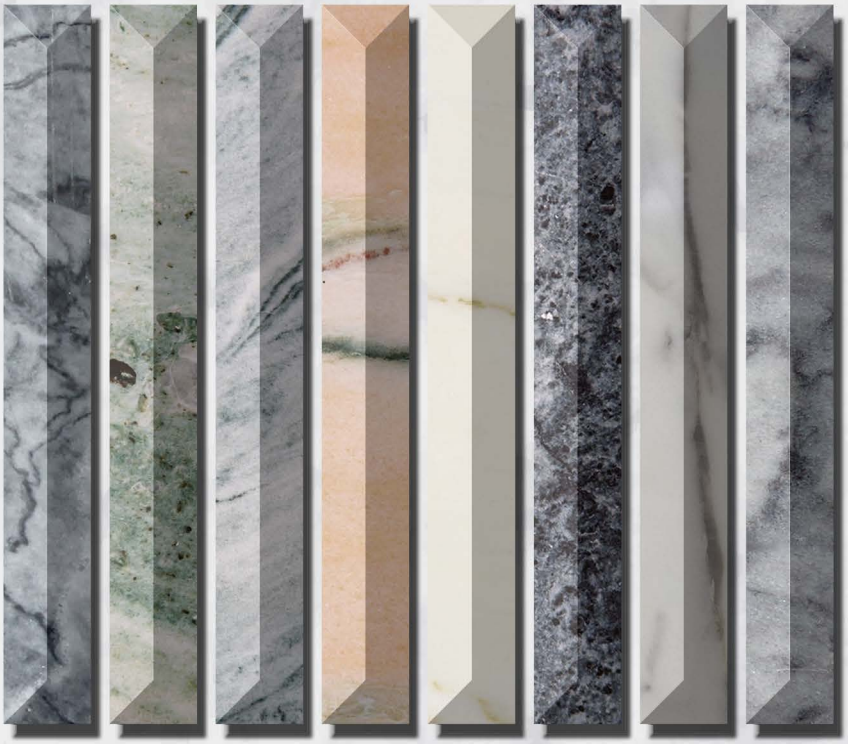
DISCOVERING
"WHITE GOLD"

SCIENCE & MARBLE NR. 2



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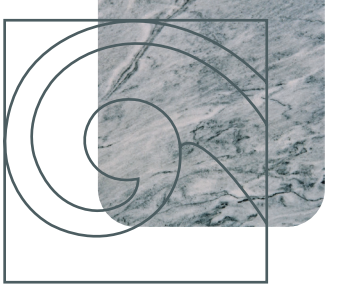


Who am I??

Marble is considered a monomineralic rock (constituted mostly by one mineral), generally presenting a granular texture. Its basic constituent mineral is usually calcite, although dolomite marbles are abundant. Calcite and dolomite are both minerals from the group of carbonates, calcite being a calcium carbonate and dolomite a calcium-magnesium carbonate.

What are marbles made of?

Marbles are metamorphic rocks (we will see what that is later) and, by definition, a rock is a natural solid aggregate composed of minerals, mineraloids or fragments of other rocks; like all matter, rocks and minerals are composed of chemical elements. Rocks can be composed of only one mineral (monominerals) or by an association of minerals (polyminerals). Marbles are considered to be monomineral rocks, composed of carbonates and generally exhibiting high mineralogical purity. However, the varying presence of accessory minerals of various natures such as silicates (micas, chlorite, quartz, feldspars, diopside, olivine, among others or sulphides (pyrite is the most common) is common. The greater or lesser abundance of these minerals will condition the marbles' colours, textures and chemism.

A calcitic marble is essentially composed of three elements of the periodic table: calcium, carbon and oxygen. If the marble has dolomite as the main mineralogical element, then magnesium must be added as the dominant element. Depending on the percentage of the accessory mineralogy, marbles can have considerable percentages of other elements such as silicon, aluminium, iron or potassium.

Why do marbles vary in colour?

Although marbles are considered to be monomineral rocks they may have a more diverse mineralogical composition as a result of the geological processes that gave rise to them and the intrinsic features of the original rock itself (protolith). Thus, the chromatic variations in marbles are the result of these compositional and/or mineralogical "impurities". As an example, we explore four chromatic varieties common in calcitic marbles:

01. The white and cream marbles generally present high mineralogical and compositional purity, and in many cases can be composed of more than 99% calcite.

02. The marbles with dark shades, between black and bluish-grey, generally present a non-negligible content of disseminated organic matter, which, although in small quantities, gives them these tones.

03. Pink marbles generally present a considerable content of some metallic elements such as titanic, manganese, magnesium and iron, either as crystalline defects or replacing

calcium in the crystalline structure of calcite.

04. Green marbles are generally mineralogically impure marbles, in which the appearance of greenish minerals is common, usually diopside, olivine, epidote, tremolite, actinolite or chlorite.

However, the appearance of marbles with high uniformity in colouring is the least common. What is more usual is the appearance of levels/bands of distinct tonalities and compositions within a mass of more or less uniform colour; these bands are generally called veins or venules. It is these veins that bring about the patterns, sometimes of high complexity, so typical in marbles as a result of the concentration of mineralogical and/or compositional impurities, and may have diversified tonalities.

did you know that ...

Reaction to acids

Carbonates, notably calcite, are insoluble in water and are a relatively stable group of minerals at the Earth's surface. However, the water on the earth's surface is commonly acidic due to the presence of elements or compounds in solution in the water (for example carbonic acid - H2 CO3) and carbonates react in the presence of acids. This is one of the most differentiating characteristics of the rocks composed by carbonates, such as marbles or limestones. As an example, there is the reaction between calcium carbonate and hydrochloric acid:

$CaCO_3$ (solid) + 2HCl (aqueous) > $CaCl_2$ (aqueous) + CO_2(gas) + H_2O (liquid)

A gas (carbon dioxide) is released from this reaction, giving rise to an effervescence, which in the case of calcite is visible to the naked eye. In other carbonates, such as dolomite, this reaction is less intense under normal atmospheric conditions.

Texture

Marbles are generally considered to be massive rocks with a granular texture (called granoblastic), nonfoliated, marked by the mosaic arrangement of the carbonate crystals that constitute them, whether calcite or dolomite. However, the appearance of a texture marked by the preferential orientation of the carbonate crystals according to preferential orientations is frequent. Also the existence of an internal mineralogical or compositional banding in some marble varieties (veins) can give the marbles an occasionally foliated texture.

Calcite
its composition and shape

Marbles are commonly calcitic, which gives them a set of characteristics of their own. The calcite presents in its composition:

01. Carbon, a tetravalent element (C^{4-} or C^{4+} ; it has four electrons in the valence layer), tends to make four covalent bonds to become stable, thus filling the valence layer with 8 electrons.

02. Oxygen, a bivalent element (O^{2-} ; it has six electrons in the valence layer), which tends to make two covalent bonds to become stable, thus filling the valence layer with 8 electrons.

03. Calcium, an element that tends to lose its two valence layer electrons, becoming a positive ion (Ca^{2+}).

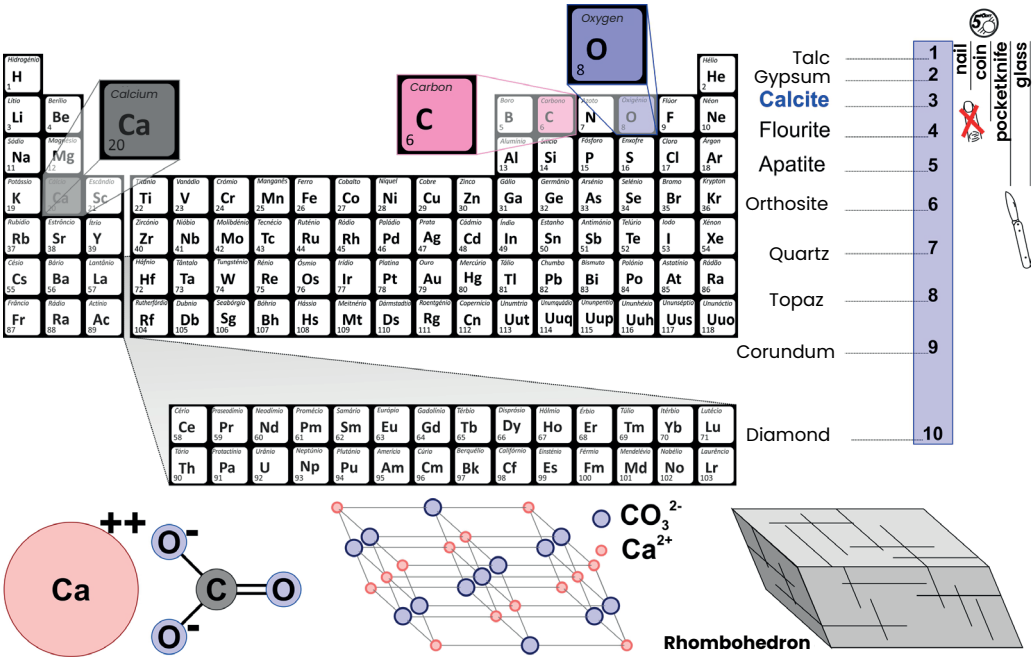
Carbon and oxygen have a great bonding affinity for each other, becoming stable and sharing valence electrons: one carbon atom can bond to two oxygen atoms, forming a stable compound, Carbon Dioxide ($O = C = O \rightarrow CO_2$). However, a carbon atom can also bind to three oxygen atoms, forming a compound in solution, the carbonate ion (CO_3^{2-}). This compound tends to form chemical compounds with cations that would take its two excess electrons, allowing a bond with the calcium cation (Ca^{2+}), giving rise to calcium carbonate (CaCO3), or calcite (or other calcium carbonate), the main mineral in marble.

Carbon and oxygen form covalent bonds (strong bonds, with the sharing of electrons in the valence layer) and may bond to the calcium cation through an ionic bond (strong bond, but less strong than the covalent one). The nature of the existing chemical bonds influences the hardness of minerals. Calcite is a mineral characterised by low hardness, a feature common to all minerals of the carbonate family (ionic compounds). Thus, calcite represents level 3 of hardness on the Mohs Scale.

Calcite crystals (as well as those of other carbonates) grow and mimic its crystalline organization, generally presenting rhombohedral shapes. Rhombohedrons are geometric solids with similarities to a parallelepiped, but their faces have a rhomboid shape (a geometric shape whose adjacent sides have different sizes, and angles are equal two by two - note the difference from rhombuses, which have all sides the same size).

Calcite has yet another very particular characteristic, which is the fact that calcite crystals break according to well-defined structural planes; these planes are called cleavage. When broken, a rhombohedral shaped calcite crystal gives rise to smaller rhombohedrons, and

when these are broken, they give rise to even smaller rhombohedrons. The cleavage planes' orientation reflects the atomic structure of the calcite crystals.



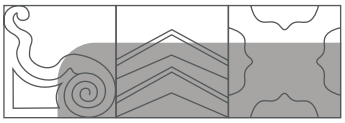
01. Composition, shape and hardness of calcite. Noel Moreira.

How are marbles formed?

Marbles are included in a typology of rocks called metamorphic rocks. These rocks, as their name indicates, result from the very slow transformation of an initial rock into a final rock (the word comes from the Greek: *"meta"* means change and *"morpho"* means shape). This slow change happens on the scale of millions of years, taking place at depth and as a result of the increase of temperature and pressure (with associated fluids), thus generating a set of physical and chemical transformations, always in the solid state, in the initial rocks.

What was the original type of rock that gave rise to marbles?

Marble and limestone exhibit similar composition: both rocks are composed of carbonate minerals, calcite being the dominant mineral. However, marble and limestone have distinct origins.



Limestones are sedimentary rocks. Sedimentary rocks result from the accumulation, compaction and cementation of material of organic and inorganic origin. Organic materials can include any part of a living being or its organic activity, from shells, shells, bones or waste. Inorganic materials, on the other hand, are the result of the physical and chemical weathering of rocks and minerals, i.e. the processes of decomposition or disintegration resulting from exposure to external agents such as water, wind or living beings. This includes from clasts resulting from the disintegration of rocks, to the elements that are in solution and result from the chemical alteration of the rocks. In fact, limestones may have two origins:

01. Limestone resulting from the direct precipitation of ions dissolved in water, notably Ca^{2+} and CO_3^{2-}, in much the same way as limestone precipitates from a hot water tap or washing machine, ***or***

02. Limestones resulting from organic activity, in particular from the accumulation of remains of living shell/skeleton carbonate creatures or from carbonate precipitation mediated by living beings, as in bioconstructions such as reefs.

Thus, the depositional environment of limestone rocks occurs mostly in aquatic environments. The vast majority of carbonate sedimentation occurs in shallow marine environments, at the continental shelf level, and is associated with intense biological productivity in these environments.

We may then move on to the genesis of marble. As mentioned, marble is a metamorphic rock and as such a rock that is formed through the transformation of an initial rock (called protolith).

We can then deduce from the compositional complementarity that the protolith of the marbles are limestones (or dolomites - dolomitic limestones - for a significant part of the dolomitic marbles). This transformation of limestones into marbles is due to the physical-chemical transformation of limestones inside the terrestrial lithosphere by the action of temperature, pressure and fluids over time, through the phenomena involved in the process of metamorphism. The increase in temperature and pressure that leads to the transformation of limestones into marbles can have two main origins:

01. Temperature increase associated with the installation of magmatic rock bodies (such as granites) in carbonate regions, which will "bake" the limestones - contact metamorphism (sometimes called thermal metamorphism);

02. Pressure and temperature increase over large areas associated with the thickening of the Earth's lithosphere, related to the genesis of mountain ranges - regional metamorphism.

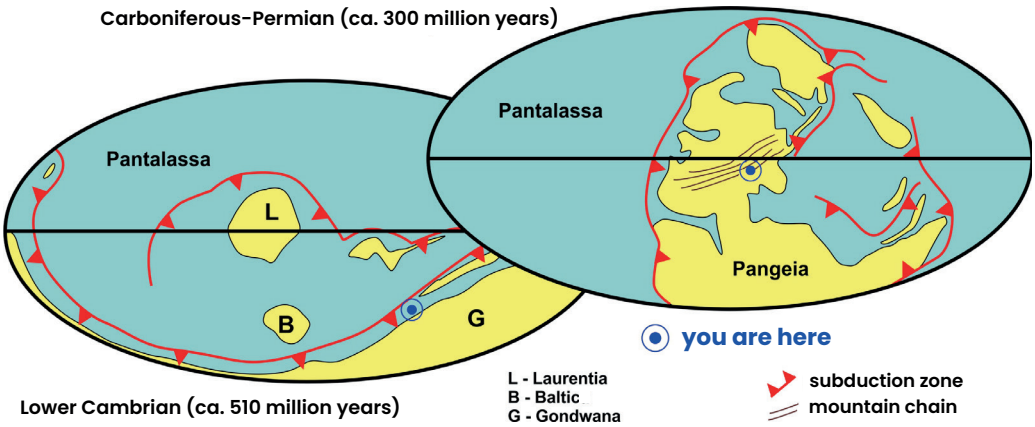
In both cases, limestones will suffer a set of physicochemical transformations that will be more intense the higher the temperature (and pressure) the limestones are subjected to, which in many cases may erase all the limestones' primary characteristics, especially the present structures and textures. These transformations are either associated with the recrystallization of carbonate minerals (calcite and dolomite), or the existence of metamorphic reactions

that will transform the minerals present in the sedimentary protolith. If the metamorphism occurs in the presence of chemically active fluids, marbles with a more exotic mineralogy can be formed.

Why are marbles abundant in the Alentejo?

This is a complex story, which begins during the lower Palaeozoic, millions of years ago, when the arrangement of continents and oceans was quite different from the arrangement we know today. Testimonies to this story are included in what is commonly known as the Iberian Massif, which stretches from Galicia (Spain) to the Algarve (Portugal) and where the oldest rocks of the Iberian Peninsula outcrop, with ages between the Paleozoic (541-251 Ma) and the Ediacalic (635-541 Ma).

The rocks located in the Iberian Massif, including much of the Alentejo, tell the story of the opening of an ocean, the Rheic, where limestone was deposited at least four different times. But oceans are not eternal. During the upper Palaeozoic this ocean closed, giving rise to an ancient continent that agglomerated all the continental blocks we know today, called Pangea.

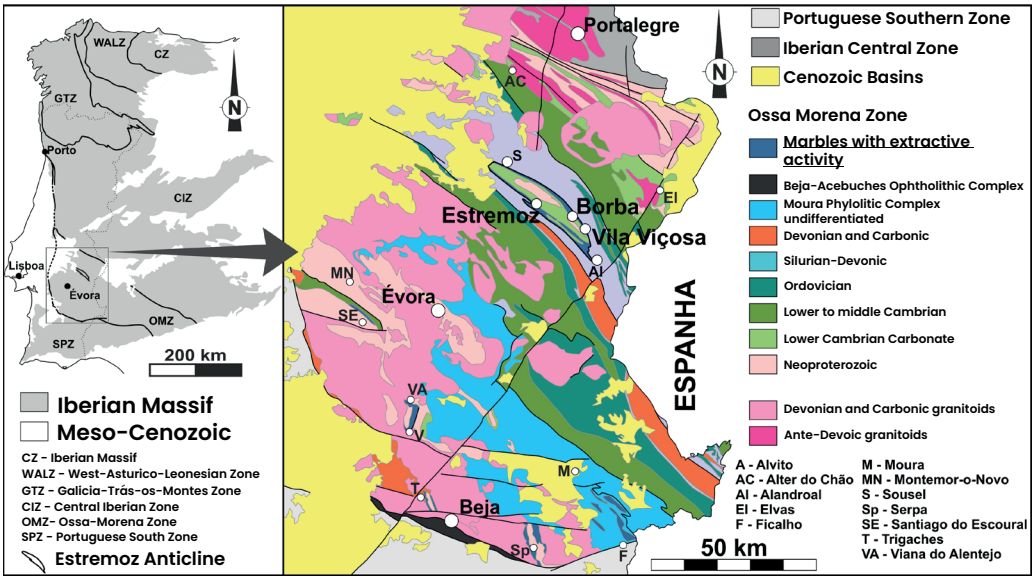


02. Oceans and continents from the past. Noel Moreira.

Where can we find marbles in the Alentejo?

Marbles are abundant rocks in Alentejo, and in some of these regions these marbles have been exploited throughout history. The marbles existing in the region of Sousel-Estremoz-Vila Viçosa- Borba-Alandroal, Viana do Alentejo-Alvito, Trigaches-São Briços, Santiago do Escoural (Montemor-o-Novo), Vila Verde de Ficalho-Moura, Serpa and Alter do Chão-Elvas stand out.

There are doubts as to the exact age of some of these marbles, due to the absence of fossils; according to the Principle of Palaeontological Identity, fossils are of the same age as the rocks that contain them and as such, fundamental to knowing their age. and the almost general absence of fossils, geologists interpret all these units as being of the same age, although they may represent more than one carbonate sedimentation event in the region. Moreover, between the Cambrian and Devonian, that is, between 540 and 360 million years ago, there are four episodes of carbonate sedimentation, making it necessary to carry out further studies on the age of all these marbles.



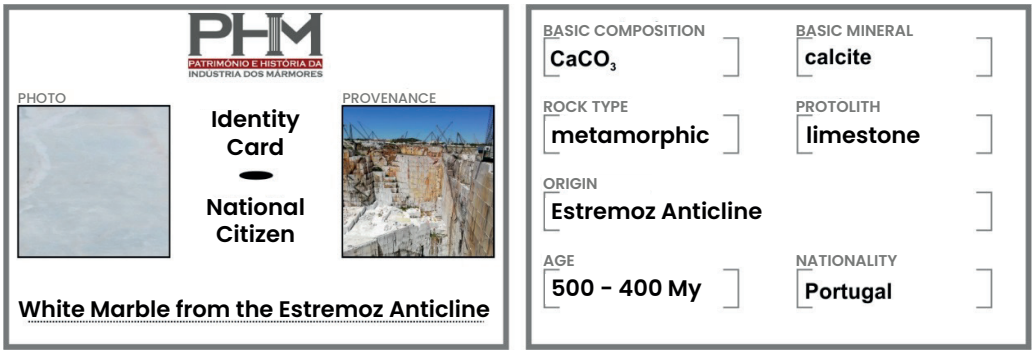
03. The marbles of the Alentejo, with emphasis on the marbles of the Estremoz Anticline. Noel Moreira.

What is the Estremoz Anticline?

Among the several occurrences of marble in Alentejo, one of them has a high importance, for its great extension and its exploitation throughout history. The region between Sousel and Alandroal includes a large geological structure, having been actively exploited at least since Roman times, and is still today exhibits great socio-economic and patrimonial significance relevance in the region. This region, called Estremoz Anticline, the so-called Estremoz Marble is explored, with active explorations in the counties of Estremoz, Vila Viçosa and Borba; the set of these three counties is called Marble Triangle. These marbles represent one of the most important marble deposits worldwide, and undoubtedly the most important nationally. There are several types of marbles explored here, from the marbles of clear tonalities, pink, black and veined.

The Estremoz Anticline consists of a fold with a general NW-SE direction, extending about 40km long and 7km wide, with marble outcropping at the edges of this regional-scale structure. A fold?
Yes, a cartographic fold that bears witness to the action of the tectonics associated to the genesis of the supercontinent Pangea. This fold has a downward-facing concavity, with the oldest geological units arranged at its core (incidentally, that is the meaning of the word anticline).

In short, the Alentejo marbles, and in particular the Estremoz Marbles, were formed in the Upper Palaeozoic (approximately 350-300 million years ago), in a time when what we know today as Portugal was in the middle of a mountain chain (Varisca Chain) resulting from the collision between several continental blocks, giving rise to Pangea. Due to the high pressures and temperatures inside the mountain chain, the limestones, formed in an oceanic environment in the Lower Palaeozoic (500-400 Ma), were transformed into marbles.



04. Identity Card of the Estremoz Anticline›s Marble. Noel Moreira.

Lime
as a component of mortars

What is lime?

Lime is an inorganic material that, since Classical Antiquity, has been widely used both in architecture and in the decorative arts. Rafael Bluteau, author of Vocabulario Portuguez e Latino describes it as being a "(...) stone burnt and converted into white lumps that crumble into powder (...)".

Lime is obtained through the calcination of limestone origin rocks composed mainly by calcium carbonate (CaCO3) and by other materials, such as clays. This calcination was performed at a temperature above 900 degrees, which resulted in the so-called "quicklime" (calcium oxide - CaO2).

The burning of limestone rocks was carried out in large ovens, of which there are important archaeological remains from the Roman period in the Alentejo region (for example in Baleizão, Beja).

In the 17th and 19th centuries there are frequent references to lime kilns in historical documentation, which reveals the importance of the production of this material in Portugal.

05. Borba, Barro Branco, Kiln and lime production by António Festas. | CECHAP | PHIM.
06. Borba, Barro Branco, Kiln and lime production by António Festas | CECHAP | PHIM.

In several parts of our country and, also, in Alentejo, in municipalities that integrate the Anticlinal of Estremoz there are lime kilns that have survived until our days, although, throughout the 20th century, they stopped producing.

When lime is in solid form (rock or white coloured blocks) it can be immersed in water and hydrated to a paste. During this chemical process, called "lime quenching", intense heat is released while the (now "quenched") lime is transformed into calcium hydroxide - $Ca(OH)2$. This paste has great plasticity and malleability, acting as a binder for various aggregates (sand, brick dust, gypsum dust, clay, etc.) in mixtures known as mortars. Furthermore, lime is a porous material and permeable to water vapour, which makes it possible to control the presence of humidity inside buildings.

When exposed to air, lime suffers a slow hardening reacting with carbon dioxide ($CO2$) present in the atmosphere until it is reconverted into calcium carbonate ($CaCO3$). It is this chemical reaction (carbonation of lime) that, in the case of fresh painting, allows the fixation of the pigments to the wall plaster.

The use of lime remained constant in Europe until the 19th century, when the introduction of Portland cement reduced its use, especially in construction. Cement became more and more used as a building material while, at the same time, the knowledge about the lime working techniques and their application was lost.

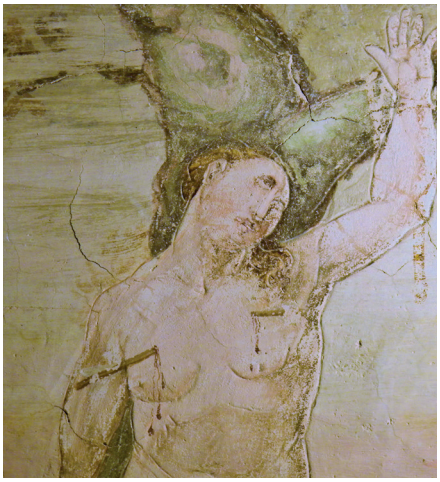
vocabulary

Portland Cement
Material discovered by the Englishman Joseph Apsdin in 1824, and which, after hardening, had a high resistance that remained unchanged, even after exposure to air or even in water. In Portugal, the first cement factory was established in 1890 (Alhandra), with production starting a little later (1906) in Outão (Setúbal).

Despite the importance of the introduction of this new material in the context of the 20th century architecture, its application in the field of the rehabilitation of old buildings brought serious problems. The mechanical (and chemical) properties of cement make it incompatible

with lime mortars, not only because of its great rigidity, but also because it gives rise to the appearance of soluble salts on the surface of the renders, thanks to the infiltration of water by capillarity.

Lime knew a wide application, also, in the decorative arts, through mixtures of diverse nature. In the Alentejo region the millenarian use of lime allowed the implementation and development of techniques such as mural painting, sgraffito or stuccoes in embossing. To the set of these techniques the designation of "lime arts" has already been applied, precisely because they use lime as their main constituent material.



07. Detail of building wedge with sgraffito. Rua 5 de Outubro street (Évora). Patrícia Monteiro.

08. Detail of mural painting. São Bento de Cástris Convent (Évora). Patrícia Monteiro.

vocabulary

Sgraffito

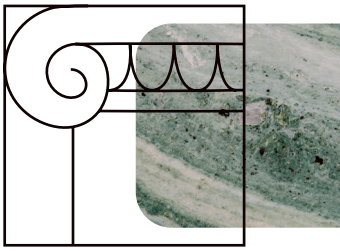
Sgraffito is an ornamental technique that dates back to Classical Antiquity.

It consists of superimposing two layers of plaster, each with a distinct colour (white, ochre, grey or red). The design is defined on the upper plaster layer and then, with the help of a pointed object, some areas are removed, leaving the colour of the lower plaster visible. The contrast of colours has a great decorative effect, which is why sgraffito is often found in the decoration of building façades.

Among the most original decorative solutions in the Alentejo that make use of lime, the stuccos imitating marble must be highlighted, a curious practice since both the material to imitate (marble) and the one used in the imitation (lime) share, in their essence, the same chemical composition.

The success of the use of lime in Alentejo is, therefore, due to the abundance of limestone rocks that, after being extracted from quarries, went through a process of burning and transformation resulting in a resource widely used in different contexts.

09. Detail of stucco frame on a façade in Portalegre. The stucco is covered with ochre paint; however, it was intended to create the effect of imitating marble (above, centre).



Technical objects
from marble extraction

The singular beauty of marble often arouses the public's admiration during visits to monuments where this ornamental stone has been applied, followed by a series of questions about the ways in which it was placed there and how the work was done to extract the marble from the inside of the earth.
The exploitation of marble is old, known since the Roman period and the way it was worked

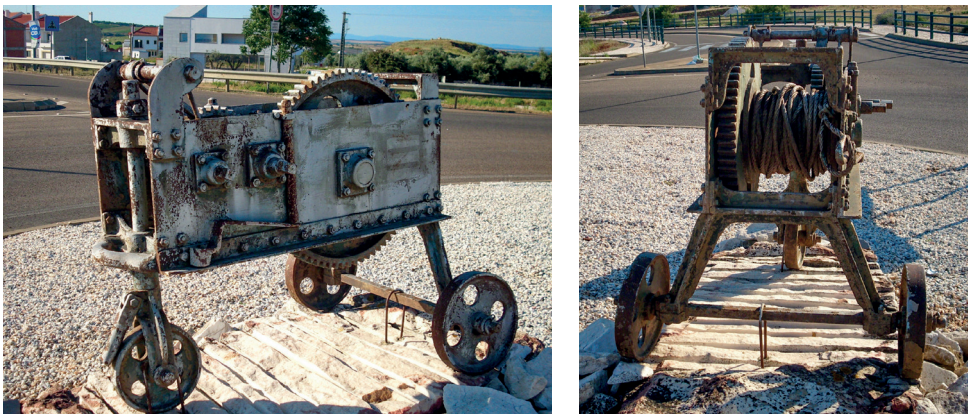
in the quarry changed little until the beginning of the 20th century in terms of tools and the process of getting the stone out.

10. Old quarry at Cerca de Santo António (Estremoz), 1901. C.M. Estremoz | CECHAP | PHIM.

The human strength of the workers and the help of animals were used, that is, these men who worked in the quarries, called cabouqueiros (hewers of stone), would remove the marble using hand tools. They placed metal scopes and wedges in the natural fractures of the stone and, hitting them with large hammers, they forced these veins to open up separating the pieces of marble from each other.

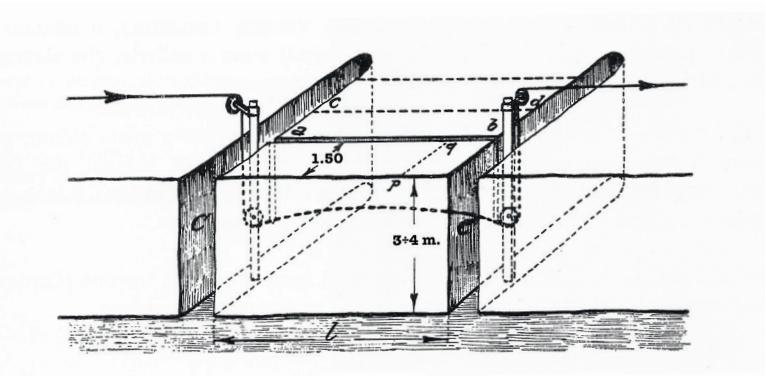
11. Quarry in the Borba municipality, c. 1950. Espalha Brasas Restaurant | CECHAP | PHIM.

It was very difficult and slow work, which required a lot of strength, as today's machines did not exist. It took much longer, even days to be able to pull pieces of marble out of the quarry due to their weight. Therefore, the pieces of marble were also smaller, being transported by carts pulled by several oxen. Each quarry needed many dozens of workers.

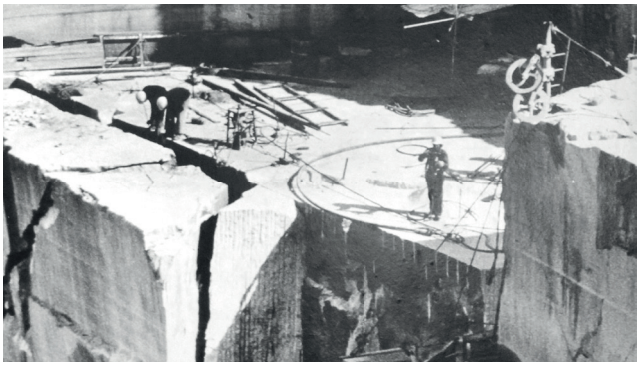


12. Manual Winch, 1920›s /1930›s | CECHAP | PHIM.

From the 20th century onwards, primitive machines were evolving and changing due to the industrial evolution of the last two hundred years. When marble became more sought after and sold more, its exploitation had to be more intense and modern machines had to be installed in order to be able to extract a greater quantity of marble in less time.



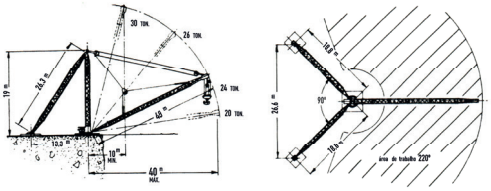
13. Diagram explanation of the helical wire, Marmi d›Italia, 1960 | CECHAP | PHIM.



14. Quarry of Vila Viçosa, Extraction using helical wire, 1960s | CECHAP | PHIM.

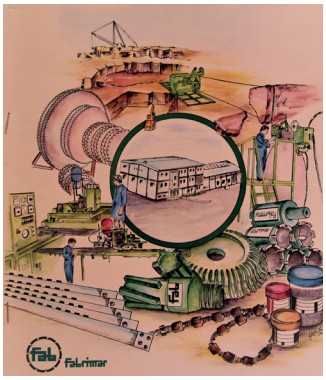
Firstly, hammers and chisels were replaced by pneumatic hammers using compressed air, which allowed deeper and faster drilling. Secondly, the way of pulling out the marble changed: the natural fractures of the stone were no longer used in order to cut the marble geometrically into block shapes. This was done using the helical wire, which was a steel cable that passed around the quarry and entered the holes made in the marble, cutting a larger block of marble. Thirdly, the removal of the marble from the quarry was done using small vehicles, first steam-powered and then diesel-powered, which were later replaced by trucks. More recently, with the arrival of electricity, large cranes were used, which can be seen in the quarries, and the helical wire was replaced by a synthetic diamond wire, which cuts the marble from a machine with rails placed next to the block to be cut and no longer around the quarry. As can be seen, the machines and tools used to extract the marble today are representative of this industry's technological evolution.

15. Motorized Winch «Crapaud», 1950/1960s | CECHAP | PHIM.



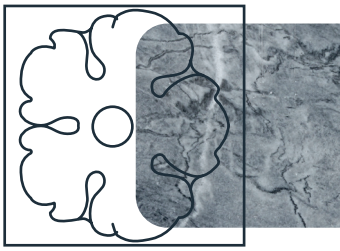
16. Derrick Cranes, marble quarry in the region of Extremoz and Vila Viçosa| CECHAP | PHIM

17. Catalogue of Firma Pirra, 1980. | CECHAP | PHIM.



18. Diamond wire cutting machine, 1990›s model. Catalogue Fabrimar | CECHAP | PHIM.

19. Marble quarry in Vila Viçosa, 2021 | CECHAP | PHIM.

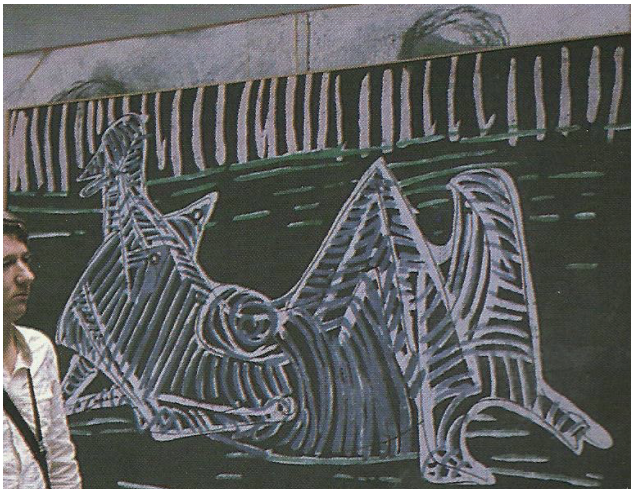


Atelier
the making of a marble sculpture

Sculpture is a plastic art that materialises in three-dimensional forms in space, in a game of volumes and hollows, full and empty, using several techniques and instruments that vary according to the raw material. In the case of stone, we speak of sculpting or progressively carving the material until the desired shapes are obtained.

The white marble, with a medium consistency and crystalline structure, imposed itself from the Classical Antiquity, becoming one of the preferred stones of the sculptors for being compact

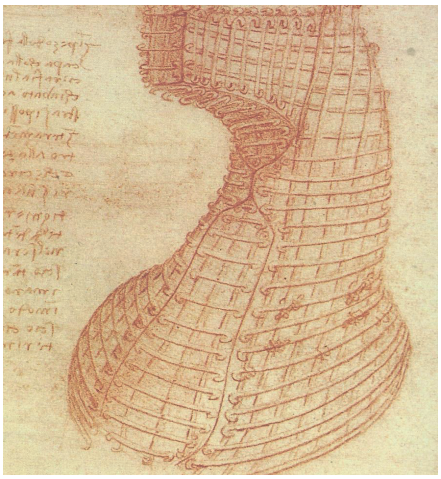
and homogeneous, not flaking or cracking easily under the blows of the instruments, and for its uniform colour with slight transparency, enhancing the light/shadow game and being able to take the appearance of several textures.
The first stage in the execution of a sculpture is its idealisation, followed by the respective drawing - project or study - indicating the real measurements of the piece.



20. Sculpture project by Henry Moore. https://stringfixer.com/pt/Henry_Moore

21. Model in clay and plaster of sculpture by Henry Moore.. https://stringfixer.com/pt/Henry_Moore

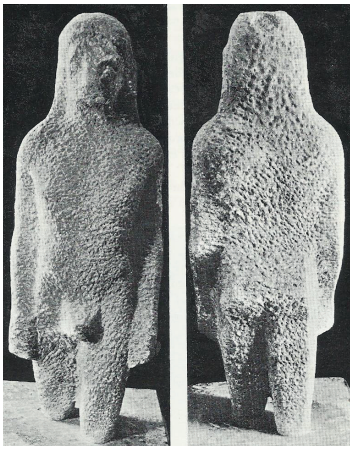
From the project, the artist can carve the stone block immediately, executing the so-called direct attack technique, or make one or more models in clay, plaster or wax on a wood and wire frame - soul or skeleton - reproducing the figure in three dimensions in a material that allows him to rectify and modify the project in a creative and practical way.



22. Leonardo da Vinci. Frame of a horse head sculpture model. National Library of Madrid.

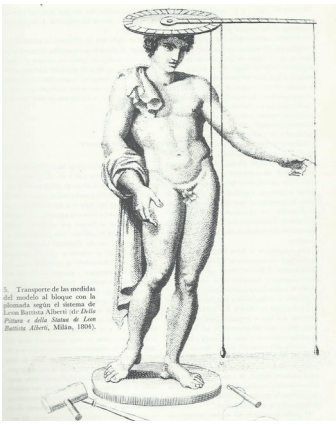
Once the model is made, it must be placed on the marble block, that is, it must be transformed into a sculpture, mechanically translating a plastic idea into another material, which implies carrying out the transportation of the measurements from the clay model to the stone.

The oldest method is called spot-taking, used in Greece since the 6th century BC, where the model was placed inside a box with the same size as the block, made of wooden slats that formed a grid on each side, which was repeated in the stone. Spikes were then inserted through the squares of the box until they reached various points on the model, marking its profiles and volumes. The length of the spikes and their location on the grid were marked on the block with dots, and these were then perforated with a punch or trepan, according to the measurements obtained. Finally, the sculpture was started, by grinding the stone until the end of the hole was reached. Unfinished sculptures bear witness to this process.

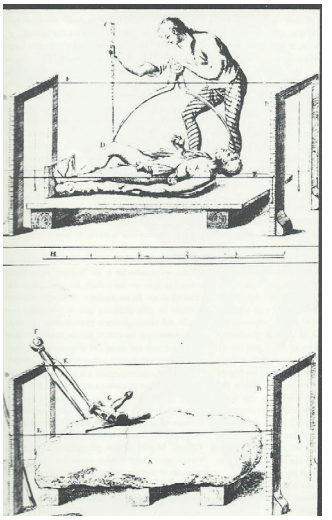


23. Unfinished torso, Naxos, Greece, 6th century B.C. WittKower, Rudolf. La escultura. Processos y principios. Madrid: Alianza Editorial, 2018, p. 22.

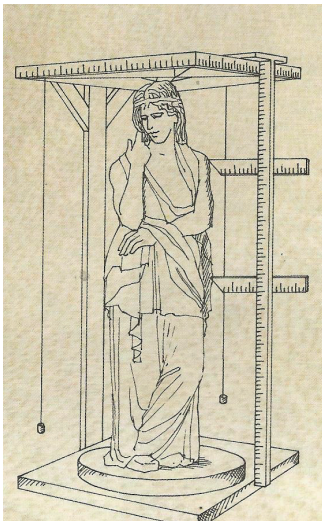
Plumb lines were also used to measure the distances to the protruding and reentrant ends of the model, and then holes were drilled in the block according to the measurements. These techniques were recovered in the Renaissance, appearing in artistic treatises.
Leonardo da Vinci made use of the classical method of point-taking, which has since been improved. In the 15th century, Leo Baptista Alberti presented an instrument called exempeda, which consisted of a modular ruler for measuring lengths and a pair of mobile squares for diameters. For the profiles, he invented the definitor, a graduated horizontal disc, which was fixed at the highest point of the model and had a graduated rotating arm from which plumb lines were hung to take the extreme measurements of the model using a system of coordinates. The stone block was then drilled following these measurements.

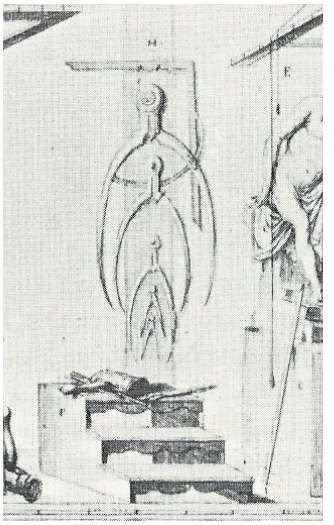


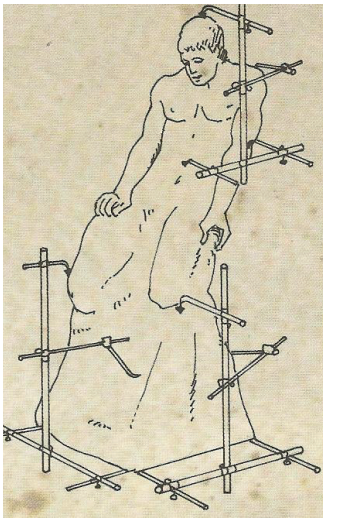
24. Definitor. Alberti, Leon Batista . *Della Pintua e della Statua. Milan*: Tipografia de Classici Italiani, 1804.



25. Vasaris Device . Francesco Carradori. *Intruzione elementare per gli studiosi della scultura.* Italian, Pistoia, Pisa, 1802.





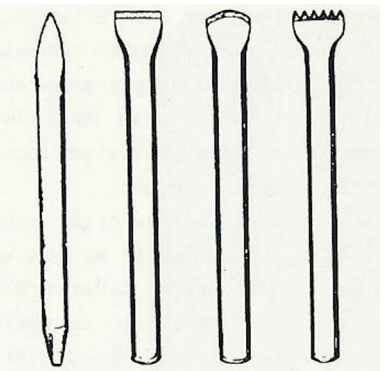


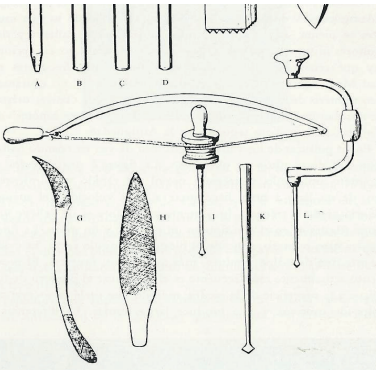
26. Baroque frame. Francesco Carradori. *op. cit.* *27.* Three-compass machine. Francesco Carradori. *op. cit.*
28. Gatheaux' crosshead. Jack C. Rich. *The Materials and methods of Sculpture.* New York. Dover Publications Inc., 1967.

In 1822, the manufacturers Durand and Girard presented the French Academy with a machine with three compasses that made it possible to transpose measurements more quickly and faithfully. Still in the 19th century, Gatheaux invented the crosshead, made up of iron bars with spikes, which are fixed at certain points on the model, and articulated arms with points which slide in any direction to obtain all the other necessary measurements, taking a very high number of points. This instrument proved to be the most effective and is still used today by sculptors.

Once the measurements have been taken, the mechanical execution of the sculpture begins, carried out in successive phases. First the stone is roughened, removing small splinters little by little, and only then the progressive carving takes place, in layers, to avoid irreparable mistakes.

Since ancient times, pointers and chisels of various shapes and sizes have been used to carve stone, which are struck with iron mallets, in order to remove larger or smaller pieces of the blocks and to obtain various effects. The perforations and very dug and hollow reliefs are obtained with the use of drills and core drills (manual drills) and, nowadays, making use of electric instruments.





29. Tools of the stonemason: pointer, flat chisel, head chisel, toothed chisel.
WittKower, Rudolf. *La escultura. Processos y princípios. Madrid*: Alianza Editorial, 2018, p. 19.

30. Construction site tools: chisel, hand borer, drill, hand drill.
WittKower, Rudolf. *op. cit.*

The last phase is that of touching up and treating the surface, giving texture or polishing with fine chisels, files and natural (sand and pumice stone), artificial (acids) or mechanical (grinders, sharpeners and polishers) abrasives. Another finishing was the gánosis - a wax-based coating applied on marble, accentuating the transparency and brightness of the material.

Since antiquity there are also records of the practice of colouring stone sculptures. The marbles of the Parthenon were covered with a thin layer of lime and painted in soft colours. But it was the unpainted white marble sculpture which became dominant in the Classical period, a taste which reappeared in the Renaissance and has lasted until the present day.

31. Pope Pius XII, marble statue by the sculptor Soares Branco. Fatima Sanctuary | CECHAP | PHIM.

Marble
Heritage - medieval Period

Urban portals

In the historical centres of some Alentejo towns, such as Estremoz, Évora, Évora Monte and Vila Viçosa, there are a number of medieval remains that show the use of marble in an urban context in a continuous and coherent way. They are mostly **portals** with a medieval structure and decoration.

The **urban centre of Estremoz** stands out for the diversity and quality of these remains. These are door and window frames which may present different shapes: broken arches, straight lintels and chamfered angles or quatrefoiled lintels. Taking into account these different structures, and their decoration, we can see that these houses were built between the 14th

century and the first decades of the 16th century.
These houses, located either inside the castle walls or outside, are one or two-storey buildings of simple architecture.

In the so-called **old town of Vila Viçosa**, inside the castle, there are some houses that also have medieval marble vestiges. Rua de Estremoz street stands out, with one-storey buildings of simple construction, built between the 14th and 15th centuries. These houses preserve marble elements, such as door frames in broken arches.





32. Houses with broken arched doors, Estremoz, Alcáçova | CECHAP | PHIM. *33.* Houses with quadrangle arched doors and arch segments, Estremoz, Alcáçova | CECHAP | PHIM. *34.* House with epigraphic (gothic) door, Estremoz, Alcáçova | CECHAP | PHIM. *35.* Houses with brokenarched doors, Vila Viçosa, Alcáçova | CECHAP | PHIM. *36.* Door of the Church of São Tiago, Vila Viçosa | CECHAP | PHIM.

Pillories

In the geography of the Marble Anticline, and throughout Alentejo, there are several **pillories** totally or partially built in marble: Alvalade, Arraiolos, Avis, Azaruja, Cabeção, Campo Maior, Cano, Elvas, Estremoz, Fronteira, Messejana, Monsaraz, Moura, Sousel, Terena, Veiros, Vila Viçosa. The pillories are symbols of municipal power and freedom and of the exercise of justice.
These structures evolved from simple columns, in some cases made of wood, to more elaborate and durable structures, following various shapes, the main ones being: rattle, pinecone, ball and cage. Mostly they are made up of a platform composed of steps, base, shaft and capping.

The **pillory of Estremoz** was moved from its original location, inside the castle, in the late 17th century and dismantled in the 19th century. Part of the pieces that made it up were used in its reconstruction, which took place in the 20th century. This pillory was classified as a National Monument in 1920. It was made of white marble and was classified as a pinecone pillory.







37. Pillory, Estremoz | CECHAP | PHIM. *38.* Pillory, Aviz | CECHAP | PHIM. *39.* Pillory, Terena (Alandroal) | CECHAP | PHIM. *40.* Pillory, Veiros | CECHAP | PHIM. *41.* Pillory, Fronteira | CECHAP | PHIM. *42.* Pillory, Vila Viçosa | CECHAP | PHIM. *43.* Pillory, Arraiolos | CECHAP | PHIM.

Town hall of the municipality of Estremoz

The **Town Hall of Estremoz** was housed in a building, initially built in the 14th century, but later remodelled. It consists of three bodies: the council porch, the clock tower and the council hall. The meetings of the councilors were held in this building; it also served as a court and jail.

The facade of the audience house and the council porch were built in marble stone; the structure of the building elements and the decorative themes are Gothic.
On one of the abacuses of the main entrance portal lies an inscription that identifies one of the builders of the building: "ANTON ME FES".

44. Town Hall House, galley, Estremoz | CECHAP | PHIM.

Donjon of the Castle of Estremoz

The **donjon of Estremoz castle** was built in marble and is next to the town hall, both located inside the castle walls. This military construction was completed in 1370 and was an innovative defensive structure about 27 metres high, square in plan and on three storeys.

45. Donjon, Estremoz | CECHAP | PHIM.

Other military buildings, such as the castles of Borba (XIII-XIV centuries), Veiros (XIV century) and Vila Viçosa (XIII-XIV centuries), also used marble in parts of their construction, such as door frames and marble blocks in the walls.

The **chapel of Nossa Senhora dos Mártires**, located on the outskirts of Estremoz, is a Gothic religious building that uses marble in its construction. The work began around 1371 and was sponsored by D. Nuno Álvares Pereira, Lord of the town of Estremoz. The building has a strong influence of mendicant architecture and was reformulated in the 17th and 18th centuries.

46. Chapel of Nossa Senhora dos Mártires, Estremoz | CECHAP | PHIM.

The main façade, the south side portal, the external buttresses, the triumphal arch, the headboard (vestments and vault), the arch and the balustrade of the high choir (already from the 16th century) were built in marble.

The **Nossa Senhora dos Mártires Hospital** was founded in 1370 and was run by a brotherhood of the same name. The original building has been successively altered, with only a staircase and a small cloister with marble elements from the beginning of the 16th century remaining.

The cloister consists of two sections of arcade supported by double columns, the shaft of these columns being made of white marble. The original structure of this cloister was altered by the construction of the hospital entrance. In the old hospitals, the cloister was an important space; it could have cisterns and wells that supplied the building with water, served as a place of distraction for the sick, as a burial area or as an area for growing medicinal plants.

Marble
in 17th and 18th - century architecture

Marble was the material par excellence used in the Modern Age architecture in Europe, but also one of the raw materials chosen in the context of the architectonic finishings of the 17th and 18th centuries in Portugal, due to its resistance, durability and plastic qualities.

The existence of this raw material in High Alentejo and part of Central Alentejo allowed rapid extraction on Portuguese soil and subsequent application in the three major segments of architecture: religious, civil and military.

This ornamental stone, being a "noble" material and artistically appealing, was applied in exterior and interior cladding, and, in the latter, in details of a sculptural nature, such as columns, wedges, mouldings, staves, capitals, corbels and portals.

Both the application of marble on slabs in architecture and its use in high-relief sculptural pieces in the same spaces was, *broadly speaking*, designed by architects and other artists qualified to design.

The same solutions were also executed by bricklayers and masons, who progressed from apprentices to masters. These craftsmen learned their trade from their families, through oral transmission of knowledge, and by practising their trade on building sites.

47. Façade of the Ducal Palace of Vila Viçosa. CECHAP | PHIM

48. Façade of the Charterhouse of Évora. Late 16th century. CECHAP | PHIM

49. Façade of the chapel of Senhor Jesus dos Aflitos, Borba. C. 1679. CECHAP | PHIM

Religious architecture, which included in the façades of churches, monasteries and convents, under the influence of the artistic trends that prevailed in the Modern Age, decoration in monochrome, bi- or trichrome and ornamentation of portals and windows, was one of the areas favoured with this ornamental stone.

The inclusion of sculptures of a perfect figure in this material in niches, which livened up façades and made it possible to recognise its patron saint, was another way of enhancing the use of this endogenous resource.

50. Façade and portal of the church of São João Baptista de Campo Maior. CECHAP | PHIM

51. Church of the Congregates Estremoz. CECHAP | PHIM

In religious interiors, marble was the material of choice for flooring and equipment, such as altarpieces, washbasins, pulpits, baptismal fonts and webs or chancels.

The altarpieces, situated in spaces such as the main chapel of the temple, the transept or transept and the naves, were an expression of their commissioners' taste, as well as

of their ability to commission works with current figurines. The application of marble in Portuguese altarpiece works knew a greater increment in the beginning of the 18th century, rivalling with the golden carving, strongly implanted in national territory.

It was, therefore, from the second half of the 18th century that the stone retable structures experienced great exuberance, but also a greater artistic quality.

Although formally integrated in models of a classical nature, they stood out for their use of an Italianate decorative language, resulting from the influence of engravings from that region of Europe, but also for the chromatic diversity of the marbles of the Anticline of Estremoz.

learn more

Marble altars or altarpieces are structures whose main function is that of worship and religious celebration, and in Portugal, in the 17th and 18th centuries, they were also made of other materials. The marble examples are, in their majority, constituted, in the lower part or base, by an altar table, with a frontal, tabernacle and stool, and, in the upper part or body, by a tribune or dressing room, with or without a throne for exposition of the Blessed Sacrament. These devotional structures are topped by an entablature and an attic, which can present various morphologies.

vocabulary

Washbasins
Pieces integrated in the sacristy walls, which were used for the ablution rite for priests. These pieces of equipment are composed of a basin and backrest and conceal a reservoir inside.

52. Church of Nossa Senhora das Neves de Borba Washbasin. 18th century. CECHAP | PHIM

vocabulary

Weaves (*teias*) or barriers (*cancelos*)

Objects that delimit spaces, generally religious, composed of balustrades of one or more morphologies. These sets may be in marble or in wood, like marble acroteria.

53. Weave of the church of Nossa Senhora da Expectação in Campo Maior. CECHAP | PHIM

Since the 17th century, the same branch of architecture has also included the Way of the Cross or the Passages of Christ, in the form of chapels, with original structural solutions but, above all, which took great advantage of the use of this material and its sculptural component.

This use of marble showed affinities with that of the Joanine altarpieces, irrespective of whether they were made of carved and polychrome wood or of stone materials, but also with portals and gates of printed works, inexhaustible sources of compositional and ornamental repertoires.

54. Passage of Christ or Way of the Cross. Elvas. CECHAP | PHIM

55. Passage of Christ or Way of the Cross. Borba. 18th century. CECHAP | PHIM

With regard to the use made of the various existing chromatic options, it should be noted that one of the trends in religious architecture was that of marble inlays.

By combining Portuguese marbles and limestones with marbles from other sources, with different colours, these decorative works distributed, in some cases, the marbles in a geometric way, and, in other situations, in compositions of an ornamental nature, by joining several fragments of distinct marbles, simply enhancing the different polychromes and simulating "stone paintings".

This art prevailed in Portugal, through the influence of the art produced in the Italian Peninsula, stimulating sets and conveying compositions that were transversal to otherartistic manifestations.

learn more

The inlays of polychromatic stonework were a decorative technique, used on paving and wall surfaces, which combined various stone materials, such as limestone and marble. The stonework inlaid in Portugal in the 17th and 18th centuries was the direct inheritor of a Roman technique, which was recovered in the Italian Peninsula during the Modern Period and arrived in Portugal through multiple cultural contacts. This decorative resource took advantage of the different polychromes of these materials, creating particularly dynamic and appealing effects.

historical testimony

[...] were now contracted and agreed with the said masters José de Oliveira and Miguel Pinheiro to make the altarpiece of the main chapel of Nossa Senhora da Conceição of the same church of inlaid stone and masonry, all in the form of the plan that was to be given to them, which came from Lisbon [...].

[...] the said masters are obliged to make all the inlays with fire bitumen, made in the best possible way, and only black, yellow and red Lisbon stone shall enter these inlays; and the white stone shall be the best that there is and that is usually taken in this town and its surroundings [...]".

Modernised excerpt from the contract for the making of a stonework altarpiece, between the masonry workers José de Oliveira and Miguel Pinheiro and the brotherhood of the Slaves of Nossa Senhora da Conceição de Vila Viçosa, for the church of the Immaculate Conception of this town. Évora County Archive, Cartório Notarial de Vila Viçosa, L. º 182, fols. 99 v.º–101 v.º.

Civil architecture, in turn, integrated pilasters, wedges, portals, mouldings and staves in marble, which strongly enlivened the facades of palaces and other types of housing in the

sixteenth and eighteenth centuries, consecrating their use in interiors to floors, staircases and cookers.

In the context of civil architecture, marble also gave life to garden equipment, such as portals and other elements that delimit spaces, replicating ephemeral figurines and showing the plastic potential of the supports, through the abundant sculptural load that they integrated.

56. Stairs to the Borba Council Chambers. 18th century. CECHAP | PHIM

57. Portal from the Carmo Manor/D. Maria. Estremoz. CECHAP | PHIM

58. Portal from the D. Maria Manor. Estremoz. 18th century. CECHAP | PHIM

59. Portal from the Barahona Palace. 18th century. Évora. It comes from the Espinheiro Convent and is an example of integrated marble heritage. Maria João Pereira Coutinho

Military architecture, particularly that built in the context of the Restoration wars, and in the following moments, resorted to the use of marble in specific and excellent situations, as happened with the doors of the walls, sacralised with various patron saints, and portals belonging to other defensive equipment. These projects mimicked compositional and plastic schemes of European military treaties, adapted to the materials and the Portuguese construction practice, which gave each of these examples a unique character.

60. Farmstead Portal of Estremoz.. CECHAP | PHIM

suggestions for visits to the Alentejo

Religious architecture: Nossa Senhora da Expectação Church in Campo Maior; Congregados Church in Estremoz; Senhor Jesus dos Aflitos Chapel in Borba; Via Sacra Steps in Borba, Elvas and Vila Viçosa.

Civil architecture: Ducal Palace of Vila Viçosa; Town Hall of Borba; Carmo Manor of Estremoz; Palace of the Marqueses of Praia and Monforte (Antigo Solar dos Albergaria) of Estremoz; Palace of the Morgados Cardosos of Borba.

Military architecture: Elvas's fortress square; Elvas's train barracks; Elvas's Graça Fort; Estremoz's wall gates.

In the 17th and 18th centuries, Portuguese marble was also exported to Brazil and Africa by the religious orders, which carved their churches, monasteries and convents, and decorated them with altarpieces, pulpits, washbasins and baptismal fonts.

In these cases, the marbles were extracted and worked in Portugal and then packed and shipped to those places. These pieces were also accompanied by a stonemason, who, after the order arrived at its destination, was responsible for placing these objects in the places for which they had been designed.

Nineteenth and twentieth *centuries*

During the 19th and 20th centuries, the marbles of the Anticlinal de Estremoz continued to play an important role in both architecture and sculpture, and their presence, more or less evident, was frequent in the places where we lived or frequented.
Due to their aesthetic characteristics, quality, durability, versatility and even the prestige that they have acquired over time, building owners, architects and sculptors have found these ornamental stones, alone or together with others, to possess the appropriate material to dignify and confer monumentality to their works. Thus, they provided greater chromatic richness to their works.

Associated with an idea of quality and even luxury, the marbles of Estremoz were used in architecture, both in public buildings and in prominent private buildings. We find them in selected applications (window and door openings, handrails, etc.), in prominent areas (wall coverings, pillars or columns, decorative details, etc.) or in areas with a high level of traffic (floors, staircases, etc.), where they ensured good hygiene solutions, as they were easy to clean, and good conservation due to their resistance.

In the 20th century, the technological development of the marble industry, namely the new cutting methods (helicoidal wire), lifting (diesel vehicles with steel cables) and transport (tractors, trucks and railways), allowed a greater and easier availability of these materials. These circumstances enabled them to be used not only in Portugal, but also abroad through increased exports, facilitated by the development of transport and road networks.

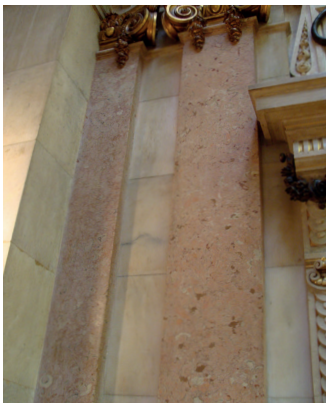
Examples are the intervention of the architect Pierre-Louis Carlier in Notre Dame de la Treille Cathedral (Lille, France), inaugurated in 1999, or the Novartis Campus - Virchow 6 Buildings (Basel, Switzerland), work of the Portuguese architect Álvaro Siza Vieira and inaugurated in 2011.

Thus, despite the emergence of new building materials provided by industrial development, such as reinforced concrete, ornamental stones, among which the Estremoz marbles, have never ceased to be fashionable, often being combined with them in architectural solutions marked by a greater or lesser modernity, as in the examples presented below, following an increasing chronological sequence. These are some important buildings constructed in our country, with projects of recognised authorship, and whose selection was based on two criteria: the knowledge acquired through the research carried out and the expressive use of the Alentejo marbles.

In the late 19th and early 20th centuries, marble from Estremoz was used by the architect Miguel Ventura Terra (1866-1919) in the reconstruction and monumentalisation of the Palácio das Cortes, current Parliament building. Contrary to the budgetary restrictions imposed by the economic and financial crisis the country was going through, the architect would not dispense with this costly material in some architectural and decorative elements. In the Passos Perdidos Room and the Sessions Room, it was used in some walls, column capitals and pilasters, combined with ornamental rocks from the Sintra region - Pêro Pinheiro.

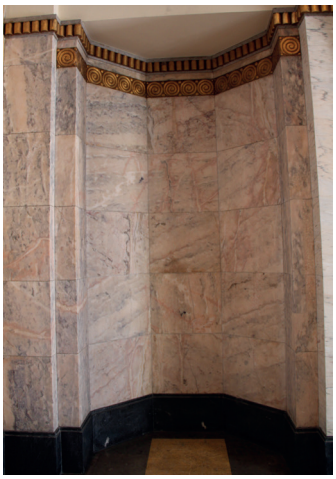
61. Parliament, Lisbon | ÍNDICE

62. Session Room, pilaster capitals in Estremoz marble | RMR



63. e 64. Passos Perdidos, details of the use of Estremoz and Encarnadão marble | RMS/CMS
65. Session Room | CMS

In 1924-25 Porfírio Pardal Monteiro (1897-1957) designed the Caixa Geral de Depósitos building at the Avenida dos Aliados Avenue, in Porto. In its interior, where *Art Deco* dominates, the architect made expressive use of Estremoz marble, in walls and floors in the lobby and *hall*, combining it with other ornamental stones, such as granite, common in the north of the country, and limestone from the Pêro Pinheiro region. *Ruivina* marbles of various shades (from light grey to black) and white/creamy very veined (visible and contrasting veins), conferred solidity, nobility and uniqueness to the interior of the banking institution, now Culturgest Porto.

66. Caixa Geral de Depósitos, current Culturgest, Porto | CECHAP | PHIM
67. Vestibule walls (access to the hall) | CECHAP | PHIM

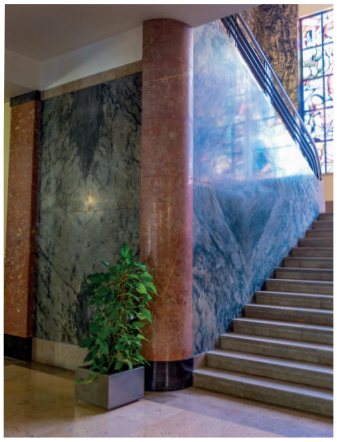
68. Vestibule floor | CECHAP | PHIM

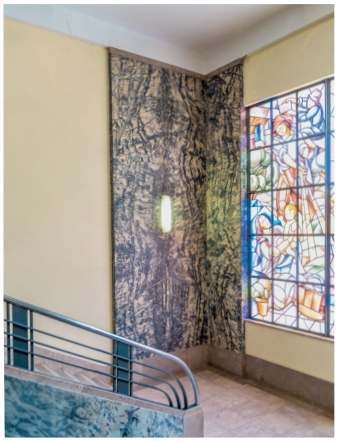
69. Floor detail of the hall | CECHAP | PHIM

The South and Southeast Boat Station (1928-1932), next to Terreiro do Paço, in Lisbon, is a work by the architect Cottinelli Telmo (1897-1948). A statement of modernity, it is a public facility, in a *Deco* style, where he used reinforced and cast concrete and large glass surfaces. Inside, in the passenger lobby, a large room with high ceilings, marble stands out: the various pillars and pilasters that pace the space are clad in *ruivina* and "tiger skin", while the lower part of the high walls have a white Estremoz finishing. Solid, durable and easy to clean materials that ennobled the space. It is believed to have been included in the project due to the engineer from the Directorate-General of Railways, Raul Couvreur (1879-1959), an alteration that Cottinelli Telmo would approve.

70. South and Southwest Boat Station, Lisbon | ÍNDICE

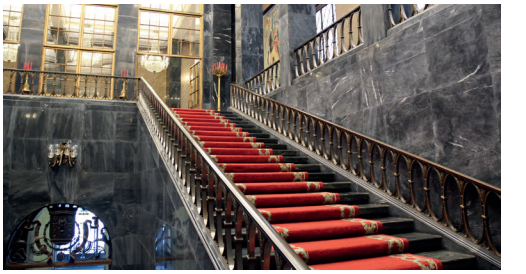
At the Statistics Portugal Institute (INE) in Lisbon, a project by architect Porfírio Pardal Monteiro, executed in the first half of the 1930s, where *Art Deco* is still very much in evidence, the ornamental stone was adapted to the new materials and new construction methods. The aim was durability, monumentality and low maintenance. Here it is possible to find the marble "tiger skin", in the pillars of the entrance hall, in the staircases and wall panels, namely, in a striking way, next to the big stained-glass window by Abel Manta.

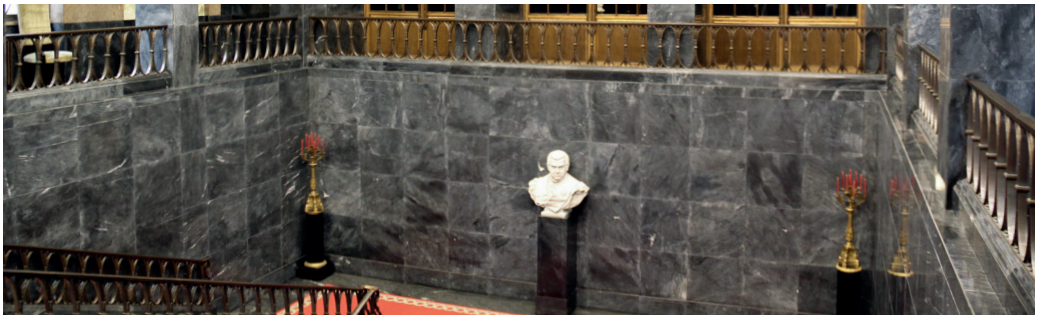




71. INE, main building façade, Lisbon | ÍNDICE *72.* Use of ornamental rocks, among which «tiger skin» marble | ÍNDICE *73.* «Tiger skin» marble flanking the stained glass window by Abel Manta | ÍNDICE

In Porto, the Paços do Concelho building (1916-1957) stands out for the significant use of Anticlinal marble, especially *Ruivina*, in the imposing staircase and Great Hall, as well as in the Session Room. The use of ornamental stone is due to the professional relationship between the architect Carlos Chambers Ramos, who coordinated the work from 1950 onwards, and the Calipolian stonemason-sculptor Bonfilho Augusto Faria.





74. City Hall, main façade, Porto | CECHAP | PHIM

75. Staircase, dark reddish on the pavement and remaining elements | CECHAP | PHIM

76. Noble Hall (Passos Perdidos), use of red and black Mem Martins marble | CECHAP | PHIM

77. Staircase, dark *ruivina* in the pavement and remaining elements | CECHAP | PHIM

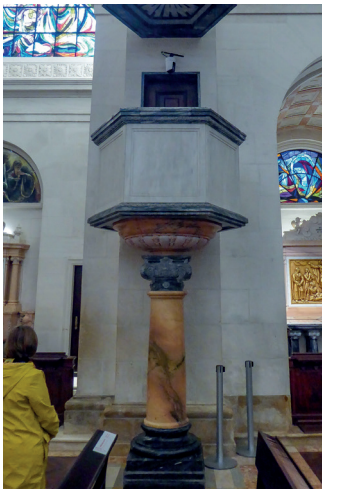
The application, selected, of marble from Estremoz is something usual and that we will find in the Sanctuary of Santa Luzia and the Sagrado Coração de Jesus, in Viana do Castelo, a project by the architect Ventura Terra, executed between 1926 and 1959, in a neo-Romantic revival. Although it is the local stone - granite - that prevails there, the marble from Vila Viçosa was used in relevant pieces: in the image of the Sacred Heart of Jesus (Martinho de Brito's reproduction of Aleixo Queiroz Ribeiro's work for the exterior) and in the two angels flanking it (by Leopoldo de Almeida, executed by Emídio de Lima), of the high altar.

78. Santa Luzia Sanctuary, exterior, Viana do Castelo | CMS

79. Main altar, marble sculpture group from Vila Viçosa | CMS

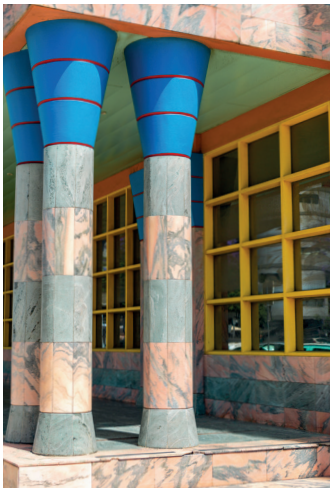
In the Nossa Senhora do Rosário de Fátima Basilica (1928-1953) and the adjoining colonnade, we find an expressive use of Estremoz marbles, applied in the architecture and sculpture. Apart from predominating in the statues of saints found inside the temple and topping the colonnade (by the most diverse and renowned sculptors, such as Leopoldo de Almeida, Álvaro de Brée, António Duarte, Domingos Soares Branco, Amélia Carvalheira among others), are also present in some pavements and in prominent elements such as the side altars, the pulpits, the high altar, or the striking sculptural ensemble crowning the chancel altarpiece (Maximiano Alves and Stella de Albuquerque, 1953).

The Estremoz marbles (*ruivinas*, rose-coloured, white-coloured and cream-coloured) with different finishes (honed, burnished or polished) stand out in the Basilica, especially in elements with symbolic andreligious value, complementing the regional limestones and the Sintra - Pêro Pinheiro limestones. Its introduction was due, in particular, to the architect João Antunes (1897- 1989), responsible for the construction between 1933 and 1951.



80. Basilica of Our Lady of the Rosary, exterior, Fátima | RMR *81.* One of the side altars - combination of several marbles from the Estremoz Anticline | Noel Moreira *82.* Pulpit | RMR *83.* Pulpit, detail; marbles of various colours, with different finishes | RMR *84.* Main altar | RMR *85.* The ensemble crowning the altarpiece | RMR

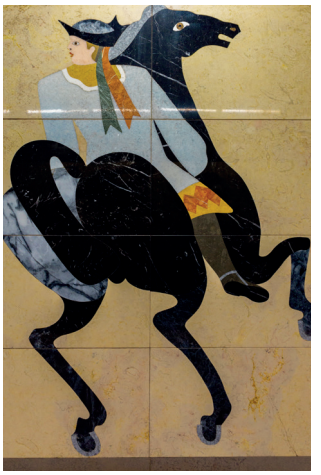
In the last decades of the 20th century, the marble from Estremoz continued to make its mark in high-profile works, particularly in Lisbon. In the 1980s, both in the Amoreiras Complex and in the building of the former headquarters of the Banco Nacional Ultramarino (now the Social Security Institute), by the architect Tomás Taveira (b. 1938), Anticline's Rose-coloured and *Ruivinas* stand out, which he combines, in its post-modern style, geometric and coloured elements and mirrored surfaces.



86. Former Banco Nacional Ultramarino (National Overseas Bank), exterior, Lisbon | ÍNDICE

87. Façade, Estremoz Anticline marble | ÍNDICE

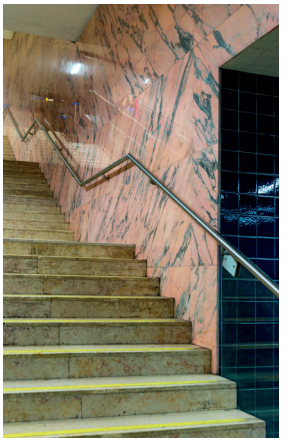
The remodelling or construction of Lisbon Underground stations, especially in the 1990s, brought the ornamental stones, among them the Estremoz marbles, even closer to the population, in a trend that continued in the first decade of the 21st century, namely in terms of cladding. For their special use of the Anticlinal stone material, the stations of Campo Pequeno and Saldanha stand out. In Campo Pequeno station, remodelled in 1994, the visual animation (sculptures and panels) was done by the sculptor Francisco Simões (b. 1946), combining the most varied ornamental rocks, among which the pink from Vila Viçosa and the Ruivina from Estremoz.



88. Campo Pequeno Metro Station, allusive panel to the Festa Brava, Lisbon | ÍNDICE

89. Campo Pequeno Metro Station, Women from Lisbon | ÍNDICE

At the Saldanha I station, refurbished in 2009, in addition to the multiple pink marble coverings that cohabit with tile panels, there is the work of the sculptor Jorge Vieira (b. 1922-1998) who, in order to represent "Man's work instruments" - the hands, arms and head (1996-97) - that occupy the walls of circulation areas, corridors and staircases, used pink marble from the Borba region.



90. Saldanha Metro Station, Man›s work tools, Lisbon | ÍNDICE

91. Saldanha Station, pink marble of Borba | ÍNDICE

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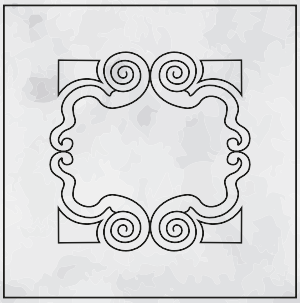

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