.2	24.4	3.1	2.0	1.2
others[1)] (%)					
4.7					

1) Apatite, sphene, zircon, monazite, opaque minerals.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2610	0.8	0.3	214	12.7

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
13.2	48	206	56	

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm³	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
20		0.2		2700	28.5

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
matt polished	50	16	6	

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	SO_3	LOI
73.07	13.99	1.63	0.19	0.29	1.21	3.48	5.00	0.05	0.07		0.82

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
11	8		< 5	< 7	< 6	34	9
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
77		342	30		241		11
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
8	31	19	< 8	< 6	15	109	15
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
			<6	17			
Tl	**Hf**						
	<5						

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main and trace elements: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

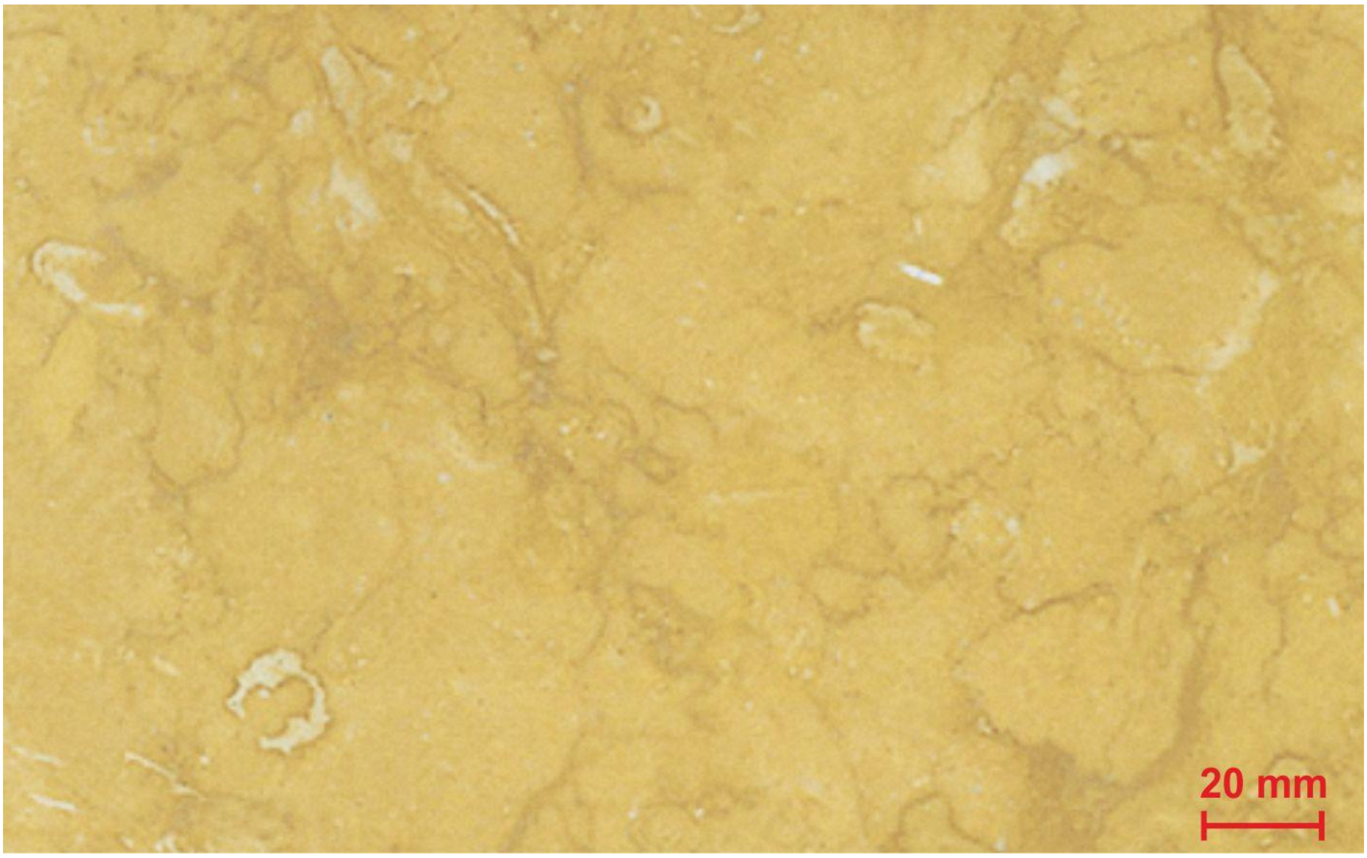
Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Naturstein - Platform for Natural Stone Primeira Pedra	https://www.naturalstone-online.com/index.php?id=356&user_dnsaeng_pi1%5BsteinID%5D=5434 http://www.primeirapedra.com/stones/cinzento-pedras-salgadas/
Commercial directory:		
Scientific publication:	Engineering Geology	http://dx.doi.org/10.1016/j.enggeo.2017.01.030
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 28/05/2021	

Commercial Limestones

Amarelo de Negrais

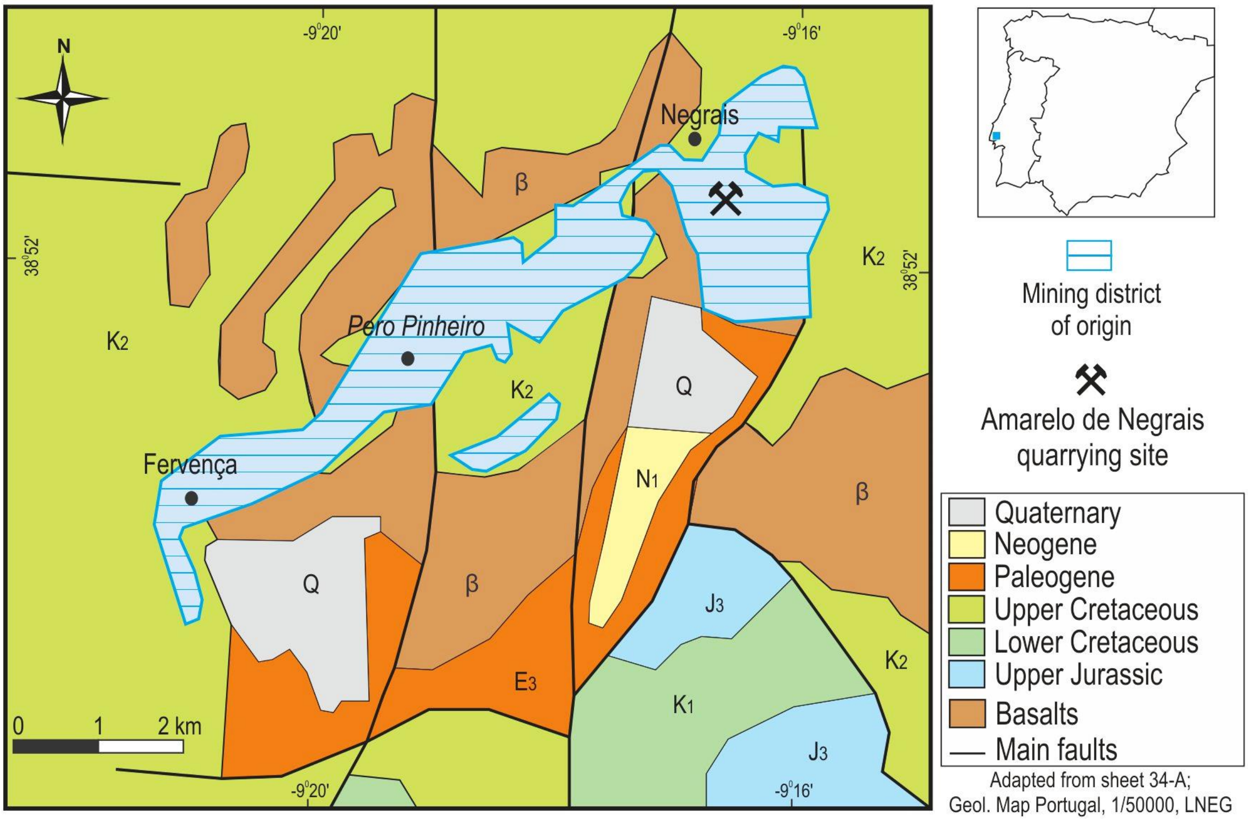
Lioz Gold



Short description:
Yellow fossiliferous limestone.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Yellow	Portugal	Lisboa	Sintra	Negrais

Geological setting



Geology:
During the mid-Cretaceous (Albian - Turonian), a rim-shelf carbonate platform set up over larger areas of the in the Western Iberian margin. Reef and lagoonal limestones with coral and rudist units of middle Turonian age occur in the region of Lisbon and are overlain by basaltic rocks. The outcropping area of these reef units (Bica Formation), and part of the basaltic tuffs that overlap them, corresponds to a mining distric of provenance for some ornamental stone varieties widely used in Portugal and, particularly, in the Lisbon region.
One of the best-known ornamental variety is called Amarelo de Negrais, which is a yellow coloured micritic fossiliferous limestone often rich in large rudist and bivalve fossils.

Production:
Amarelo de Negrais, like other varieties from this mining district, has been exploited in the Lisbon region since its occupation by the Romans and was intensively used in its reconstruction after the 1755 earthquake.
Modern exploitation reached its peak during the 60s and 70s of the last century in the Pero Pinheiro region, near Sintra. Currently only a few quarries near Negrais are operating, greatly constrained by urban expansion.
The sedimentary beds are not very thick and fracturing is relatively intense, so the extracted blocks are small and medium in size. The final cut is made parallel to the bedding plane.

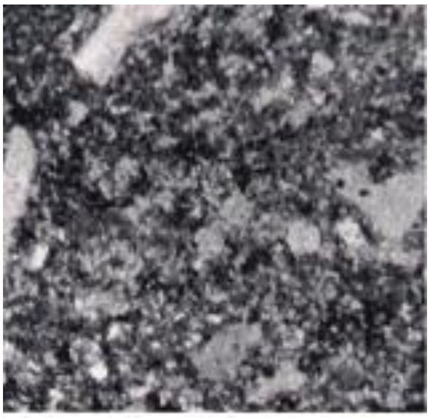
Geological age: Cretaceous / Turonian
Geological unit: Bica Formation

Application, use and heritage

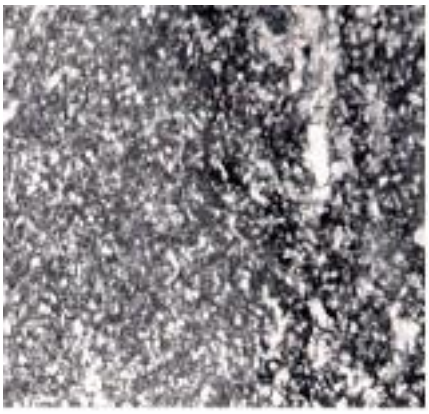
Amarelo de Negrais is very appreciated for its yellow color. It is widely used in countertops and decorative pieces, but also in coverings, as a contrasting element with other stone varieties.
It was widely used for the construction of buildings and churches in the region of Lisbon, particularly for its reconstruction after the 1755 earthquake. Like other stones from the same region, it was used for the construction of several monuments in Brazil, as it was also used as ballast of freight boats during the seventeenth and eighteenth centuries.

Amarelo de Negrais combined with other stone varieties in the floor of the Basilica of the Mafra National Palace, Portugal.

Petrography



Thin section parallel to bedding.



Thin section perpendicular to bedding.

Description:
Sparitic biointraclastic limestone.
Obs.: not representative of the framestone texture as seen by the naked-eye.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Dolomite (%)	Quartz and iron oxides (%)			
~94	~6	vest.*			

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2670	1.2	0.4	141	13.9

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	110	25	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
—	—	2.8	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	5	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
1.59	0.25	0.37	vest.	1.29	53.02	0.07	0.02	—	0.00	—	43.22

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/amarelo-de-negrais/
	Stone by Portugal	https://stonebyportugal.com/stone/amarelo-de-negrais/?lang=en
Commercial directory:		
Scientific publication:	Geoheritage	https://doi.org/10.1007/s12371-017-0267-7
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 13/09/2021	

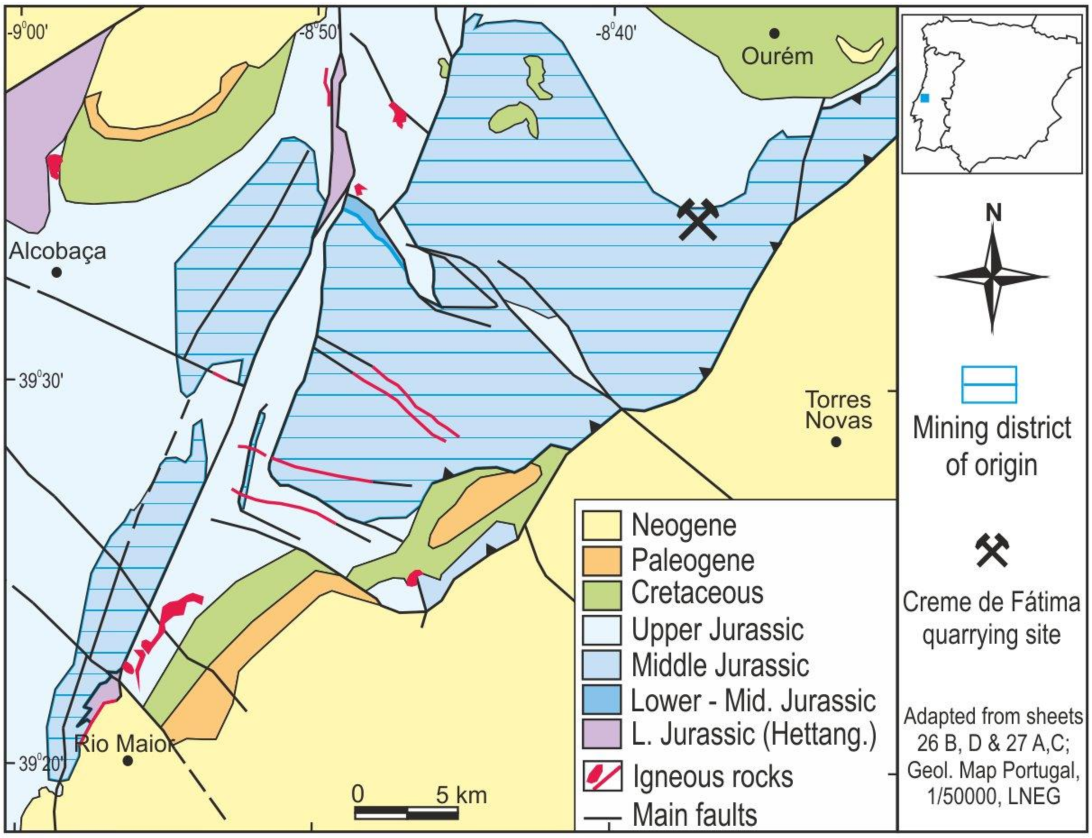
Creme de Fátima

Creme Casal, Faticreme

Short description:
Beige coloured limestone, clastic, fine to coarse grain.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Beige	Portugal	Santarém	Ourém	Casal Farto and Boleiros

Geological setting



Geology:
The Maciço Calcário Estremenho (MCE) is a morphostructural unit of the Lusitanian Basin in Portugal, which has been uplifted during the alpine orogeny. Jurassic limestones partially covered by Cretaceous sandstones and Pliocene sand patches are the main rocks of the MCE.
MCE is a mining district of several ornamental limestone varieties, in which the Santo António - Candeeiros Formation of Bathonian - Callovian age stands out.
The Pé da Pedreira Member (upper Bathonian age) is part of this formation and consists of massive beds of limestones, which are characterized by meter-scale cross-stratification sets. Ornamental varieties extracted from this unit have a direct correspondence to these cross-stratification sets, or even to individual beds with uniform sedimentary lamination.
Creme de Fátima is a medium to coarse-grained clastic limestone facies of the Pé da Pedreira Member. During the processing stage, the final cut of the blocks is made parallel to the sedimentary lamination.

Production:
The production of ornamental stones in MCE started in the 1970s. The introduction of advanced technologies and machineries in the late-1980s led to a strong development of the exploitations, which continues today in large contiguous quarries. This was favoured by the fact that the productive unit corresponds to a massive subhorizontal limestone body, which in the Fátima region is about 100 m thick, and not intensely affected by fractures, allowing to obtain very large commercial blocks.

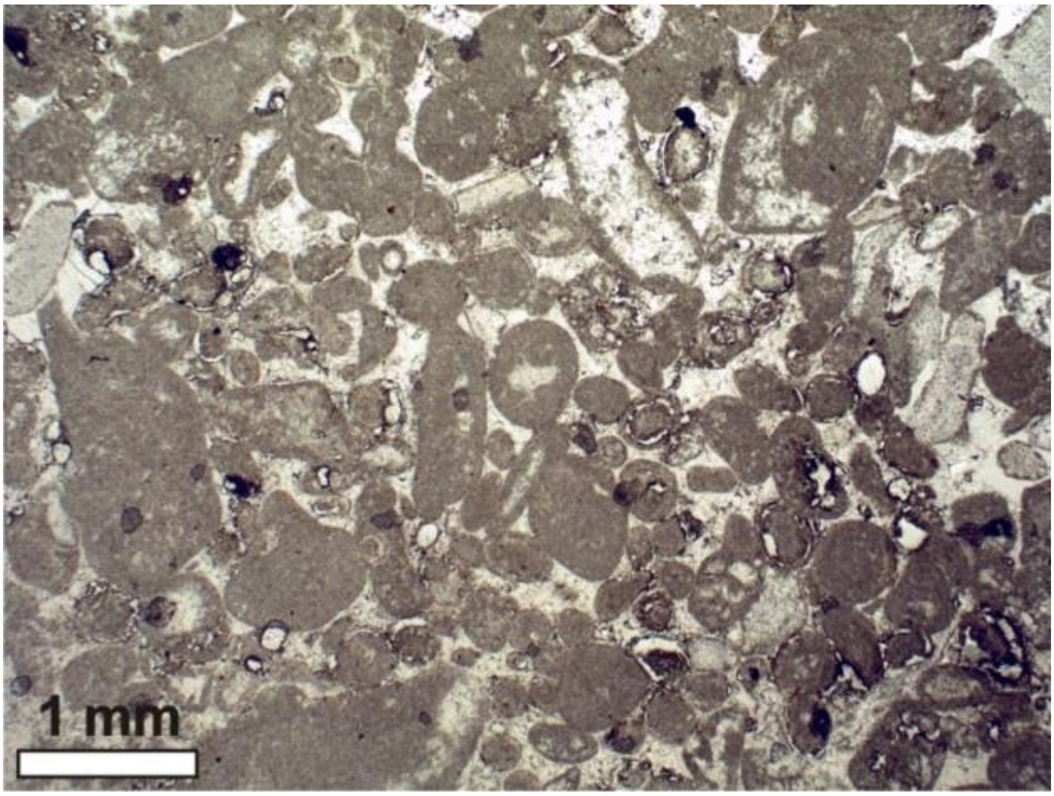
Geological age: Middle Jurassic / upper Bathonian
Geological unit: Santo António - Candeeiros Formation / Pé da Pedreira Member

Application, use and heritage

Timothy Rollins, CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons

Description:
Oklahoma City Oklahoma Temple, USA

Petrography



Description:
Thin section microphotograph of Creme de Fátima obtained parallel to the sedimentary lamination. It corresponds to a pelbiointrasparite with a grainstone depositional texture.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Opaque rusty spots (%)				
~100	vest.*				

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2410	9.3	4.3	108	13.7

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	31.2 (C_1)	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
3.5	48	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
21.5	—	—	—	2900	30.5

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
honed	70	57	4	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
< 0.86	< 0.22	0.04	< 0.02	0.37	55.68	< 0.20	< 0.03	< 0.03	< 0.04	—	43.92

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
< 5	6	—	< 5	< 7	< 6	< 6	—
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
304	—	8	< 6	—	< 3	—	< 6
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 7	7	< 5	—	< 6	< 3	< 3	< 6
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
—	—	—	< 6	< 5	< 5	—	—
Tl	**Hf**						
—	< 7						

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
< 5	16	—	8	—	—	—	—
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		
—	—	—	—	—	—		

Methods applied:
Determination of the main elements, trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

EUROLITHOS European Ornamental Stone Resources

GeoERA RAW MATERIALS

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/creme-de-fatima/
	Naturstein	https://www.naturalstone-online.com/index.php?id=360&user_dnsaeng_pi1%5BsteinID%5D=6093
Commercial directory:		
Scientific publication:	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7382-x
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	LNEG
Version / date:	V1 / 07/09/2021	

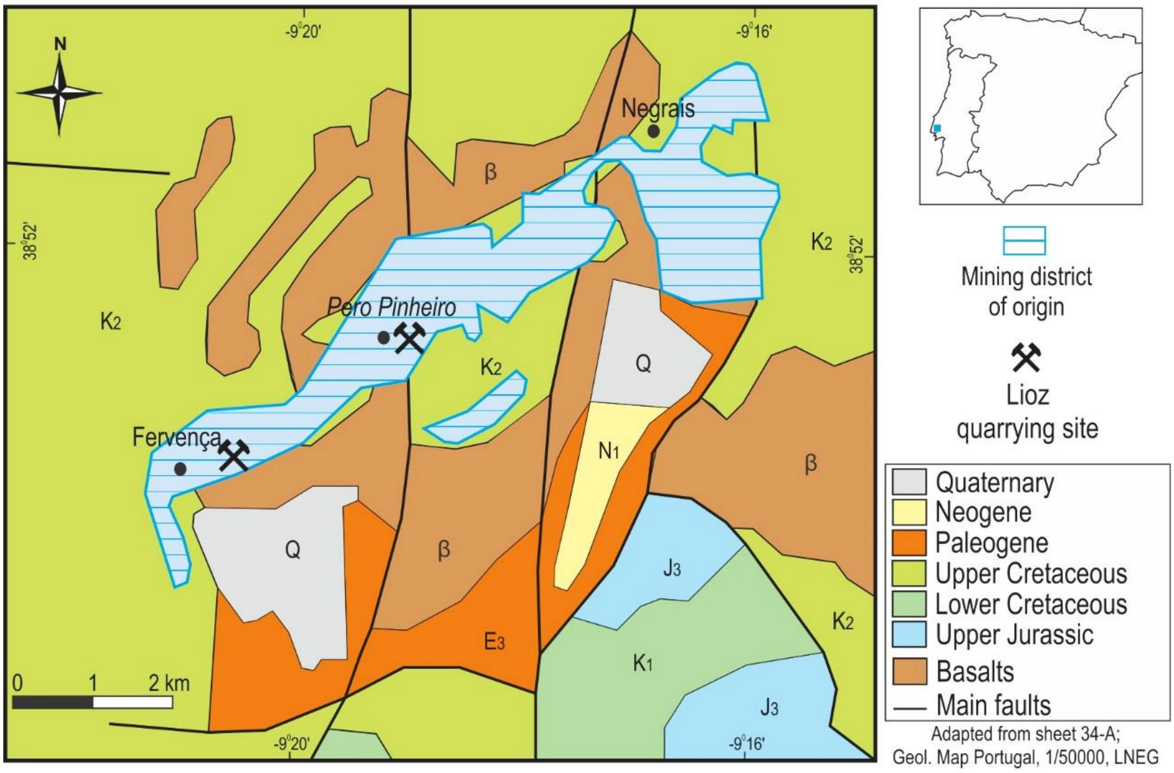
Lioz

Lioz de Pero Pinheiro

Short description:
Light beige to white coloured limestone with large fossils of rudists and bivalves.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	White	Portugal	Lisboa	Sintra	Pero Pinheiro

Geological setting



Geology:
During the mid-Cretaceous (Albian - Turonian), a rim-shelf carbonate platform set up over larger areas of the in the Western Iberian margin. Reef and lagoonal limestones with coral and rudist units of middle Turonian age occur in the region of Lisbon and are overlain by basaltic rocks. The outcropping area of these reef units (Bica Formation), and part of the basaltic tuffs that overlap them, corresponds to a mining district of provenance for some ornamental stone varieties widely used in Portugal and, particularly, in the Lisbon region.
The best-known ornamental variety is called Lioz, which is an ivory coloured micritic fossiliferous limestone typified by the presence of large rudist fossils. Colour variations give place to other commercial varieties (Amarelo de Negrais, Chainette, Encarnadão, and others).

Production:
Lioz and similar varieties have been exploited in the Lisbon region since its occupation by the Romans and were intensively used in its reconstruction after the 1755 earthquake.
Modern exploitation reached its peak during the 60s and 70s of the last century in the Pero Pinheiro region, near Sintra. Currently only a few quarries are operating, greatly constrained by urban expansion.
The sedimentary beds are not very thick and fracturing is relatively intense, so the extracted blocks are small and medium in size. The final cut is made parallel or perpendicularly to the bedding plane. When cut perpendicularly, the aesthetics of the stone changes dramatically due to the presence of abundant closed stylolites.

Geological age: Cretaceous / Turonian
Geological unit: Bica Formation

Application, use and heritage

Because of its remarkable aesthetical and technical characteristics, Lioz is a much-appreciated building construction material. It was widely used for the construction of buildings and churches in the region of Lisbon, particularly for its reconstruction after the 1755 earthquake, but its use is widespread in Portugal. Lioz and similar varieties were also used for the construction of several monuments in Brazil, as they were also used as ballast of freight boats during the seventeenth and eighteenth centuries.

By Alvesgaspar - Own work, CC BY-SA 3.0; https://commons.wikimedia.org/w/index.php?curid=6580719

The Portuguese Belém Tower is a 16th-century fortification located in Lisbon, built from Lioz ornamental stone. It is a notable example of the Portuguese Manueline architectural style. Since 1983, the tower has been part of the UNESCO World Heritage, together with the Jerónimos Monastery, in which Lioz was also used.

https://en.wikipedia.org/wiki/Bel%C3%A9m_Tower

By Deensel - Lisbon main square, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=62192653

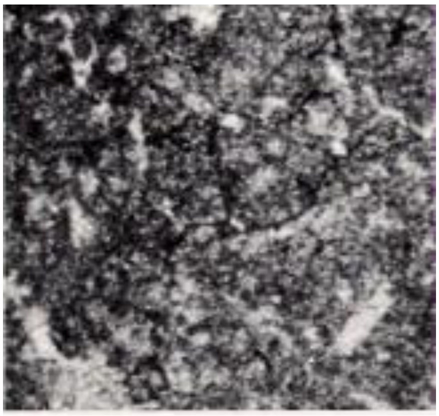
The Lisbon downtown (*Baixa Pombalina*) is a district constructed with Lioz after the 1755 Lisbon earthquake. It is one of the first examples of earthquake-resistant construction. Notable features of Pombaline structures include the Pombaline cage, a symmetrical wood-lattice framework aimed at distributing earthquake stresses, and inter-terrace walls that are built higher than roof timbers to reduce fire propagation.

https://en.wikipedia.org/wiki/Lisbon_Baixa

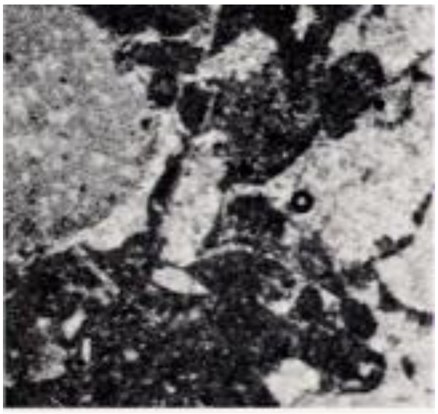
By Therese C - Flickr: DSCN5750, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=16119126

Centro Cultural de Belém, built in 1992, is a complex of artistic spaces located in Lisbon and a flagship example of the modern use of Lioz.

Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Spathized intrabioclastic limestone (Biosparite-microsparite
Obs.: not representative of the framestone texture as seen by the naked-eye).

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)					
~100					

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2690	0.5	0.2	103	11.0

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	135	25	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
21.7	—	2.2	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	4	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
0.20	0.41	0.02	0.00	0.39	55.54	0.04	0.05	—	vest.	—	43.34

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/lioz/
	Stone by Portugal	https://stonebyportugal.com/stone/lioz/?lang=en
Commercial directory:		
Scientific publication:	Geoheritage	https://doi.org/10.1007/s12371-017-0267-7
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 13/09/2021	

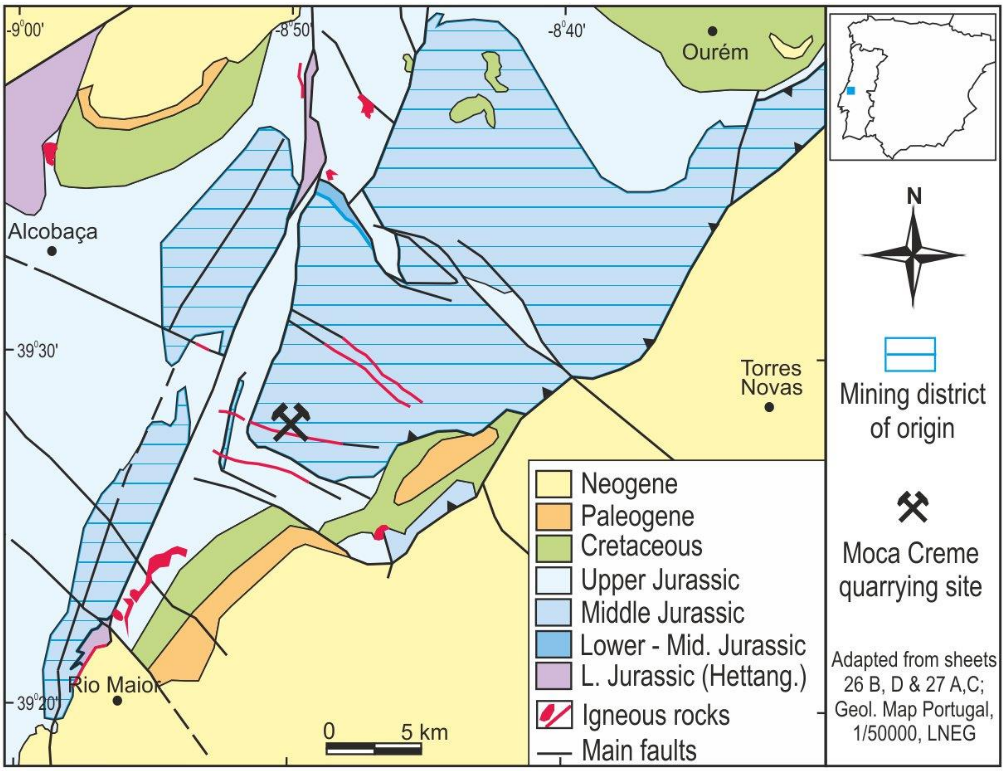
Moca Creme

Moca Creme de Grão Médio

Short description:
Beige coloured limestone, clastic, medium to coarse grain. Marked sedimentary lamination represented by alternating levels with different grain sizes and preferential alignment of elongated grains.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Beige	Portugal	Santarém	Santarém	Pé da Pedreira

Geological setting



Geology:
The Maciço Calcário Estremenho (MCE) is a morphostructural unit of the Lusitanian Basin in Portugal, which has been uplifted during the alpine orogeny. Jurassic limestones partially covered by Cretaceous sandstones and Pliocene sand patches are the main rocks of the MCE.
MCE corresponds to a mining district for several ornamental limestone varieties, in which the Santo António - Candeeiros Formation of Bathonian - Callovian age stands out.
The Pé da Pedreira Member (upper Bathonian age) is part of this formation and consists of massive beds of limestones, which are characterized by meter-scale cross-stratification sets. Ornamental varieties extracted from this unit have a direct correspondence to these cross-stratification sets, or even to individual beds with uniform sedimentary lamination.
Moca Creme is a coarse-grained, bioclastic and oncolitic limestone facies that occurs preferentially at the base of the Pé da Pedreira Member. During the processing stage, the final cut of the blocks is made perpendicularly to the sedimentary lamination.

Production:
The production of ornamental stones in MCE started in the 1970s. The introduction of advanced technologies and machineries in the late-1980s led to a strong development of the exploitations, which continues today in large contiguous quarries. This was favoured by the fact that the productive unit (the Pé da Pedreira Member) corresponds to a massive subhorizontal limestone body about 50 m thick, not intensely affected by the existing orthogonal system of fractures, allowing to obtain large commercial blocks.

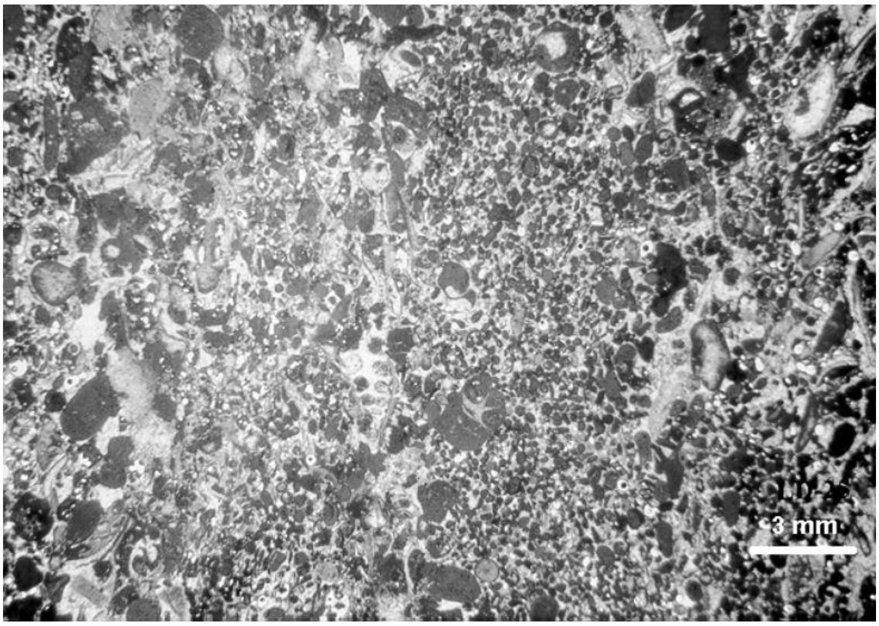
Geological age: Middle Jurassic / upper Bathonian
Geological unit: Santo António - Candeeiros Formation / Pé da Pedreira Member

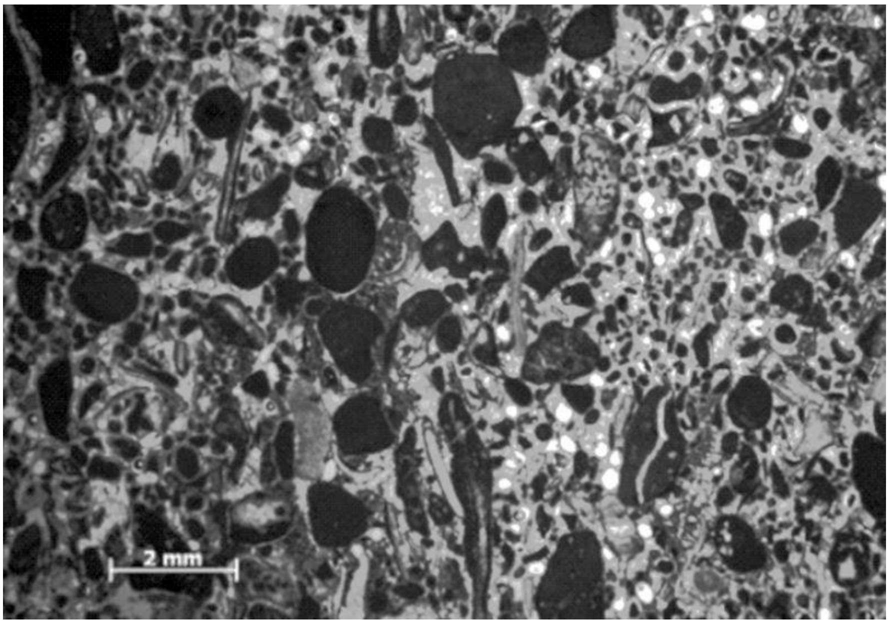
Application, use and heritage

Moca Creme, like other varieties of ornamental stones from Maciço Calcário Estremenho, is spread all over the world, both in public and private buildings. It has been used mainly for interior and exterior cladding of buildings, paving, and staircases.

Description:
Moca creme has been used for the exterior cladding of some reference buildings, as is the case of the headquarters of the Central Bank of Kuwait, built in 2016. (https://www.skyscrapercenter.com/building/the-central-bank-of-kuwait-new-headquarters-building/1002

Petrography





Description:
Thin section microphotographs (parallel polarized light) of Moca Creme obtained perpendicularly to the sedimentary lamination. Both are limestones with a grainstone depositional texture, but the upper thin section corresponds to a biointrapelsparite and the lower thin section is a pelbiointrasparite. The different proportions of allochems, with regard to their nature and size, vary according to the sedimentary lamination, which is characteristic of these limestones, and the precise place where the thin section was made.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)					
100					

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2480	6.9	3.1	135	14.9

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
		17.4 (C_2)	

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
12.4	48			

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
20.5				2900	30.5

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
matt polished	71	64	3	

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	SO_3	LOI
< 0.86	< 0.22	0.04	< 0.04	0.31	55.79	< 0.20	< 0.03	< 0.02	< 0.03		43.80

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
< 5	5		< 5	< 7	< 6	< 6	
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
143		< 7	< 6		< 3		< 6
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 7	< 3	< 5		< 6	< 3	< 3	< 6
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
			< 6	< 5	< 5		
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
< 5	8		11				
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/moca-creme/
Commercial directory:		
Scientific publication:	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7382-x
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7670-5
	Geol. Soc. London Spec. Publ.	https://doi.org/10.1144/SP333.15
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 14/09/2021	

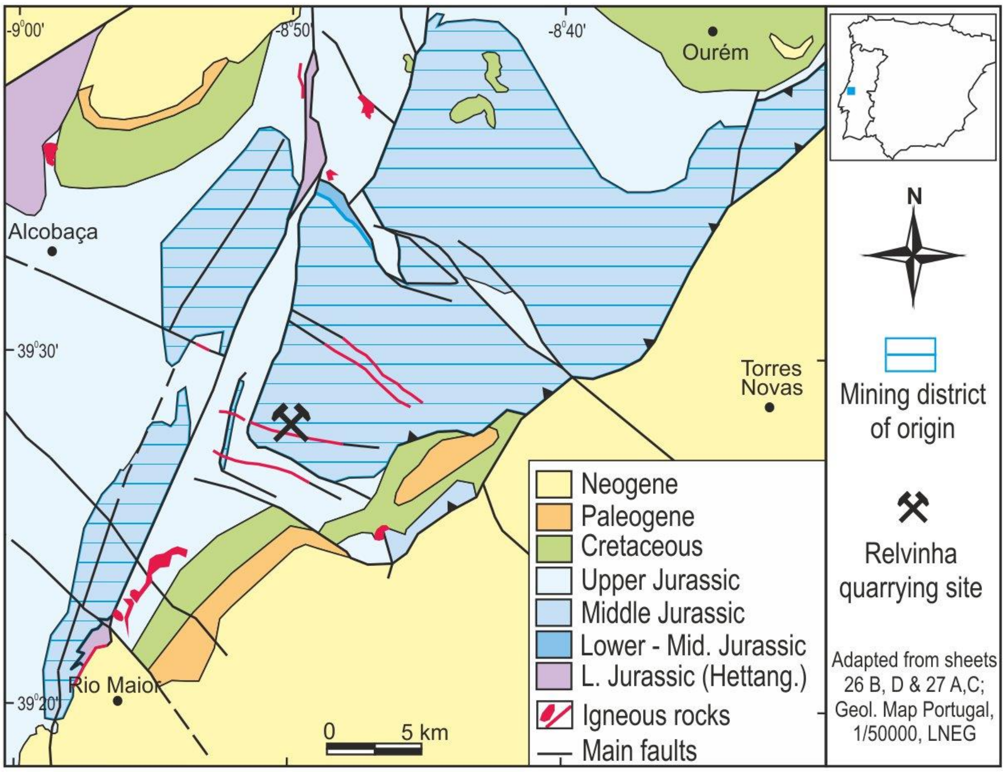
Relvinha

Moca Creme de Grão Fino

Short description:
Beige coloured limestone, clastic, fine grained, with thin parallel sedimentary lamination usually represented by regular and parallel laminae.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Beige	Portugal	Santarém	Santarém	Pé da Pedreira

Geological setting



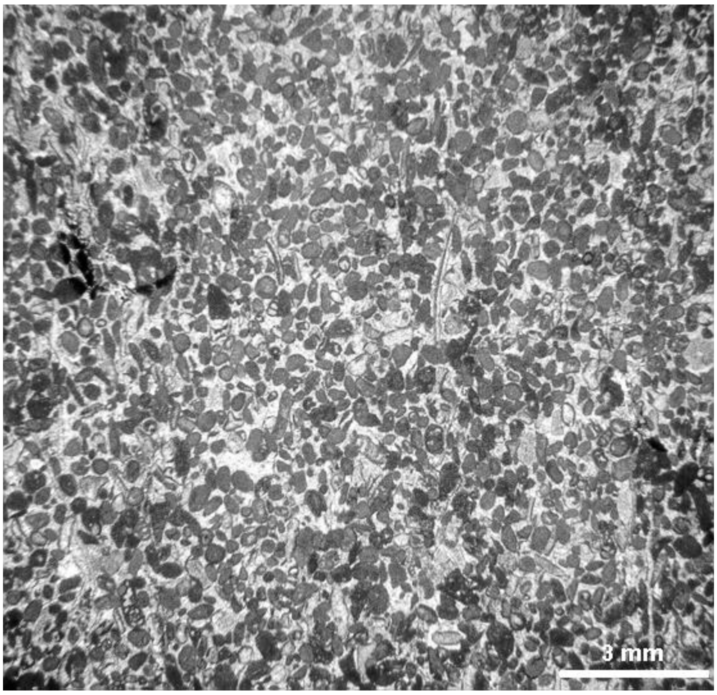
Geology:
The Maciço Calcário Estremenho (MCE) is a morphostructural unit of the Lusitanian Basin in Portugal, which has been uplifted during the alpine orogeny. Jurassic limestones partially covered by Cretaceous sandstones and Pliocene sand patches are the main rocks of the MCE.
MCE is a mining district of several ornamental limestone varieties, in which the Santo António - Candeeiros Formation of Bathonian - Callovian age stands out.
The Pé da Pedreira Member (upper Bathonian age) is part of this formation and consists of massive beds of limestones, which are characterized by meter-scale cross-stratification sets. Ornamental varieties extracted from this unit have a direct correspondence to these cross-stratification sets, or even to individual beds with uniform sedimentary lamination.
Relvinha, also known as Moca Creme de Grão Fino, is a fine-grained peloidic limestones facies of the Pé da Pedreira Member. During the processing stage, the final cut of the blocks is made perpendicularly to the characteristic thin sedimentary lamination.

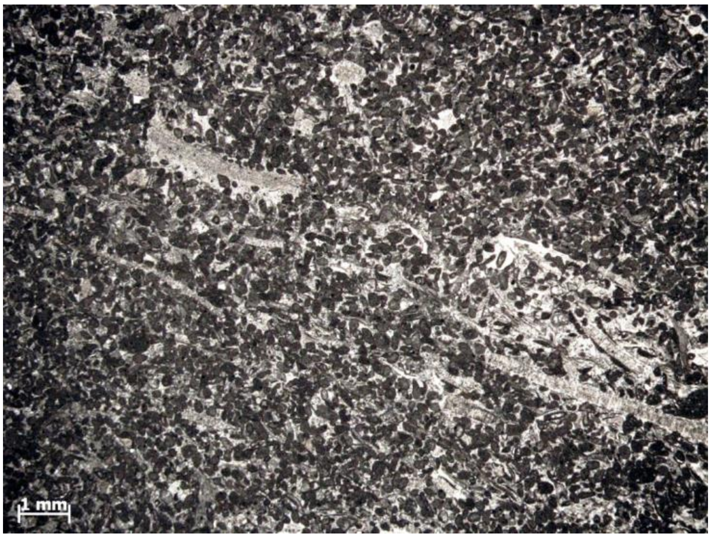
Production:
The production of ornamental stones in MCE started in the 1970s. The introduction of advanced technologies and machineries in the late-1980s led to a strong development of the exploitations, which continues today in large contiguous quarries. This was favoured by the fact that the productive unit (the Pé da Pedreira Member) corresponds to a massive subhorizontal limestone body about 50 m thick, not intensely affected by the existing orthogonal system of fractures, allowing to obtain large commercial blocks.

Geological age: Middle Jurassic / upper Bathonian
Geological unit: Santo António - Candeeiros Formation / Pé da Pedreira Member

Application, use and heritage

Petrography





Description:
Thin section microphotographs (parallel polarized light) of Relvinha obtained parallel to the sedimentary lamination (upper photo) and perpendicularly (lower photo). Both are limestones with a grainstone depositional texture, but the upper corresponds to a pelsparite with few thin bioclasts, and the lower is a biopelsparite with parallel-oriented bioclasts mark the sedimentary lamination..

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)					
~100					

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2450	8.1	3.5	97	12.8

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	76	25	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
—	—	4.8	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	3	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
0.03	0.00	0.12	vest.*	0.44	54.85	0.07	vest.*	—	0.00	—	43.97

* vestiges (traces)

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/stones/relvinha/
	Stone by Portugal	https://stonebyportugal.com/stone/moca-creme-de-grao-medio/?lang=en
Commercial directory:		
Scientific publication:	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7382-x
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 07/09/2021	

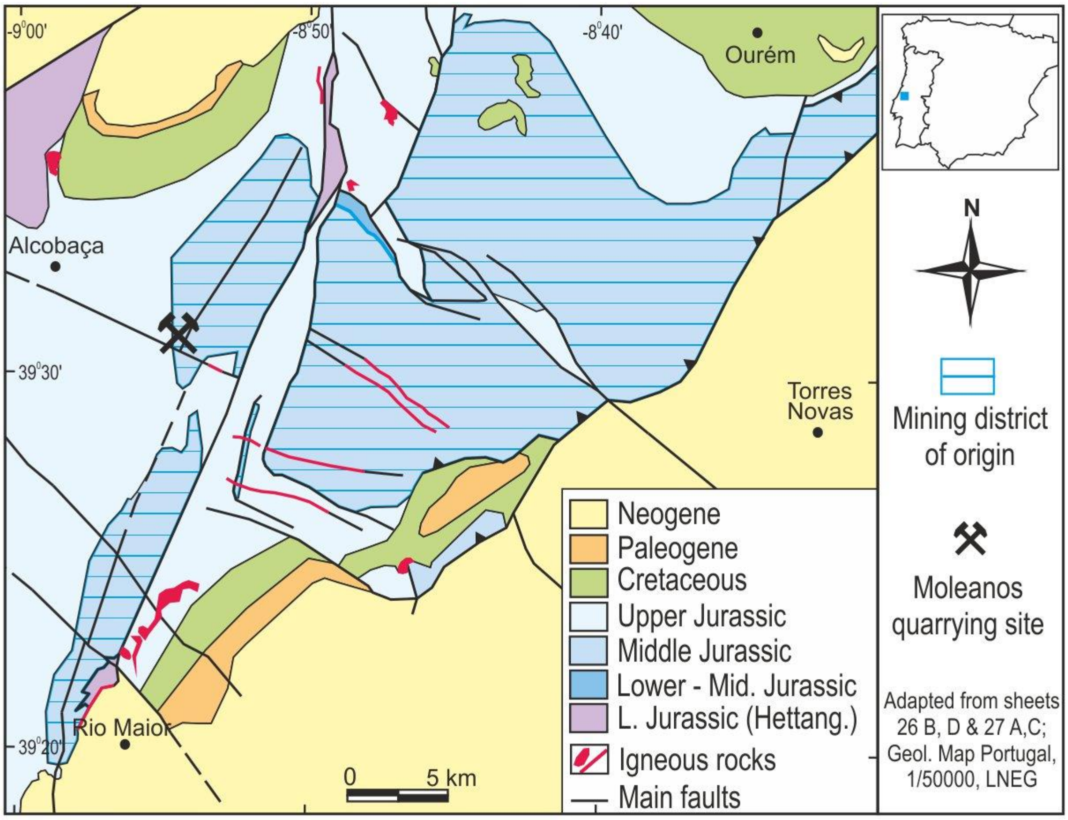
Moleanos

Vidraço de Moleanos, Creme Moleanos

Short description:
Light beige coloured limestone with coarse brownish grey grains dispersed in a fine- to medium-grained matrix.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Beige	Portugal	Leiria	Alcobaça	Moleanos

Geological setting



Geology:
The Maciço Calcário Estremenho (MCE) is a morphostructural unit of the Lusitanian Basin in Portugal, which has been uplifted during the alpine orogeny. Jurassic limestones partially covered by Cretaceous sandstones and Pliocene sand patches are the main rocks of the MCE.
MCE corresponds to a mining district of several ornamental stone varieties, in which the Santo António - Candeeiros Formation of Bathonian - Callovian age stands out. The Moleanos Member (Callovian age), over 150 m thick, is part of this formation and consists of of stacked limestone bodies, where meter-scale cross-stratification sets are distinguishable.
The Moleanos ornamental variety corresponds to peloidic/bioclastic/intraclastic, sometimes oolitic limestones with grainstone to rudstone depositional textures. During the processing stage, the final cut of the blocks is parallel to the sedimentary laminations.

Production:
The modern production of ornamental limestones in MCE started in the 1970s. The introduction of advanced technologies and machineries in the late-1980s led to a strong development of the exploitations, which continues today in large contiguous quarries. This is the case of the Moleanos quarrying site where the sparse fracturing allow for obtaining very large commercial blocks.

Geological age: Middle Jurassic / Callovian
Geological unit: Santo António - Candeerios Formation / Moleanos Member

Application, use and heritage

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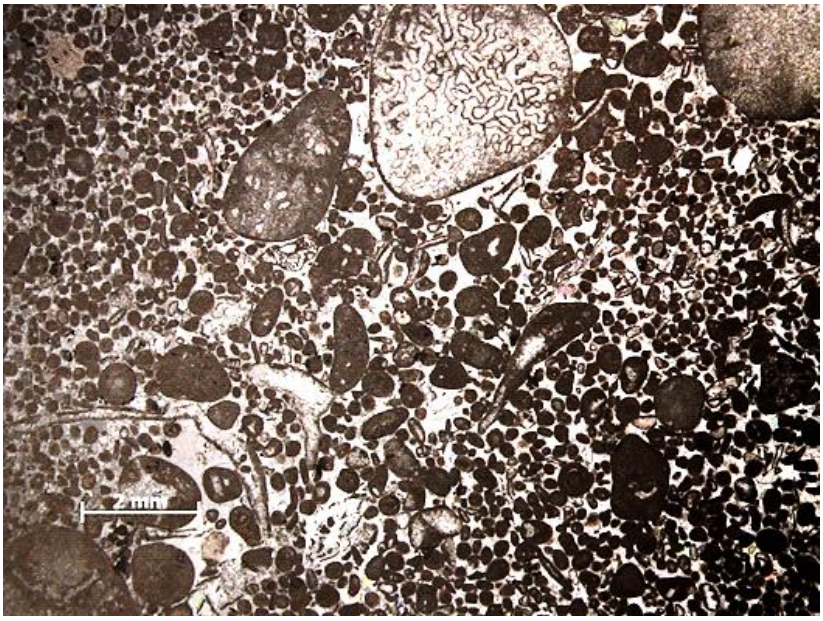
Description:
The Coronation Circle Mall, Hong Kong

Petrography



Description:
Thin section microphotograph (parallel polarized light) of Moleanos obtained perpendicularly to the sedimentary lamination. It corresponds to an intrabiopelsparite with a grainstone depositional texture.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Hydrated iron oxides and opaque minerals				
~100	vest.*				

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2600	3.4	1.4	146	11.9

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	5.59 (C_1)	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
10.8	56	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
19.0	—	—	—	2750	31.0

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
honed	70	52	3	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
< 0.86	< 0.22	0.04	< 0.02	0.19	55.77	< 0.20	< 0.03	< 0.03	< 0.04	—	43.84

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
< 5	6		< 5	< 7	< 6	< 6	—
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
157	—	< 7	< 6	—	< 3	—	< 6
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 7	8	< 5	—	< 6	< 3	< 3	< 6
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
—	—	—	< 6	< 5	< 5	—	—
Tl	**Hf**						
—	< 7						

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
< 5	19	—	11	—	—	—	—
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		
—	—	—	—	—	—		

Methods applied:
Determination of the main elements, trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/stones/vidraco-moleanos/
	Stone by Portugal	https://stonebyportugal.com/stone/vidraco-moleanos/?lang=en
Commercial directory:		
Scientific publication:	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7382-x https://doi.org/10.1007/s12665-018-7670-5
Other publication:		

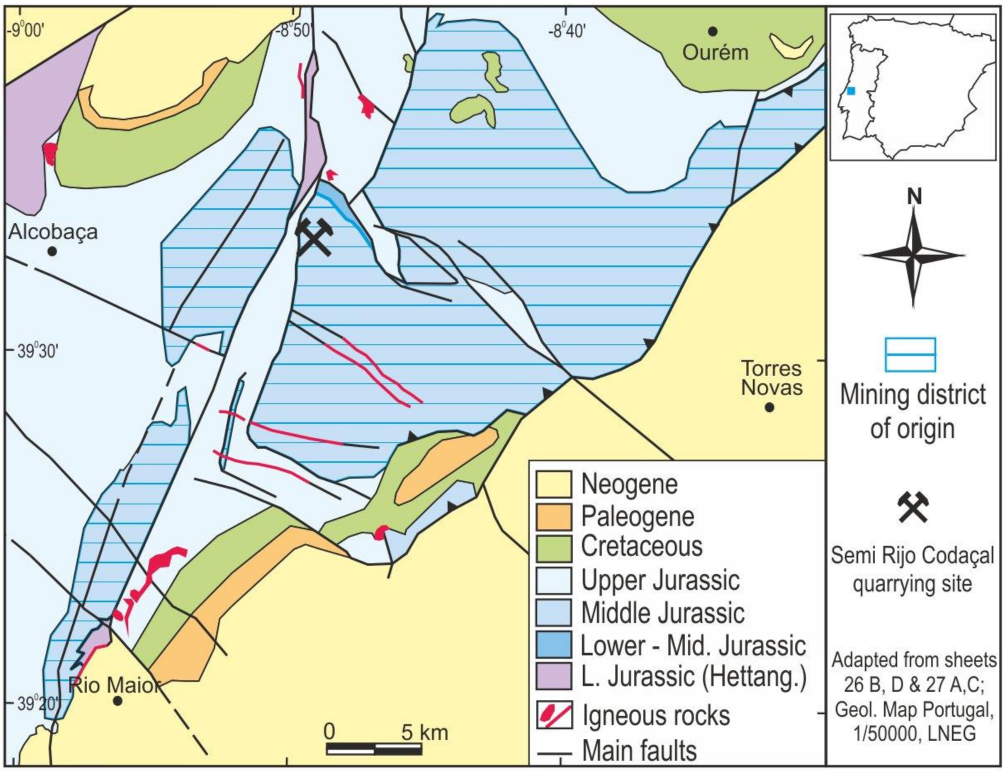
Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt
Version / date:	V1 / 07/09/2021

Semi Rijo do Codaçal

Short description:
Light-beige oolitic limestone with brownish to greyish small spots.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Limestone	Limestone	Beige	Portugal	Leiria	Porto de Mós	Codaçal

Geological setting



Geology:
The Maciço Calcário Estremenho (MCE) is a morphostructural unit of the Lusitanian Basin in Portugal, which has been uplifted during the alpine orogeny. Jurassic limestones partially covered by Cretaceous sandstones and Pliocene sand patches are the main rocks of the MCE.
MCE corresponds to a mining district for several ornamental limestone varieties, in which the Santo António - Candeeiros Formation of Bathonian - Callovian age stands out.
In the Codaçal region, the productive unit (Codaçal Member - lower Bathonian age) hosts near horizontal stacked limestone bodies that individually can reach 20 m thickness, in a total of 80 m. Meter-scale (up to > 6m) cross-stratification sets are distinguishable in these limestones, comprising predominantly parallel sedimentary thin laminations.
Semi Rijo do Codaçal corresponds to light-beige coloured oolitic limestones with grainstone texture. During the processing stage, the final cut of the blocks is parallel to the sedimentary laminations.

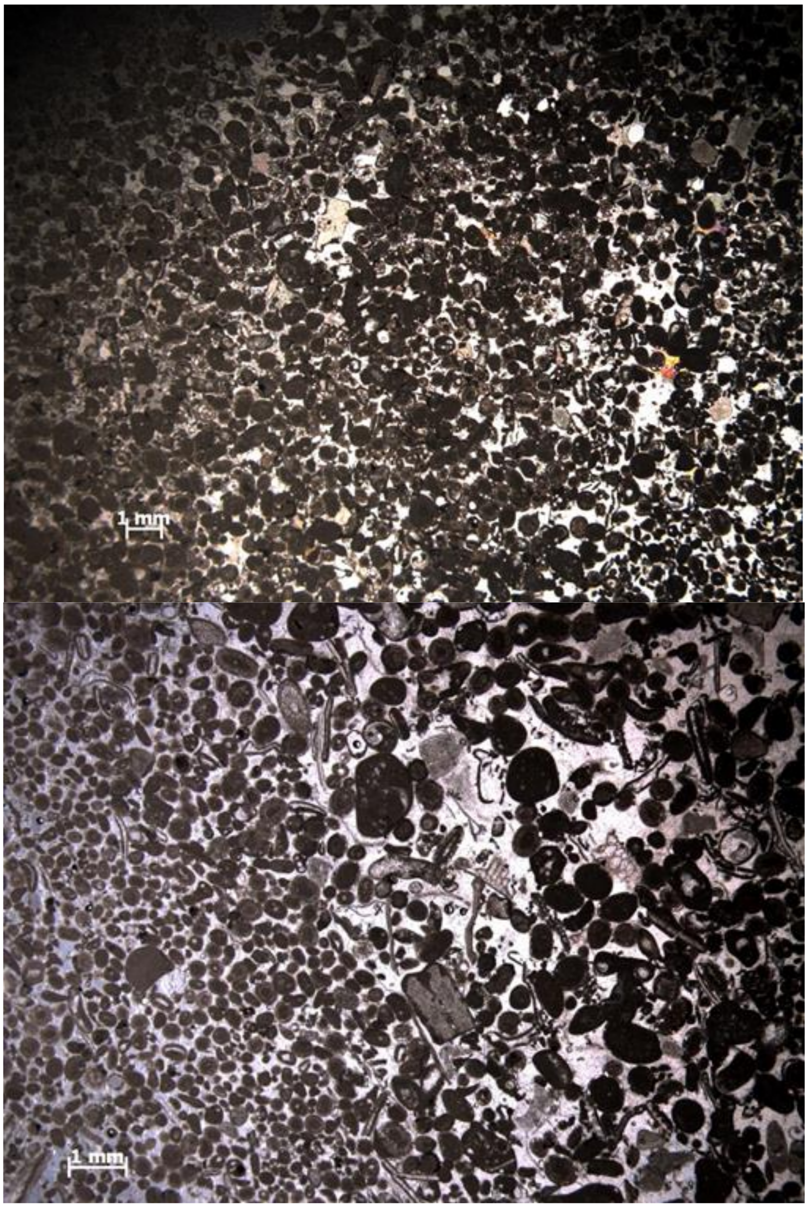
Production:
The modern production of ornamental stones in MCE started in the 1970s. The introduction of advanced technologies and machineries in the late-1980s led to a strong development of the exploitations, which continues today in large contiguous quarries. This is the case of the Codaçal quarrying site, where the thickness and homogeneity of the cross-bedding sets allow for obtaining very large commercial blocks.

Geological age: Middle Jurassic / lower Bathonian
Geological unit: Santo António - Candeeiros Formation / Codaçal Member

Application, use and heritage

Description:

Petrography



Description:
Thin section microphotographs (parallel polarized light) of Semi Rijo do Codaçal obtained parallel to the sedimentary lamination (upper photo) and perpendicularly (lower photo). Both are limestones with a grainstone depositional texture, but the upper corresponds to a peloosparite, and the lower is a biointrapelsparite in which the sedimentary lamination is denoted by a very fine-grained band of peloids and some ooids and a coarser-grained band of intraclasts and bioclasts.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)					
~100					

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2310	12.3	5.5	64	9.4

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	33.2 (C_1)	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	56	25	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
—	—	5.2	- 20.4	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	2	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
0.07	0.25	0.05	vest.*	0.34	55.37	0.07	vest.*	—	0.00	—	43.88

* vestiges (traces)

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/semi-rijo-do-codacal/
	Naturstein	https://www.naturalstone-online.com/index.php?id=360&user_dnsaeng_pi1%5BsteinID%5D=6102
Commercial directory:		
Scientific publication:	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7382-x
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt
Version / date:	V1 / 07/09/2021

Commercial Marbles

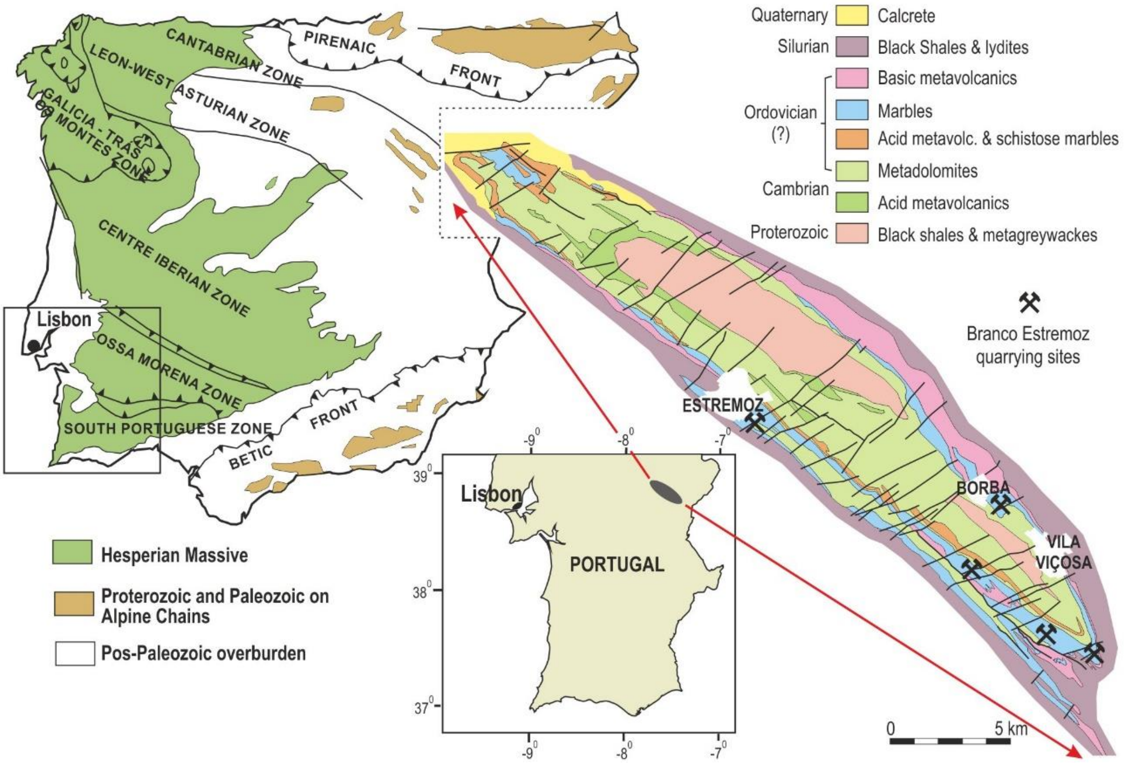
Branco Estremoz

Branco Corrente, Branco Pardais

White calcitic marble with thin to medium grain. On the white background, which occasionally may be somewhat pinkish, small stains and thin greyish or brownish streaks usually occur.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Marble	Calcitic Marble	White	Portugal	Évora	Estremoz, Borba, and Vila Viçosa	

Geological setting



Geology:
The Paleozoic Estremoz Anticline is the primary mining district of origin of most of the Portuguese marbles. It is a 40 km long and 8 km wide anticline with a dominant NW-SE orientation. It integrates the Ossa Morena Zone, which is a tectonostratigraphic unit of the Iberian Variscides. The stratigraphic sequence of the Estremoz Anticline was deformed and metamorphosed under green-schist to lower-amphibolite metamorphic conditions during the Carboniferous Variscan Orogeny, responsible for the development of two non-coaxial folding events and NW-SE oriented brittle-ductile shear zones, parallel to the later folding event.
Marbles in the Estremoz Anticline are part of the Estremoz Carbonate Volcano-Sedimentary Complex of probable Ordovician age. Several varieties of marble occur within this complex, reflecting, not only the original composition of the limestones, but also the interaction with volcanic rocks during deformation and metamorphism. They are fine to coarse grain calcitic marbles with granoblastic texture. Their background colours range from white to beige, pink and dark grey and may or may not have coloured streaks and spots. The folding complexity makes it impossible to determine the exact places where the different varieties may occur.

Production:
The marbles of the Estremoz Anticline have been extracted since antiquity. With the introduction of modern exploration and manufacturing technologies in the 70s of the 20th century, the production had a strong increase and started to be exported all over the world.
Extraction is carried out in dozens of quarries grouped into five main extraction sites called Estremoz, Borba, Vigária, Lagoa and Pardais, the last three in the municipality of Vila Viçosa. Mainly because of geological constraints, but also due to the quarries' arrangement in space, production yields are very low, usually, less than 15%.

Geological age: Ordovician (?)
Geological unit: Estremoz Carbonate Volcano Sedimentary Complex

Application, use and heritage

Dating back to the Roman Empire, marbles from the Estremoz Anticline were used for the construction of buildings and monuments in Iberia. In Portugal, they have been used in the construction of about two hundred national monuments. Currently, they are used on several applications around the world: interior and exterior cladding, interior flooring and decoration (fireplaces, staircases, countertops, etc.), funerary art, masonry in engineering works and are still used as structural elements in buildings.

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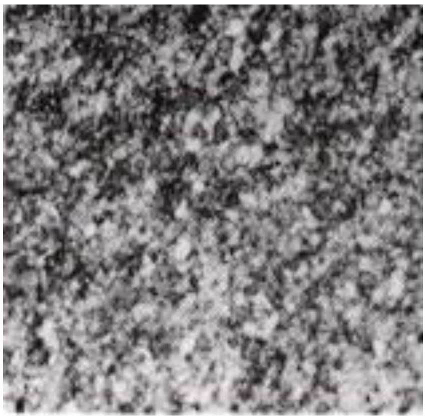
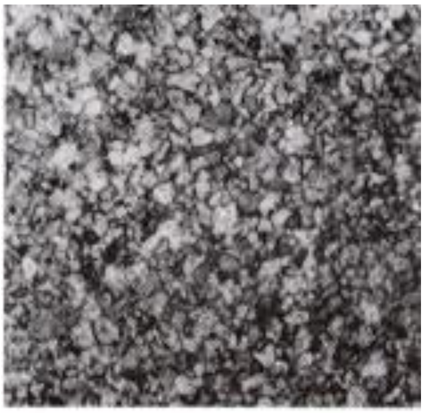
Gerd Eichmann, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>

The Évora Roman Temple (Templo Romano de Évora) where white marble from Estremoz (Branco de Estremoz) and grey granites were used.

Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Medium to thin grain, holocrystalline calcitic marble, with textural homogeneity and high purity.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Quartz, feldspar, muscovite and opaque minerals (%)				
~95	~5				

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2710	0.2	0.1	85	14.6

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
25.0	—	—	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	10	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
1.32	< 0.22	0.06	< 0.02	0.34	54.86	< 0.20	0.07	< 0.03	< 0.04	—	43.08

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

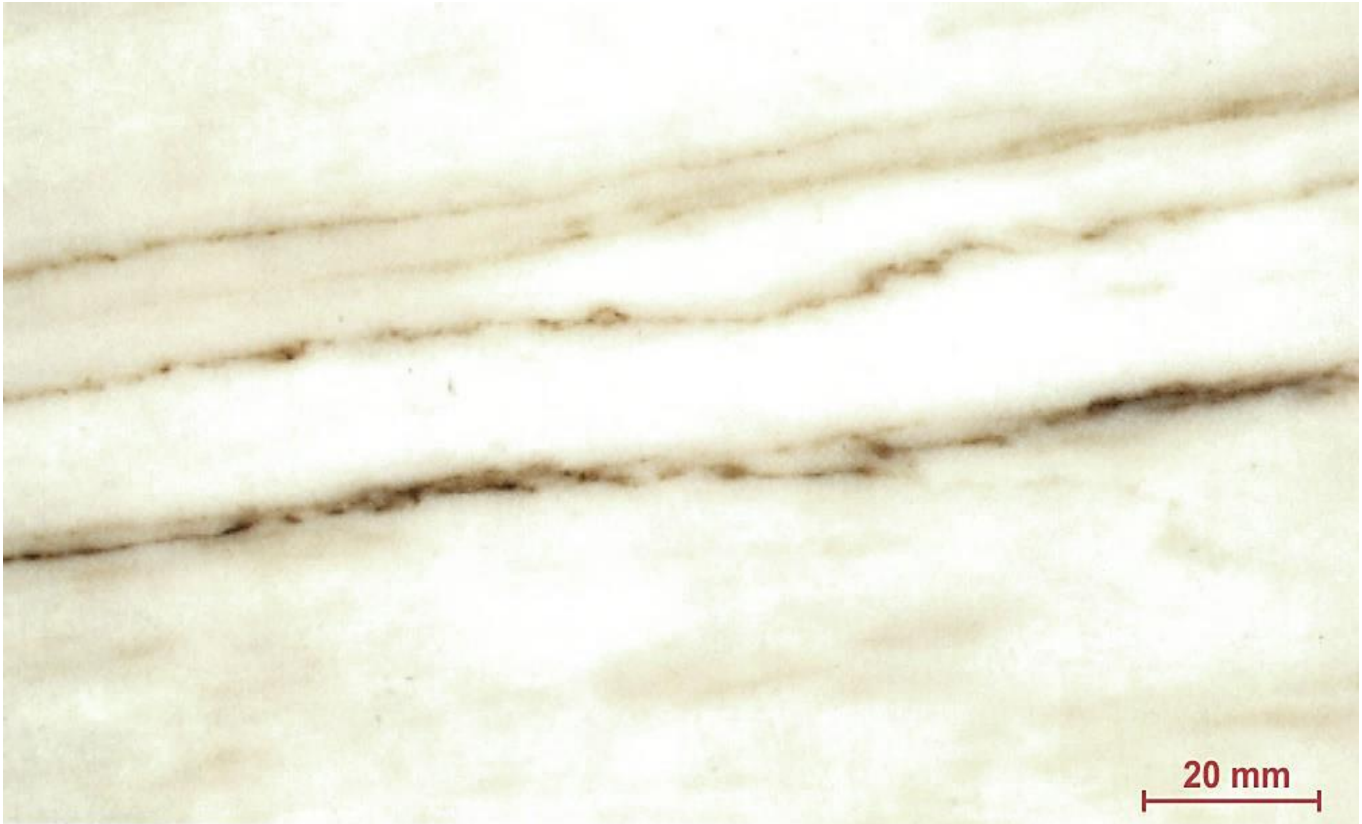
Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/branco-rosado/
	Naturstein	https://www.naturalstone-online.com/index.php?id=360&user_dnsaeng_pi1%5BsteinID%5D=1040
Commercial directory:		
Scientific publication:	Geological Society, London, Special Publications	http://dx.doi.org/10.1144/SP407.10
	Journal of Archaeological Science	http://dx.doi.org/10.1016/j.jas.2012.12.030
	International Journal of Rock Mechanics and Mining Sciences	https://doi.org/10.1016/j.ijrmms.2008.01.005
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7328-3
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 23/09/2021	

Branco Venado Estremoz

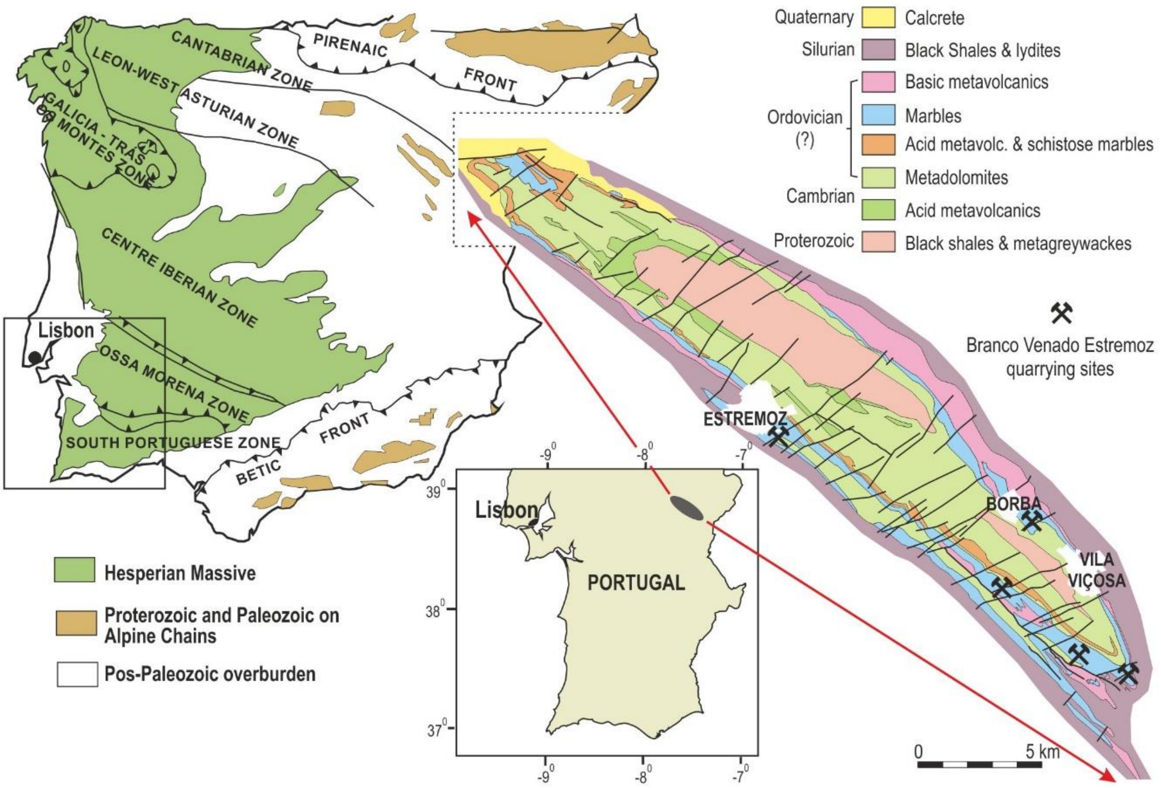
Branco com Vergadas, Branco Venado do Poço Bravo



Thin to medium grained white calcitic marble with light yellowish stains and greyish, brownish or reddish streaks.

Commodity	Lithology	Typical colour	Place of origin			
			Country	**District**	**Municipality**	**Place**
Commercial Marble	Calcitic Marble	White	Portugal	Évora	Estremoz, Borba, and Vila Viçosa	

Geological setting



Geology:
The Paleozoic Estremoz Anticline is the primary mining district of origin of most of the Portuguese marbles. It is a 40 km long and 8 km wide anticline with a dominant NW-SE orientation. It integrates the Ossa Morena Zone, which is a tectonostratigraphic unit of the Iberian Variscides. The stratigraphic sequence of the Estremoz Anticline was deformed and metamorphosed under green-schist to lower-amphibolite metamorphic conditions during the Carboniferous Variscan Orogeny, responsible for the development of two non-coaxial folding events and NW-SE oriented brittle-ductile shear zones, parallel to the later folding event.
Marbles in the Estremoz Anticline are part of the Estremoz Carbonate Volcano-Sedimentary Complex of probable Ordovician age. Several varieties of marble occur within this complex, reflecting, not only the original composition of the limestones, but also the interaction with volcanic rocks during deformation and metamorphism. They are fine to coarse grain calcitic marbles with granoblastic texture. Their background colours range from white to beige, pink and dark grey and may or may not have coloured streaks and spots. The folding complexity makes it impossible to determine the exact places where the different varieties may occur.

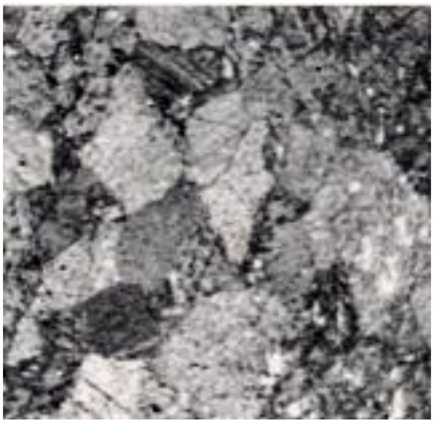
Production:
The marbles of the Estremoz Anticline have been extracted since antiquity. With the introduction of modern exploration and manufacturing technologies in the 70s of the 20th century, the production had a strong increase and started to be exported all over the world.
Extraction is carried out in dozens of quarries grouped into five main extraction sites called Estremoz, Borba, Vigária, Lagoa and Pardais, the last three in the municipality of Vila Viçosa. Mainly because of geological constraints, but also due to the quarries' arrangement in space, production yields are very low, usually, less than 15%.

Geological age: Ordovician (?)
Geological unit: Estremoz Carbonate Volcano Sedimentary Complex

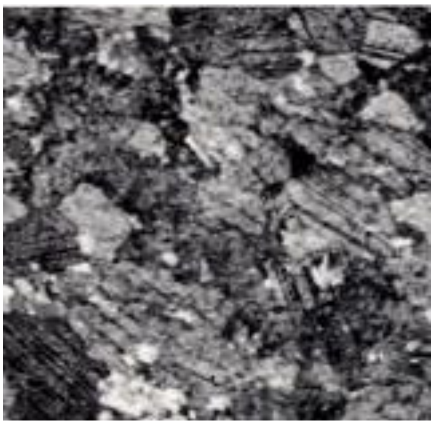
Application, use and heritage

Dating back to the Roman Empire, marbles from the Estremoz Anticline were used for the construction of buildings and monuments in Iberia. In Portugal, they have been used in the construction of about two hundred national monuments. Currently, they are used on several applications around the world: interior and exterior cladding, interior flooring and decoration (fireplaces, staircases, countertops, etc.), funerary art, masonry in engineering works and are still used as structural elements in buildings.

Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Calcitic marble, granoblastic texture, medium grained, holocrystalline, high purity.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Quartz (%)	Opaque minerals (%)	Iron Oxides (%)		
~99	< 1	vest. *	vest. *		

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2710	0.2	0.1	92	10.0

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
22.5	—	—	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	6	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
< 0.86	< 0.22	< 0.04	< 0.02	0.37	56.33	< 0.20	0.01	< 0.03	< 0.04	—	42.96

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/branco-com-veios-castanhos/
Commercial directory:		
Scientific publication:	Geological Society, London, Special Publications	http://dx.doi.org/10.1144/SP407.10
	Journal of Archaeological Science	http://dx.doi.org/10.1016/j.jas.2012.12.030
	International Journal of Rock Mechanics and Mining Sciences	https://doi.org/10.1016/j.ijrmms.2008.01.005
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7328-3
Other publication:		

Compiled by:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP) www.lneg.pt	
Version / date:	V1 / 23/09/2021	

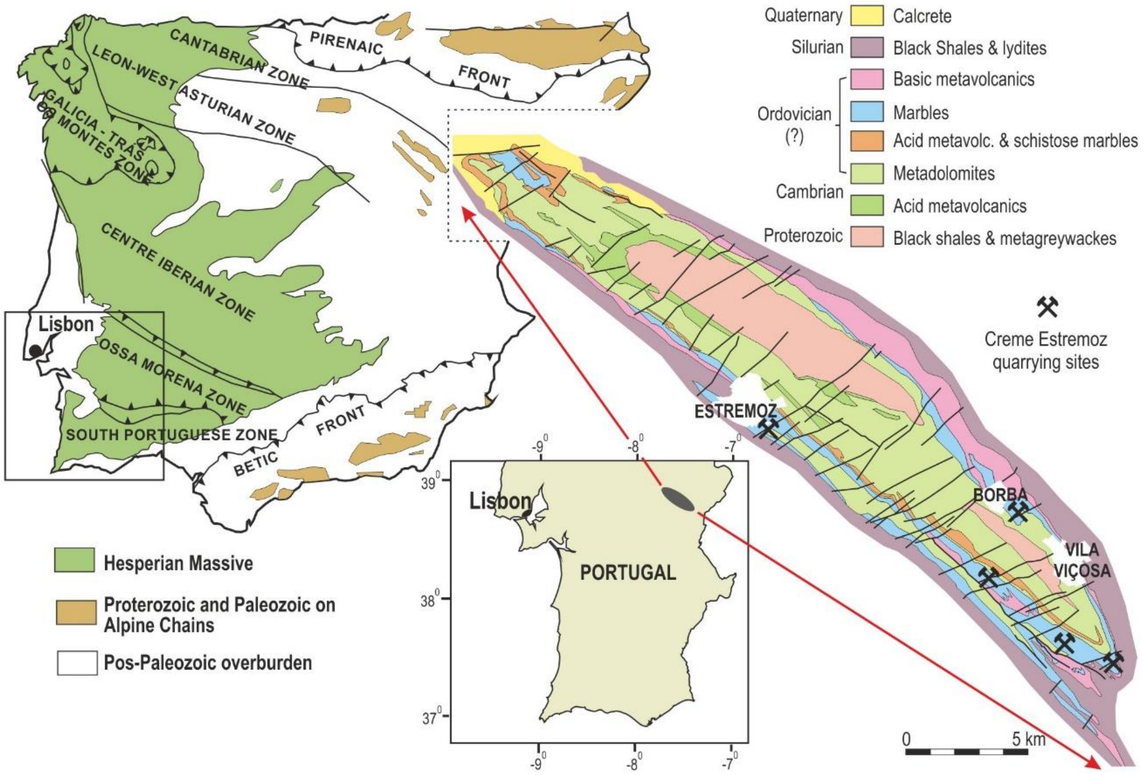
Creme Estremoz

Creme da Lagoa, Creme do Mouro

Short description:
Light beige calcitic marble, thin-grained. May present thin greyish or brownish coloured streaks and stains.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Marble	Calcitic Marble	White	Portugal	Évora	Estremoz, Borba, and Vila Viçosa	

Geological setting



Geology:
The Paleozoic Estremoz Anticline is the primary mining district of origin of most of the Portuguese marbles. It is a 40 km long and 8 km wide anticline with a dominant NW-SE orientation. It integrates the Ossa Morena Zone, which is a tectonostratigraphic unit of the Iberian Variscides. The stratigraphic sequence of the Estremoz Anticline was deformed and metamorphosed under green-schist to lower-amphibolite metamorphic conditions during the Carboniferous Variscan Orogeny, responsible for the development of two non-coaxial folding events and NW-SE oriented brittle-ductile shear zones, parallel to the later folding event.
Marbles in the Estremoz Anticline are part of the Estremoz Carbonate Volcano-Sedimentary Complex of probable Ordovician age. Several varieties of marble occur within this complex, reflecting, not only the original composition of the limestones, but also the interaction with volcanic rocks during deformation and metamorphism. They are fine to coarse grain calcitic marbles with granoblastic texture. Their background colours range from white to beige, pink and dark grey and may or may not have coloured streaks and spots. The folding complexity makes it impossible to determine the exact places where the different varieties may occur.

Production:
The marbles of the Estremoz Anticline have been extracted since antiquity. With the introduction of modern exploration and manufacturing technologies in the 70s of the 20th century, the production had a strong increase and started to be exported all over the world.
Extraction is carried out in dozens of quarries grouped into five main extraction sites called Estremoz, Borba, Vigária, Lagoa and Pardais, the last three in the municipality of Vila Viçosa. Mainly because of geological constraints, but also due to the quarries' arrangement in space, production yields are very low, usually, less than 15%.

Geological age: Ordovician (?)
Geological unit: Estremoz Carbonate Volcano Sedimentary Complex

Application, use and heritage

Dating back to the Roman Empire, marbles from the Estremoz Anticline were used for the construction of buildings and monuments in Iberia. In Portugal, they have been used in the construction of about two hundred national monuments. Currently, they are used on several applications around the world: interior and exterior cladding, interior flooring and decoration (fireplaces, staircases, countertops, etc.), funerary art, masonry in engineering works and are still used as structural elements in buildings.

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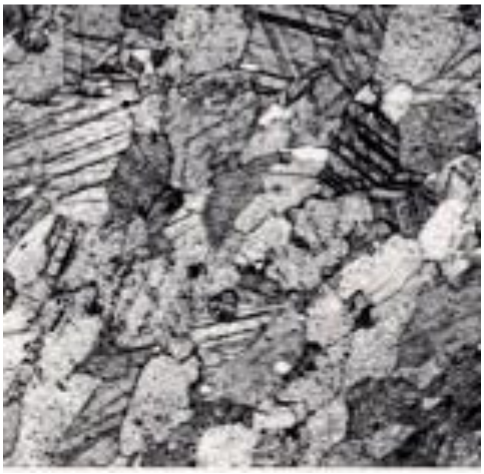
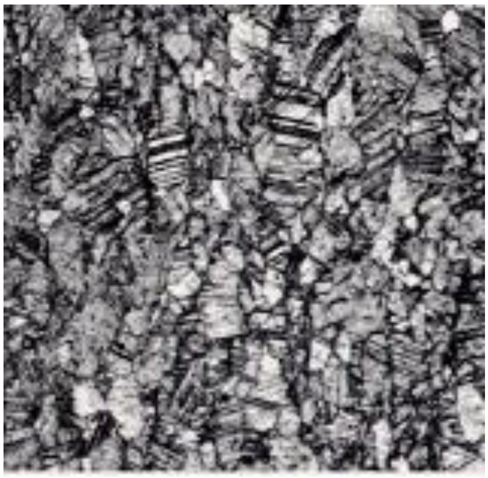
Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Calcitic marble with granoblastic texture and slightly deformed, as it is clearly seen in the cleavage lines of the calcite crystals.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Quartz, microcline and muscovite/sericite (%)				
~100	vest.*				

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2710	0.2	0.0	69	13.1

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
11.1	48	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
22.5	—	—	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	6	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
0.40	0.07	< 0.04	< 0.02	0.47	55.82	0.18	< 0.03	< 0.03	< 0.04	—	42.81

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
—	—	—	—	—	—	—	—
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
138	—	13	—	—	< 3	—	—
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
—	< 3	< 5	—	< 15	6	4	< 4
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
—	—	—	—	—	—	—	—
Tl							
—							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

EUROLITHOS European Ornamental Stone Resources

GeoERA RAW MATERIALS

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/creme-com-veios-castanhos/
	Naturstein	https://www.naturalstone-online.com/index.php?id=360&user_dnsaeng_pi1%5BsteinID%5D=1041
Commercial directory:		
Scientific publication:	Geological Society, London, Special Publications	http://dx.doi.org/10.1144/SP407.10
	Journal of Archaeological Science	http://dx.doi.org/10.1016/j.jas.2012.12.030
	International Journal of Rock Mechanics and Mining Sciences	https://doi.org/10.1016/j.ijrmms.2008.01.005
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7328-3
Other publication:		

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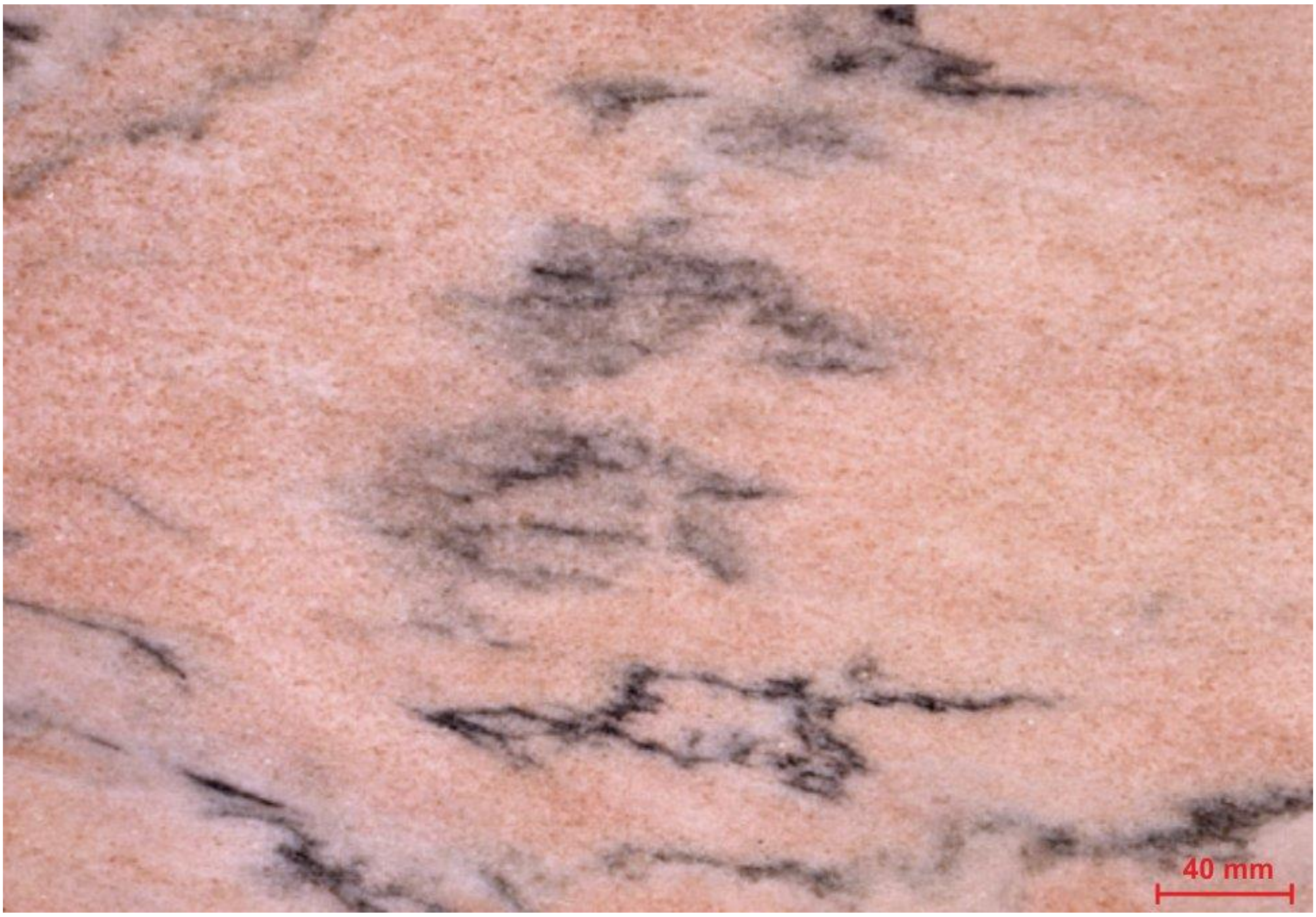
Version / date:	V1 / 23/09/2021	

Rosa Portugal

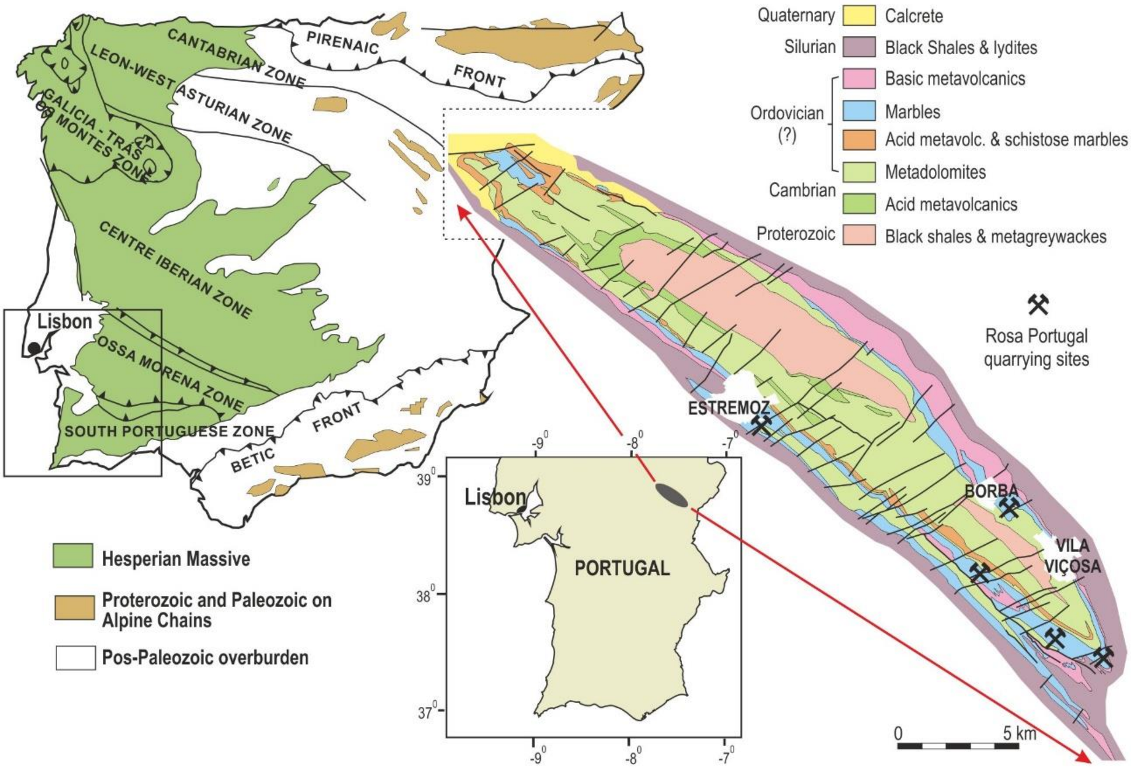
Rosa Aurora, Rosa



Short description:
Pink coloured calcitic marble; fine to coarse grain. Variations are very common: the pink background may be more or less vivid and uniform, and usually has greyish, brownish or greenish veins and spots, which may be more or less persistent.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Marble	Calcitic Marble	Pink	Portugal	Évora	Estremoz, Borba and Vila Viçosa	

Geological setting



Geology:
The Paleozoic Estremoz Anticline is the primary mining district of origin of most of the Portuguese marbles. It is a 40 km long and 8 km wide anticline with a dominant NW-SE orientation. It integrates the Ossa Morena Zone, which is a tectonostratigraphic unit of the Iberian Variscides. The stratigraphic sequence of the Estremoz Anticline was deformed and metamorphosed under green-schist to lower-amphibolite metamorphic conditions during the Carboniferous Variscan Orogeny, responsible for the development of two non-coaxial folding events and NW-SE oriented brittle-ductile shear zones, parallel to the later folding event.
Marbles in the Estremoz Anticline are part of the Estremoz Carbonate Volcano-Sedimentary Complex of probable Ordovician age. Several varieties of marble occur within this complex, reflecting, not only the original composition of the limestones, but also the interaction with volcanic rocks during deformation and metamorphism. They are fine to coarse grain calcitic marbles with granoblastic texture. Their background colours range from white to beige, pink and dark grey and may or may not have coloured streaks and spots. The folding complexity makes it impossible to determine the exact places where the different varieties may occur.

Production:
The marbles of the Estremoz Anticline have been extracted since antiquity. With the introduction of modern exploration and manufacturing technologies in the 70s of the 20th century, the production had a strong increase and started to be exported all over the world.
Extraction is carried out in dozens of quarries grouped into five main extraction sites called Estremoz, Borba, Vigária, Lagoa and Pardais, the last three in the municipality of Vila Viçosa. Mainly because of geological constraints, but also due to the quarries' arrangement in space, production yields are very low, usually, less than 15%.

Geological age: Ordovician (?)
Geological unit: Estremoz Carbonate Volcano Sedimentary Complex

Application, use and heritage

Dating back to the Roman Empire, marbles from the Estremoz Anticline were used for the construction of buildings and monuments in Iberia. In Portugal, they have been used in the construction of about two hundred national monuments. Currently, they are used on several applications around the world: interior and exterior cladding, interior flooring and decoration (fireplaces, staircases, countertops, etc.), funerary art, masonry in engineering works and are still used as structural elements in buildings.
The most common applications of the Rosa Portugal variety are in bathrooms, staircases, stonework and art pieces.

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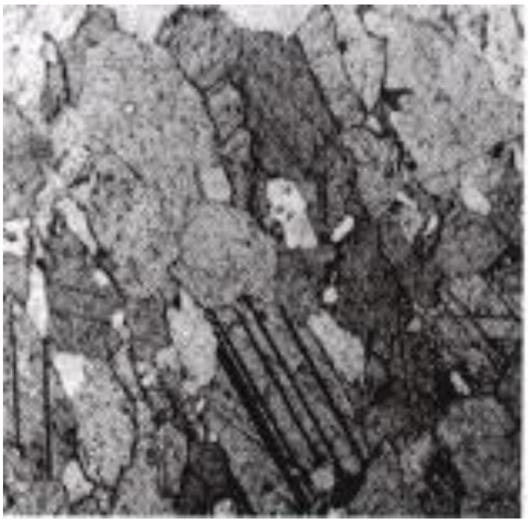
http://www.primeirapedra.com/en/stonesinuse/amoreiras-housing-complex/

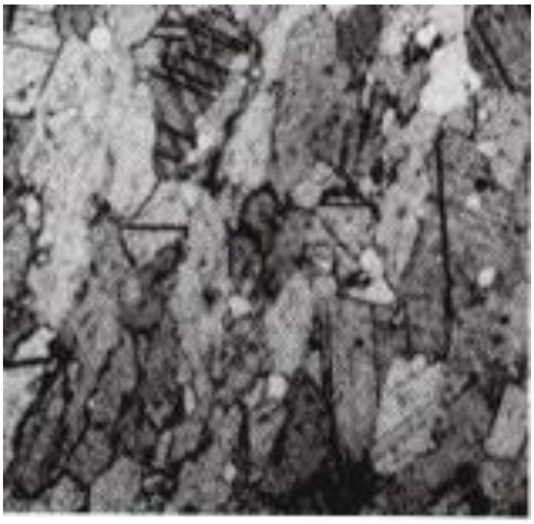
Cathédrale Notre-Dame de la Treille, Lille, France

Amoreiras Housing Complex and Mall, Lisboa, Portugal

Petrography



Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Calcitic marble, holocrystalline, granoblastic texture and with boundaries between the crystals slightly sutured.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Quartz, feldspars (plagioclase and potassic feldspar), muscovite and opaque minerals (%)				
~99	vest.*				

* vestiges (traces)

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2710	0.2	0.1	100	14.0

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
—	—	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
23.5	—	—	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	8	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
4.51	0.94	0.31	< 0.02	1.12	51.26	< 0.20	0.73	0.03	< 0.04	—	40.95

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
Tl							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		

Methods applied:
Determination of the main elements trace elements and REE: X-Ray Fluorescence.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

EUROLITHOS European Ornamental Stone Resources

GeoERA RAW MATERIALS

Sources of more information

Type of information	Name of provider	URL
This data sheet:	Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP	www.lneg.pt https://rop.lneg.pt/rop/index_en.php
Non-commercial directory:	Primeira Pedra	http://www.primeirapedra.com/en/stones/rosa-com-veios-verdes/
	Stone by Portugal	https://stonebyportugal.com/stone/rosa-portugal/?lang=en
Commercial directory:		
Scientific publication:	Geological Society, London, Special Publications	http://dx.doi.org/10.1144/SP407.10
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	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7328-3
Other publication:	Lithos	https://www.litosonline.com/en/article/marble-rosa-portuguese

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Version / date:	V1 / 13/09/2021	

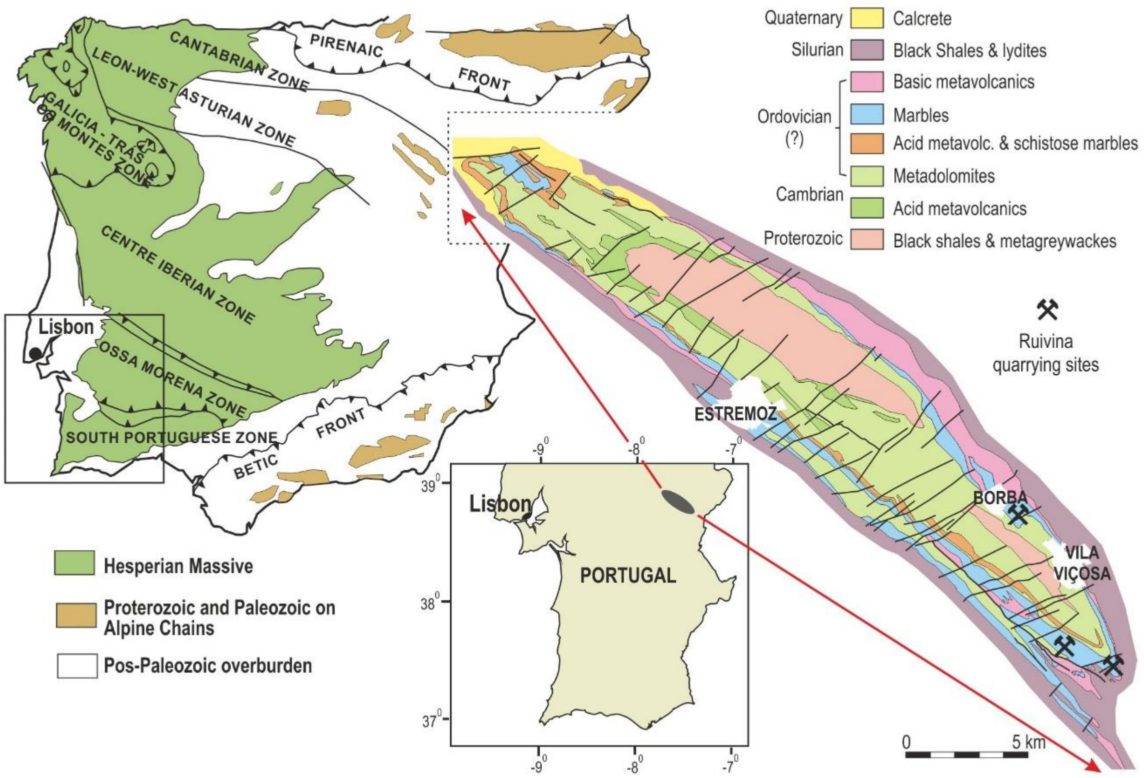
Ruivina

Azul Lagoa, Ruivina Escuro

Short description:
Dark grey calcitic marble, medium grain. May present lighter grey coloured patches and streaks.

Commodity	Lithology	Typical colour	Place of origin			
			Country	District	Municipality	Place
Commercial Marble	Calcitic Marble	Dark-Grey	Portugal	Évora	Borba, and Vila Viçosa	

Geological setting



Geology:
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Geological age: Ordovician (?)
Geological unit: Estremoz Carbonate Volcano Sedimentary Complex

Application, use and heritage

Dating back to the Roman Empire, marbles from the Estremoz Anticline were used for the construction of buildings and monuments in Iberia. In Portugal, they have been used in the construction of about two hundred national monuments. Currently, they are used on several applications around the world: interior and exterior cladding, interior flooring and decoration (fireplaces, staircases, countertops, etc.), funerary art, masonry in engineering works and are still used as structural elements in buildings.

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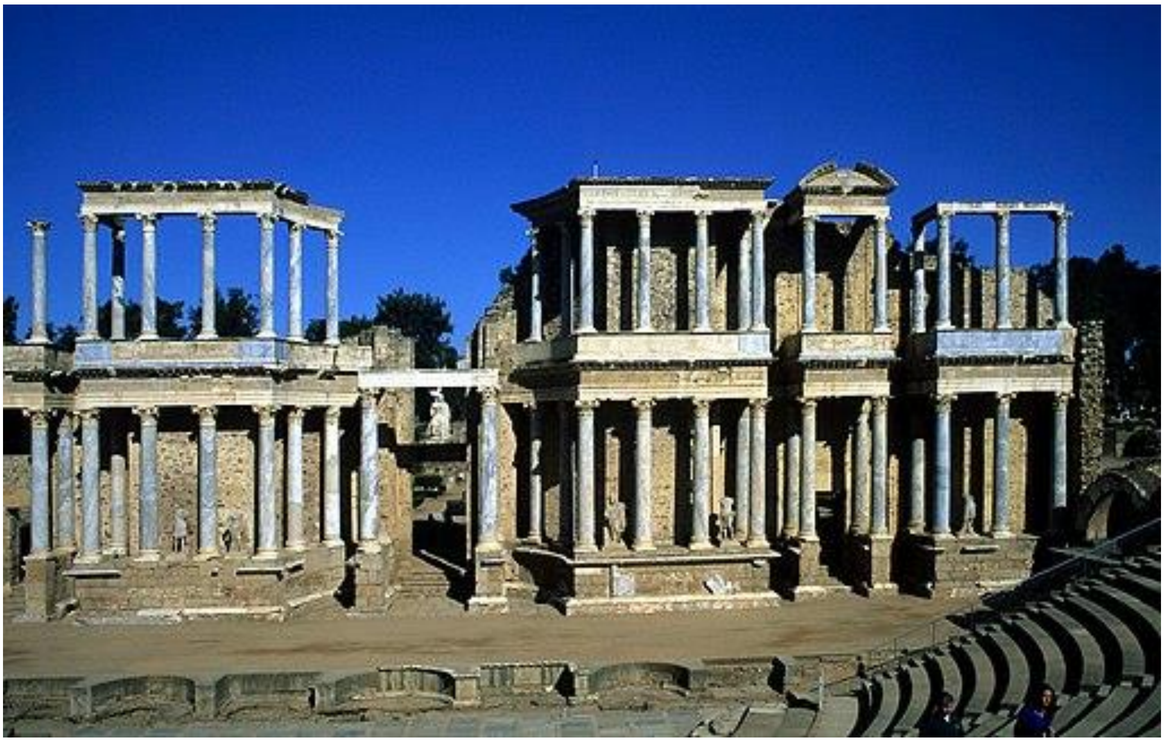

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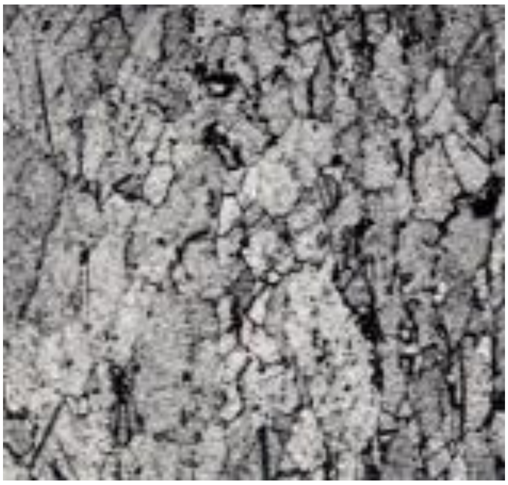
Ruivina marble used it the columns of the Roman Theatre of Merida

Petrography

Thin section parallel to the preferred orientation plane, when applied.



Thin section perpendicular to the preferred orientation plane, when applied.

Description:
Calcitic marble with granoblastic, slightly oriented, texture and reasonably uniform grain size (medium to fine). It presents zones with slight deformation.

Source of information:
Geological Survey of Portugal (LNEG - Laboratório Nacional de Energia e Geologia, IP).

Mineral composition

Calcite (%)	Dolomite, quartz, apatite, muscovite, clay minerals and carbonaceous matter (%)				
~98	~2				

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Physical properties

Apparent density (EN 1936) kg/m3	Open porosity (EN 1936) % vol	Water absorption at atmospheric pressure (EN 13755) % wt	Uniaxial Compressive strength (EN 1926) MPa	Flexural strength under concentrated load (EN 12372) MPa
2710	0.3	0.1	80	11.7

Real density (EN 1936) kg/m3	Total porosity (EN 1936) % vol	Water absorption coefficient by capillary (EN 1925) (g/m2 x s0,5)	Flexural strength under constant moment (EN 13161) MPa
—	—	—	—

Frost resistance (EN 12371)				
Technological Test (Test A)				Identification Test (Test B): Number of cycles completed prior to stone failure
Flexural strength (EN 12372) after freeze-thaw cycling, MPa	Number of cycles	Uniaxial compressive strength (EN 1926) after freeze-thaw cycling, MPa	Number of cycles	
8.3	48	—	—	—

Resistance to ageing by thermal shock (EN 14066)			
Change in dynamic modulus of elasticity (increase: +; decrease: -) %	Change in open porosity (increase: +; decrease: -) %	Change in ultrasound pulse velocity (increase: +; decrease: -) %	Change in flexural strength under conc. load (increase: +; decrease: -) %
—	—	—	—

Abrasion resistance (EN 14157)			Resistance to salt crystallisation (EN 12370)	Breaking load at dowel hole (EN 13364)	
Method A - Wide Wheel Abrasion Test, mm	Method B - Böhme Abrasion Test, mm^3	Method C - Amsler Abrasion Test, mm	Change in mass (increase: +; decrease: -), %	Breaking load, N	Thickness of the test specimens, mm
22.0	—	—	—	—	—

Slip resistance by means of the pendulum tester (EN 14231 / CEN/TS 16165)			Rupture energy (EN 14158), Joule	Thermal Conductivity (EN 1745), W/m·K
Tested surface finish	Slip Resistance Value — SRV			
	Dry test condition	Wet test condition		
—	—	—	9	—

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Chemical properties

Main elements (%)

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	LOI
< 0.86	< 0.22	0.04	< 0.02	0.51	55.39	< 0.20	0.03	< 0.03	< 0.04	< 0.07	42.89

Trace elements (ppm)

V	Cr	Mn	Co	Ni	Cu	Zn	As
< 0.3	8	26	< 0.9	10	1	2	< 2
Sr	**Cd**	**Ba**	**Pb**	**Be**	**Rb**	**Bi**	**U**
179	< 0.1	14.5	0.6	< 0.1	0.8	—	< 0.1
Sc	**Y**	**Th**	**Sb**	**Ta**	**Nb**	**Zr**	**Sn**
< 0.3	0.4	< 5	< 12	< 15	< 0.2	5	< 4
Ag	**B**	**Mo**	**W**	**Ga**	**Ge**	**Se**	**Cs**
< 2	< 8	0.2	< 18	0.07	0.2	< 0.3	< 0.2
Tl							
< 0.04							

REE (ppm)

La	Ce	Pr	Nd	Sm	Eu	Gd	Tb
0.9	1.4	0.17	0.5	0.06	0.01	0.06	< 0.02
Dy	**Ho**	**Er**	**Tm**	**Yb**	**Lu**		
0.05	< 0.02	0.03	< 0.02	< 0.03	< 0.02		

Methods applied:
Determination of the main elements (except SO_3): X-Ray Fluorescence.
Determination of Zr, Ta, Sn and Th: X-Ray Fluorescence.
Determination of the SO_3, Ag, B, Sb and W: Direct current plasma emission spectrometry.
Determination of the remaining Trace elements and of REE elements: Inductive plasma mass spectrometry.

Source of information:
Geological survey of Portugal (Laboratório Nacional de Energia e Geologia, IP)

Sources of more information

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Scientific publication:	Geological Society, London, Special Publications	http://dx.doi.org/10.1144/SP407.10
	Journal of Archaeological Science	http://dx.doi.org/10.1016/j.jas.2012.12.030
	International Journal of Rock Mechanics and Mining Sciences	https://doi.org/10.1016/j.ijrmms.2008.01.005
	Environmental Earth Sciences	https://doi.org/10.1007/s12665-018-7328-3
Other publication:		

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Version / date:	V1 / 23/09/2021	