NATURAL STONE IN ARAGON (SPAIN)
1. WHAT IS NATURAL STONE?

Throughout history, human beings have made use of natural stone for their social and cultural manifestations. The greatest legacy we have received from our ancestors derives from their use of stone. It is through the use of natural stone that we have found out most of what we know about their way of life.

Cloister of San Juan de la Peña Monastery (Huesca).

Cross of Iñigo Arista in San Juan de la Peña (Huesca)
1.1. DEFINITION

The term natural stone includes all those stony products traditionally used by men in the construction industry, including those used in decoration and indoor flooring and walls. The applications of this material are manifold and, as is the case with other materials, new products and applications are continuously found.
However, natural rock is more than just a mere construction element to be used for a given work. It is a product that is full of symbolism, has excellent durability and great plastic beauty. This has been proven by stonework carried out by human beings throughout History.

Omphalos in Delphi, which represents the centre of the world

The Mora Slab, dolmen in Sierra de Guara
1.2. FEATURES AND PROPERTIES

The most relevant characteristics of natural rock are hardness, resistance to different stress types, composition, porosity, colour, and durability. The latter is perhaps the most important technological feature. There are numerous architectural remains where stone has been the only remaining material, which demonstrates its stability at real scale.

The best uses of natural stone require good knowledge of its properties, which are determined through testing. The European standards of these products establish the specific parameters to be determined in the laboratory, namely,

- Petrographic analysis to determine composition and structure.
- Resistance to bending stress.
- Resistance to compressive stress.
- Resistance to impacts.
- Slip resistance.
- Resistance to thermal changes.
- Frost resistance.
- Resistance to SO$_2$ (sulphur dioxide) pollution.

For natural stone to be used correctly, these and other complementary characteristics should be determined in a laboratory.

1.3. CLASSIFICATION

Natural stone may be classified according to the genetic classification of crustal rocks:

**Igneous Rocks**

**a) Plutonic rocks**

They are formed by slow cooling and consequent solidification of magmas inside the terrestrial crust. They are also called crystalline rocks because the slow
solidification process allows complete mineral matter crystallization. Among plutonic rocks, the most commonly used ones are acid rocks, above all granite, which is the basic constituent of continental plates, and syenite, also called pink quartz due to its high alkali feldspars (orthose) content.

**b) Volcanic Rocks**

The outcropping magma in volcanic complex has reached the surface and it undergoes rapid cooling, which hinders minerals crystallization. Basalt is probably the best-known rock among volcanic rocks. Its composition is the same as that of the Earth’s crust, although it is rare in continental zones.

**Sedimentary Rocks**

They originate as a result of the external geodynamic activity on the surface of the Earth’s crust. On the surface, rocks become weathered, disintegrate or decompose. Later on, different types of rocks generate in different environments due to diverse crystallization, sedimentation and burial processes. These rocks can be further classified into two main groups depending on the genetic process involved in their genesis, namely,

**a) Detrital Rocks**, which are generated by accumulation of more or less cohesive fragments of other rocks. In turn, they may be classified according to the size of the fragments. Sandstones are the most appreciated as natural stone due to their cohesion.

**b) Chemical rocks**, which are formed by mineral precipitation. Carbonates are the most frequently occurring and also the most used subgroup, i.e. limestone, mainly composed by microscopic calcite crystals (calcium carbonate), although other minerals may also occur, but far less frequently: silica, clays, iron and manganese oxides, organic matter... and other carbonates. Iron oxides confer interesting yellow, orange, red and black coloration. Meanwhile, organic matter confers black or grey colours. Fossils are very common and can be clearly observed in polished sections.

If dolomite (magnesium carbonate) content is high, the term dolomite rock is used. Depending on the content of either carbonate (calcium or magnesium carbonate), rocks will receive different names, such as dolomite rock, limestone or calcareous dolomite rock.

In industry, both sedimentary rocks, i.e. limestone and dolomite rock, may be called "marbles" due to their appearance once polished, although, as discussed below, marble is not a sedimentary but a metamorphic rock. The presence of fossils in rocks determines their sedimentary origin.

Tufas are limestones in whose genesis the photosynthetic activity of microorganisms and vegetables is involved. Carbonate material accumulates around them, thus preserving a high porosity which leads to a decrease in weight. Tufas have been widely used in popular architecture (for arches and vaults) as they can be easily worked, maintaining good consistency and compactness.

Evaporites are also a type of chemical rock, so called because they form in water masses that are subjected to intense or complete evaporation. Only rarely have these rocks had any interest as natural stone, but there exists an evaporite rock in the Ebro Valley that, due to its post-sedimentary evolution, displays characteristics that have turned it into a valued material. This rock is alabaster, to which a chapter will be dedicated. At a global scale, the most important extracting sites for this rock are located in Aragon.
Metamorphic Rocks

All types of rocks may be subjected to intense pressure and/or high temperatures, as a result of the activity of the Earth's crust. This gives rise to major transformations in texture, structure and atomic organization in minerals. Rocks that have undergone such transformations are called metamorphic rocks. This group includes a variety of lithologies, among which marble, quartzite, slate or serpentine stand out.

Marble is the metamorphic rock that is most important in mining. It is a carbonate rock that has undergone metamorphism due to the proximity of hot magma, thus presenting different mineralogical composition and texture with respect to the original rock. It is, together with alabaster, the most representative natural stone because it was used by the greatest masters of the Renaissance as a raw material for their sculptures.

Slate is used mainly for roofing, as an alternative to tiles, due to the development of schistosity planes that have resulted from pressure metamorphism. Slabs can thus be obtained, their usual thickness being 2-8mm.

Quartzites are mainly composed of quartz, which is a stable mineral in surface conditions. From the point of view of alterability, this confers the rock interesting characteristics. Its use as natural stone is scarce given its high hardness.

Serpentinite is another metamorphic rock with great ornamental interest. Its colour is green and may display various tonalities, from light to dark. It is formed by regional metamorphism of ultramafic magmatic rocks (peridotites). It is frequently used in emblematic spaces such as palaces and magnificent hotels, both in floor coverings and wall linings or skirting boards. It has also been called "green marble".
2 THE ROUTE OF NATURAL STONE

2.1. A LITTLE HISTORY

The history of natural stone runs parallel to the history of the human being. The oldest dwellings erected by humans that have managed to survive are made of stone. Sometimes they are crammed with messages and built with formidable slabs and support columns. Humans erected sarcophagi and large funeral works, such as the pyramids, with stone, which is an enduring and safe material. The sepulchre-rock partnership still stands today.

The first cobbled pavements, which were laid in order to meet the demands of new means of transport, were made of stone, which contributed to their dramatic development. The Roman roads are an example of this.

Also, important public works such as the aqueduct in Segovia - the most important one in the Roman world - were made out of stone. With 813m in length and 163 arches, it supports a channel carrying water from the Fuenfría Range to the Caserón Tower, from which water was supplied all over the city.

Humans used stone to build cathedrals as a symbol of their spirituality as well as castles and city walls as defences against external attacks.

However, the greatest development of stone as a building material took place during the second half of the 20th century. It was then that the traditional architectural use of blocks of rock as structural elements in buildings was transformed into a superficial one, as thin decorative sheets of stone with no structural function started to be employed in buildings.

This new application of stone is still developing and has allowed current manufacturers to obtain increasingly reduced thicknesses, reaching dimensions of as little as 5mm, which constitutes the authentic layer of skin of architectural elements.
2.2. THE OPERATION OF NATURAL STONE

2.2.1. Research

The same techniques used in other types of mining research are generally used in the research of natural stone, though specific components related to the peculiarities of natural rock deposits are also considered. Indeed, in the case of natural stone, apart from establishing both mineral mass and physical and chemical properties, it is necessary to determine the minimum volume of non-altered mineral removable. This is what is known as "block size", whose characteristics determine, quite definitely, the profitability of a given operation.

This requires exhaustive studies on the fracturing conditions of the massif rock using very detailed geomechanical mapping studies in order to assess this highly important parameter as thoroughly as possible.

2.2.2. Rock blasting

Usually, the rock is mined in open pits, but sometimes operations are performed in
underground mines.

Both methods require detailed studies of the stability of the open pit mine, above all in the case of underground mines. It is only thus that the safety of the people working in the mines can be guaranteed against local rock falls or general site instability.

Underground mines generate much less debris than quarries, due to the fact that the bed of natural stone to be exploited can be directly extracted. However, they require a greater initial investment as, in order to reach the desired level, galleries must be cut beforehand.
In some cases, underground mines require fasteners on the roof in order to prevent sinkings during the extraction process.

Once the exploitation front is reached, rock blasting is usually carried out with diamond wire or other devices with cutting elements, which allow for a well-squared prismatic block called primary block to be obtained.

Subsequently, the primary block is divided into smaller pieces at the quarry. Their sizes are generally between 2-10m$^3$ although exceptionally, and for special jobs, blocks of up to 80-90 t can be obtained.

The price of the larger blocks is proportionately higher, due to the fact that it is difficult to obtain them intact.

In the particular case of roofing slates, the primary block, which is called “rachón”, is a completely irregular shape, is smaller in size and it weighs about 5 t.
In slate, marble and granite quarries, the extracted blocks are rather large and heavy. After the cutting process, smaller pieces can be obtained, which are treated and sold for different uses.
2.3. TRANSFORMATION AND RECYCLING PROCESSES

2.3.1. Cutting

The blocks obtained at the quarry blocks are sent to factories for the manufacturing of the finished products that are used in building sites.

The block is delivered at the factory and cut into thin layers called slabs or boards. These are typically 2-4 cm thick, but any thickness is possible.

When the block is large enough, the cutting is usually done on machines called "weavers". When the blocks are smaller, the cutting is performed with rock cuttings.

The boards of finished products are further divided into smaller pieces, usually on request. The most common examples are plates for cladding, paving tiles, pavers, kitchen worktops, washbasins etc. Diamond blades are normally used although, for
special formats, water jet cutting can be used. This is an innovative technology that has been recently providing excellent results.

WATER JET CUTTING

This cutting method requires a highly pressurized water flow which passes through a very small-diameter hole (nozzle). This extremely strong water jet impacts on a very small area of material thereby causing small cracks, which, due to the continuous impact of the water jet, "erodes" the material, which is why we can refer to this as "micro-erosion."

There are two systems that are based on this principle. The one which uses only water is suitable for cutting all kinds of soft materials such as wood, food, plastic and so on. The one which uses an abrasive product apart from water is suitable for hard materials such as steel, titanium, alloys, ornamental stone and so on.

Some of the main advantages of this method over more conventional ones are: cool cutting (there is no heat that can affect the material); the fact that it is multi-directional (it can cut in any direction), and that the cutting perforates most materials (without previous cutting). Finally, cracks do not appear and a lot of material can be saved due to reduced cutting width.

The main disadvantage of this method lies in the fact that, in the case of some materials with large thicknesses and high hardness, an excessively long cutting time is required, which involves higher costs. Besides, in the case of very thick materials, the “ideal” vertical cutting shape tends to become distorted. This is sometimes exacerbated by incorrect cutting speed.
Slabs are obtained by cutting up the blocks from the quarry with different thicknesses. For its part, the final product is obtained by cutting up the slabs with different measures, according to demand.
Lateral cutting of a primary block with a diamond wire kit
2.3.2. Surface finish

The surface finish of the stone determines its roughness or texture and also its tonality. The smoother the surface finish, the more the tonality of the stone darkens. This is specially the case with polished rocks.

The most common surface finishes are:

- Polishing: this treatment is applied with fine grain grinds and subsequent polishing with alumina powder, iron oxalate or other similar products which continuously appear on the market.

- Grinding: this surface finishing is achieved using a carborundum grinding of grain size 60.

- Honed: this surface finish is achieved with a carborundum grinding of grain size greater than 120.

- "Abujardado": this finish is obtained through the continuous beating of a hammer, or buss hammer, with square pyramidal elements on its face side, which provide a rough finishing.

- Flaming: this kind of finish is obtained with a thermal lance at a temperature of 1,200°C, which causes the release of small particles. This provides a very rough surface finish.

- "Apiconado": this surface finishing is obtained "chipping" the piece by hand with a suitable chipping hammer.

- Slicing: this is rough finishing which can be achieved by parting the piece with a press with two blades which breaks the material and creates a rough surface.

Regarding colour, natural stone is probably the building material with the widest colour range, which, together with its natural or man-made textures, provides endless design possibilities for designers. This variability is related to rock
formation mechanisms.

Indeed, the large number of completely random variables involved in rock formation processes, which are controlled solely by the physical and chemical laws of nature, provide us with a large range of varieties which, from the point of view of the market, may seem chaotic, but is in reality full of harmony and sensitivity.

However, such diversity does not occur at every quarry and may only apply to a single one, even at the same operation level. Occasionally, excessive variety may lead buyers to reject the product. Nevertheless, it should be noted that changes in tonality, texture and overall appearance are to be expected in natural stone. This may give natural stone its competitive advantage over other monotonously uniform manufactured materials.
2.3.3. Treatments for improvement

Boards are usually subjected to different improvement treatments in order to increase the durability of the product. The most common improvement treatments are the following:

- Board unseen side reinforcement with nylon mesh and resins.
- Filling of holes and hollows of the face side with special fillers.
- Priming with fluid resins in order to seal open pores of the stone.

2.3.4. Recycling

Natural stone mining generates a significant volume of waste, not only waste rock or non-usable material, but also cutting sludge coming from transformation processes. Integral recycling methods are continuously being devised which may provide global solutions to this problem.

From the technical point of view, waste recycling is perfectly feasible. Its main destination is the industrial manufacturing of aggregates for construction, but also the ceramics industry, and precast concrete products such as terrazzos and concrete tiles.

2.4. MACHINERY AND TECHNOLOGY

The extraction and transformation processes which have already been described require specific equipment machinery which, as in any other industrial activity, has evolved greatly in recent times.

In the early industrial exploitations of the late 18th century, the extraction processes of natural stone were rather undeveloped, but certainly not lacking in effective technological foundations.
The use of metallic or wood wedges, inserted following the direction of the weak plane of the rocks, which is called "hair", allowed for more or less regular blocks to be extracted by applying human strength only. The principle applied here was the fact that the resistance of the rock to tensional stress is ten times lower than to compressional stress. The introduction of helical steel wire, used in combination with sand load as an abrasive, led to the development of reduced thickness planks using well-squared blocks.

Strappings made of hardened steel are able to cut the rock with the help of a steel abrasive product called "grit". Alternatively, they may be provided with small diamond plates along their axes, with the same function. Diamond wire machines with numerical control devices are also common in the cutting of medium-sized blocks.

Currently, robotics is undergoing a major boost in the natural stone world, and machinery is being manufactured that allows for pieces to be cut using previously designed software or even software designed from the 2D or 3D scanning of the shapes that are to be reproduced.
Numerically controlled machinery for the manufacturing of special pieces

Arm of a shearer cutting in a quarry
3 APPLICATIONS AND USES OF THE NATURAL STONE

There are many applications of natural stone in the world of construction, covering a wide range of commercial products, which include paving, façades veenering, masonry, roofing and individual cut stones.

The design possibilities of ornamental stones are almost endless, especially if we take into account the sheer variety of rocks existing in nature, the combinations that can be obtained with the size and shape of the rock pieces, their colour and appearance as well as the different surface finishes that can be achieved.

3.1. PRODUCTS AND MATERIALS

3.1.1. Paving

The use of natural stone for the construction of pavements represents the single most important application of this material.

The paving of roads resulted from the need to adapt existing communication routes to new transport systems, which led to the construction of the first cobbled road surfaces in the Roman era. Cobbled roads still maintain their validity today from a conceptual perspective.

This kind of application underwent a period of crisis at the start of the second half of the 20th century, which led to the destruction of many cobbled roads in different cities, maybe due to budgeting restrictions or to a lack of expertise regarding adequate laying techniques.

Fortunately, stone paving is currently being recuperated, so much so that, these days, the restoration of the old part of a town cannot be envisaged without the use of stone.
However, apart from cobbled streets, other types of outdoor pavement and indoor flooring are also made of stone. In this case it is larger pieces of stone, or tiles, which are used.

Paving tiles are one of the most frequent applications of stone in urban areas.

In construction we can also find examples of flooring such as this marble staircase.

3.1.2. Veneering for cladding and façades

These construction work units have replaced traditional masonry as the visible external elements in buildings. From the technological point of view, façade veneering, unlike traditional masonry, does not have a structural function but it can act as an insulating material.

Although veneering can be fixed to the building with chemical adhesives or cement mortars, nowadays, the laying is more and more frequently carried out by means of
anchorages, thereby creating what is known as ventilated façades.

This construction system, which is considered by many as one of the greatest architectural achievements of the 20\textsuperscript{th} century, requires metallic anchorages made of stainless steel acting as connecting elements between the stone and the wall. An air gap between them can thus be created, which facilitates ventilation, thereby significantly increasing the design life of the rock. It is commonly said that natural stone, like man, needs to breathe, which is why this kind of solution is perfect.

Although the main technological function of claddings for façade claddings is for insulation, day by day innovations in this field appear, creating shapes from different claddings as those of the image at the top, in granite and glass, or on the left, a skyscraper with limestone cladding.

3.1.3. Masonry

Masonry is the most traditional use of stone in architecture. From the regulatory standpoint, masonry can be defined as those stone pieces with a structural function and thicknesses greater than 80mm. If the pieces are irregularly shaped, they are generally called rough ashlars, and if they are square blocks, ashlars.
The joining of the pieces is carried out with lime mortars or mixed lime and cement mortars in the load-bearing walls, arches, retaining walls, and so on, which constitute the different structural elements of this type of architecture.

The use of stone masonry has been largely replaced by other materials such as bricks or concrete. However, there are still exceptional examples thanks to which stone masonry has taken a new impulse as a symbol of wealth, durability and comfort, especially as compared to other materials.

A clear example of this is rural Galicia in NW Spain, where the use of stone masonry for a family home is almost a cultural imperative.
Masonry is the use of stone from a structural point of view. There are many historic town or city centres in our country fully built or restored with masonry

3.1.4. Slate roofs

Slate roofs constitute an additional, very important application of natural stone.

As will be seen below, Spain is the world’s largest producer of roofing slate, although only about 15% of the total production is consumed domestically. The remaining 85% is exported, mainly to other European countries.

The laying method for these stone units is quite complex, although very effective, and requires highly skilled labour.

Slate pieces overlap each other forming a scaly surface of tiles which are attached either by nailing them directly onto wooden battens, or by hooks that hold the tiles and are also nailed to the battens.

The shape of the tiles can vary greatly, but the rectangular ones predominate.
3.2. NEW APPLICATIONS

Natural stones, like any other construction material, are not unaffected by the development of new products, which mainly result from technological advances both in cutting processes and adhesives.

In this regard, it is worth mentioning the tiles or panels involving a stone slice of about 4-5mm in thickness to which a cheaper material has been adhered with suitable adhesives, thereby providing the material with enough rigidity. The materials used on the stone may be ceramic or made of fibre cement, or they may be lightweight honeycombed aluminium structures or a nylon mesh with a thick enough layer of resin.

The main advantage that these products share is that they all entail a more efficient use of mineral resources since they require a smaller volume of stony material per square metre of covered area. Some products, especially with honeycombed structures, allow us to manufacture large but very light panels, which significantly improves laying time, even though the final cost may still not be the lowest.

Other rather novel products which are increasingly entering the market are aged stone units. These are pieces that have been subjected to physical erosion treatments with abrasives, such as steel shot projection, or chemical erosion, which provides them with a rough, altered look similar to that of those materials that have been degraded by use and or by the passing of time.
4. NATURAL STONE IN SPAIN AND ARAGON

The natural stone industry, which is deeply rooted in our everyday environment, is today a thriving sector, both as regards internal consumption and export trading.

The sheer variety of natural stones on the market today, together with the quality and reliability of manufactured products, offer enough guarantee of quality for prospective buyers.

4.1. NATURAL STONE IN SPAIN AND IN THE WORLD

This is a booming market experimenting fairly steady growth, namely 33% in the last five years.

In Spain, the total annual extraction figure for natural stone exceeded 7.9 Mt in 2006.

The rapid development of this sector during the 1990s, which has more recently slowed down, especially in the last three years, generated at the time enough resources for companies to be able to modernize their manufacturing processes and to expand their commercial networks worldwide. At present, our country ranks sixth in the world ranking for natural stone production.

The slowing down of Spanish manufacturing is not an isolated phenomenon, as it also affects other traditional producing countries around us, such as Italy, whose production has remained steady, if not decreased, but also France, Portugal, Greece and the United States.

As is the case with many other sectors of the economy, this loss in the market share is related to the economic development of other rapidly-growing economies such as China or Brazil.

Thus, in the last five years China’s production has increased by 58%, and Brazil’s by 123%. Another interesting fact worth noting is that at the moment China represents 28% of world-wide production.

By subsectors, Spain is the largest producer of roofing slate, and the fourth or fifth producer of marble (calcereous rocks) and granite.

Here are some relevant examples of well-known natural rocks in our country:

Among plutonic rocks, grey granite, the most abundant one in the world, and pink porriño granite are worth mentioning. The latter comes from Porriño, a Galician town, hence its name. It stands out due to its uncommon pinkish colouring.

Among volcanic rocks, the best-known basalts are exploited in the Canary Islands and in Catalonia, although these rocks are not widely present in today's markets, which may be due to the fact that they are difficult to polish, or due to just fashion trends.

Marble is the most important natural stone. Well-known works in marble are Michelangelo’s La Pietà, David and Moses, made with Italian Carrara marble, the columns and fountain in the Lions’ Courtyard in the Alhambra Palace in Granada, which were built with marble from the Andalusian village of Macael, the caryatid columns in the façade of the Bank of Spain in Madrid, also made with Carrara marble, or the Greek marbles from the Parthenon in Athens.

The best-known natural stone in our country is ivory cream limestone. It has a light
cream colour, which is rather popular in international markets. It is exploited in Pinoso, in Alicante, in a quarry considered to be the largest in the world.

The business network in Spain comprises around 600 companies employing around 6,000 workers, which means that, on average, each company employs 10 people.

The development of this sector has been so spectacular that it has given rise to major companies with significant presence in international markets. So much so that, for example, the two largest tile manufacturers in the world are located in Spain. Between them, they represent about 35% of world-wide production. Regarding granite and limestone, there is a company which probably ranks first or second in the sales world ranking.

4.2. NATURAL AND ORNAMENTAL STONE IN ARAGON

In Aragon, the natural stone subsector has undergone an important development since large investments have been made in this sector. The number of exploitations has doubled in the last ten years, leading to important job creation. It is in the province of Teruel, followed by Zaragoza, where these economic factors have developed most significantly.

The materials that are exploited in Aragon may be classified according to their final purpose: flagstones and natural stone for construction (sandstone, calcarenite, limestone, quartzite), and ornamental rocks (limestone and marble limestone, alabaster).

Slabs and natural stone for construction (sandstone, calcarenite, limestone and quartzite)

They are widespread rocks characterized by a pleated structure, which occur in thin layers or strata that may be easily exfoliated. The predominant lithology is sandstone, which may have a high content in limestone cement (calcarenite), but also limestone. They represent a set of rocks with varied textural, mineralogical and structural characteristics. They are used as rustic stone in flooring, façades and roofs, in the construction of walls in rural areas and as stone masonry in restorations.

Little mechanization is required for operations. The uppermost and non-covered levels are exploited so that no large empty holes are formed, thus facilitating restoration work. The rock is broken on the quarry itself or in small local workshops using the natural joints, and the fragments are in turn cut by hand and later classified. Slab thickness is variable, ranging from decimetres to centimetres and, once prepared, their individual lateral dimension normally oscillates from 20 to 50cm. However, metric pieces or panels can also be produced.
Cream limestone, Maestrazgo

Limestone. Slabs from Mosqueruela (Teruel)
Ornamental rocks (Marble Limestones and dolomites)

Due to their durability and the fact that they can be easily polished, cut and carved, these rocks have a wide range of applications in the construction and interior finishing sectors.

Limestones are mostly composed of microscopic calcite (calcium carbonate) crystals, although other minerals are also present to a lesser extent, i.e. silica, clays, iron and manganese oxides, organic matter and other carbonates. Iron oxides provide interesting yellow, orange, red and black colorations; organic matter, for its part, produces black or grey colours. Fossils are very common and can be easily observed in polished sections.

Calcium carbonate is called calcite and forms limestones, whereas calcium and magnesium carbonate is called dolomite and forms dolomite rocks. Considering the proportion in which either one is present, rocks will receive different names, such as dolomitic limestones or calcareous dolomites. Tests carried out in order to determine their quality will also establish their resistance to compressive stress, expansion capacity, hardness, resistance to friction, elasticity, etc.

In Aragon, there exist large reserves of limestone and dolomite rocks and in some areas they have been exploited for centuries. A wide range of varieties may be included, some of which are exclusive products from Aragon, such as the Calatorao stone or the Fuendetodos helix-fossil-bearing rock (caracoleña stone), both located in the province of Zaragoza.
Montemuzo Palace (Zaragoza), paved with Calatorao black limestone and Albortón yellow limestone

Helix-bearing stone, from Fuendetodos (Zaragoza)
It has already been explained that in the ornamental stone sector, marble or marble limestone are the terms used to refer to polished limestones and dolomite rocks. This should not lead to confusion regarding real marble, which is a typical metamorphic rock with whitish and light grey colours. It is not exploited in Aragon because it is rather fragmented and located in protected natural spaces.
Cutting of pavers in Calatorao (Zaragoza)

Limestone quarry in la Puebla de Albortón (Zaragoza)
Most significant sites for the extraction in Aragon

Among the most significant sites for the extraction of natural and ornamental stones in Aragon, the following are worth mentioning,

- Late Paleozoic-Early Mesozoic red sandstones. They have a characteristically strong red colour. Colourful slabs are easily obtained from the "Rodeno", as these rocks are also known, especially in the areas of Illueca and Tabuenca (Zaragoza).

- Jurassic limestones, among which the Calatorao stone (Chelva Formation, Middle Jurassic), also known as "black marble", stands out. This rock, whose dark colour results from its high content in organic matter, has distinctive white veins and a high content in fossils (belemnites, ammonites, and so on), some of which are quite large. Activity in the Calatorao quarries has been documented since Roman times, and today it represents the largest industrial complex in the stone subsector in the whole region. The Calatorao stone can be easily found both in sacred and civil works in numerous cities and towns in Aragon.

- Albortón Stone. The limestone of Puebla de Albortón (Zaragoza) is obtained from the Upper Jurassic limestones. It is called “yellow marble” and is characterized by its patterns and colours. The sinuous, several-centimetre-wide grooves which cover the rock derive from the fill of the burrowing carried out by invertebrates which where contemporaneous with the deposition of the calcareous mud which would later lead to the rock formation. The intense coloration developed later due to the fact that the rock, once hardened, emerged and eroded, was covered by red clays which were rich in chromophoric elements, such as iron, providing the rocks with colour.

- Early Cretaceous Sandstones. These are reddish and white slabs which are exploited in the province of Teruel, between Mora de Rubielos and Rubielos de Mora, but also in Maestrazgo.

- Middle-Upper Cretaceous limestones, which consist of more or less thin strata separated by marl laminaes that facilitate removal of the slabs. They are exploited in Mosqueruela (Teruel) and in Blancas (Teruel).
• Upper Cretaceous limestones. Apart from forming part of the spectacular scenery of the Monasterio de Piedra (Zaragoza), the thick Upper Cretaceous limestone beds (Montoro Formation) allow for large rock blocks to be extracted. The limestones of Villarluengo (Teruel) and the stone of Abanto (Zaragoza) originate from this formation.

• Eocene calcarenites. Belonging to the turbidite units in the Pyrenean trough. The "Pyrenean slabs" are finely stratified and alternate with marl layers, which facilitate removal. There are quarries in various areas of the Intermediate Pyrenean Depression, such as Pueyo de Araguás and Fiscal (Huesca).

• Ebro Depression Sandstones. These are Oligocene and Miocene in age and alternate with marl and clay beds, both on the northern margin, near the Pyrenees, and in the southern margin, near the Iberian Range. They are mined in several places, for instance Uncastillo (Zaragoza) and Alcañiz (Teruel).

• Alabaster, which is included in the Lower Miocene deposits of the Ebro Depression and in the Intra-iberian Depression (Calatayud area). The extracting sites of this particularly interesting rock are discussed in the next section.

• Miocene Lacustrine limestones. A highly porous white calcareous sediment tends to appear in the youngest part of the stratigraphic series in the Ebro and the Intra-Iberian Depressions. In the Ebro Valley, it is called "bell limestone" because of the high-pitched sound, similar to that of a bell, that is emitted when hit. It may contain chert nodules and fossils and it is exploited in Tortajada (Teruel) and Fraga (Huesca).

• Tufas. During the Miocene, tufas generated in some marginal lacustrine areas. These limestone rocks, which are highly porous as they generated among plants, are very much appreciated in construction, due both to their low density, but also enough compactness, and the fact that they can be easily worked. They are mined in Villarluengo and Villalba Baja (Teruel).

• Fuendetodos Helix-fossil-bearing Rock (Caracoleña Stone). These Upper Miocene fossiliferous limestones, which are mainly integrated by gastropods, have been
exploited in Fuendetodos (Zaragoza) since Roman times. They are highly porous as the snail shells are largely empty and cannot be polished. Large blocks of this type of stone may be seen in the most representative buildings in the city of Zaragoza.

All these sites of natural or ornamental rocks are integrated by sedimentary materials, which are the most abundant ones in Aragon by far. In the Axial Pyrenees, slate has been used for roofing, but currently there are no exploitations of this type of metamorphic rock in the area.

Granites and other plutonic rocks, meanwhile, appear quite fractured and in areas which pose important limitations as far as extraction is concerned, due to their high altitude or environmental significance. Volcanic rocks present similar limitations, although the historic exploitation of a volcanic material called rhyolite in Pardos (Zaragoza) is worth mentioning. Also, there are research perspectives in the Iberian Range regarding the possible ornamental applications of this type of rock.
Aljafería Palace (Zaragoza)

Helix-bearing stone in a column in the Basilica of the Pillar in Zaragoza