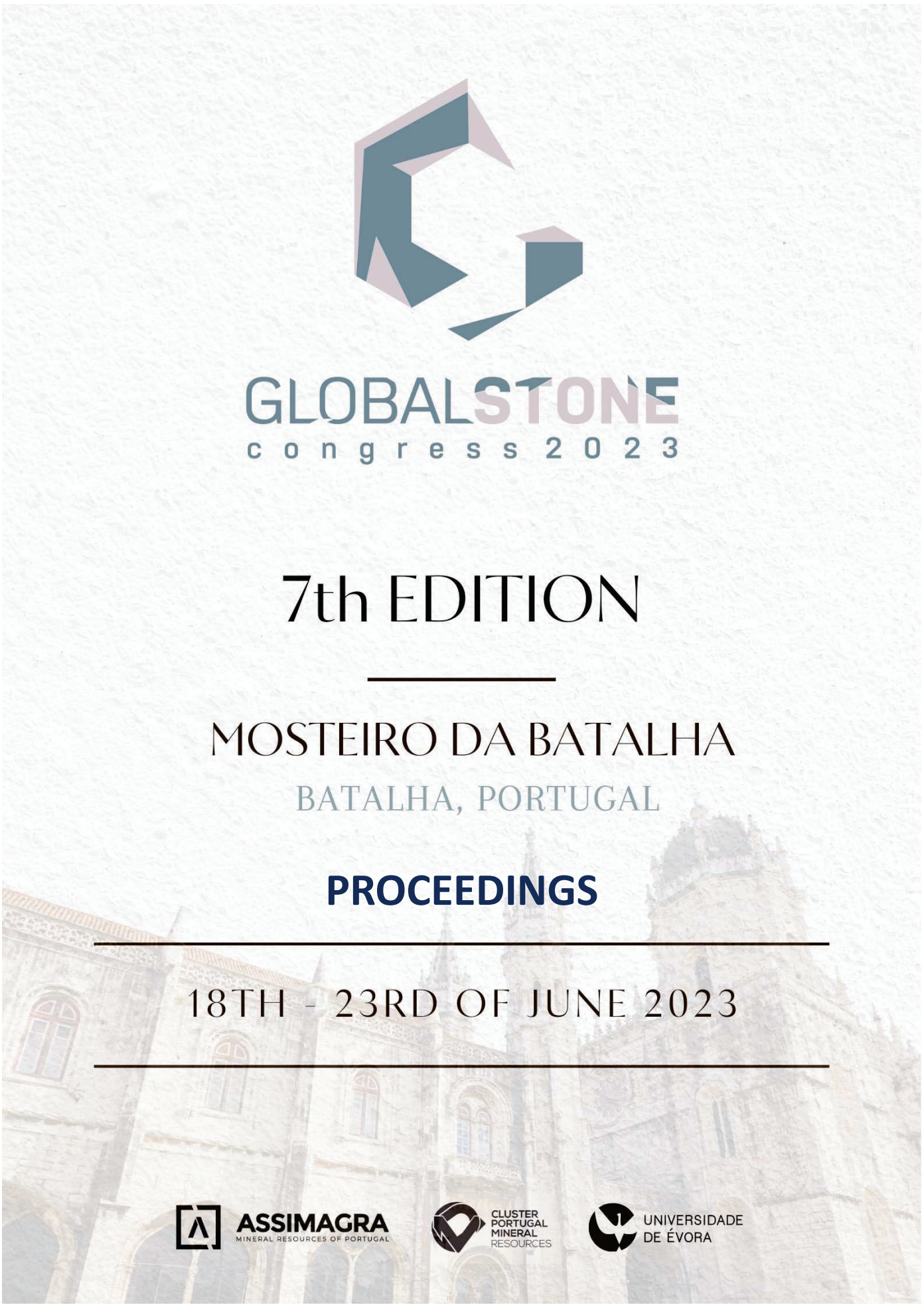

GLOBALSTONE
congress 2023

7th EDITION

MOSTEIRO DA BATALHA

BATALHA, PORTUGAL

PROCEEDINGS

18TH - 23RD OF JUNE 2023

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NEW CHALLENGES ON DIMENSION STONES, FROM PORTUGAL TO THE WORLD

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Luís Lopes, Marta Peres, Célia Marques (Organizers)

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

Cover: Inês Ribeiro, Luís Lopes
Back cover: Luís Lopes

Graphic design and pagination: Luís Lopes
Publication date: June 2023
Support Type: eBook
I.S.B.N.: 978-972-778-327-4

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

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

THE USE OF VOLCANIC STONE IN THE ARCHITECTURAL HERITAGE OF THE ISLAND OF TENERIFE (CANARY ISLANDS)

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Summary: *The volcanic origin of the Canary Islands has given the islands a great lithological diversity. The historical use that has been given to this type of material has been determined by its specific characteristics: hardness, cohesion, compactness, softness, textural heterogeneity, colour, etc. These volcanic materials, thanks to their intrinsic characteristics, give the architectural heritage of the islands a unique and differentiated character compared to the rest of Spain. Some of the most unique historical works on the island of Tenerife are highlighted (most of them have been declared of Cultural Interest) according to the lithology of the stone material used and the quarries from which these materials were retrieved. Nowadays, these quarries have been either abandoned or their extraction is restricted or prohibited. Knowing the origin of the stone used and its pathologies is of vital importance for the correct conservation and restoration of the heritage, as it allows, among other things, the replacement of a material that is compatible in behaviour with the deteriorated elements.*

Key words: *Tenerife, volcanic stone, heritage, architecture*

1. Introduction

There are no bibliographies of the quarry's locations in the history of Tenerife in general, although there are documents of great interest that deal with partial aspects of the subject. Firstly, we should mention a text by Larraz (1999), in which he analysed quarrying at the beginning of the Conquest, pointing out that "the determined policy of the council which favoured the creation of an open system of quarrying and commercialization of the material" and he also noted that the three types of stone used at this early stage, were the "Piedra Colorada'', mainly taken from the area of "Tegueste" ("Pico Bermejo" or "El Peñón)", the "Piedra Blanca" from "Portechuelo" and the slope of "San Lázaro" and the ''Piedra Jabaluna'' in the "Camecerías" ravine. Isolated references that we have found in multiple documents (articles, papers, books of works and minor contracts), which allowed the typology and extraction sites to be extended considerably. In summary, these are as follows:

i. Tuffs

- "Piedra Colorada", also known as "Bermeja" or red, of which the following quarries were mentioned in the area around "San Cristóbal de La Laguna", in the north-east of the island, the quarries of: "Pico Bermejo", "El Peñol", "Nombre de Dios", "Obispo", "Taganana", "Valle de Salazar" and in the north-west, the ones near "Masca", in "Teno" massif.

- "Piedra Blanca" of which the following quarries were cited: "Roque Maldonado", "Roque del Peñón", and on the slopes of "San Lázaro". There are also references to a quarry located in the "Portezuelo", probably on the mountain of "El Púlpito".

- "Piedra Tosca", abundant mainly in the southwest. Currently, it is exploited and marketed by "Cantos Blancos del Sur" (Arico).

ii. Ignimbrites

- "Piedra de San Juan de la Rambla", matrix of golden gray tone with well adhered centimetric flames of darker tone, medium hardness.

- "Piedra Chasnera", matrix with different colours, well adhered centimetric flames, compact and resistant. ''Chasneras'' are currently exploited and marketed by "Guamarico S.L.", distinguishing four varieties: "Brown", "Violet", "Grey" and "Green". The physical properties of these stones have been studied by Valido et al. (2023). Historically this stone has been widely used as paving, transported by boat from "Tajao" to the main historical centres, so references to it can be found as "Losa chasnera".

iii. *Basalts and trachybasalts*

- "Piedra Molinera", so called because the aborigines used them to build grain mills. In the ornamental heritage, we have found basically fine-pored vacuolar varieties. Found in the northern part in the "Mocán"

quarry and in the south of the island in of “Granadilla” quarries. Currently, it is marketed by “Rocasa S.A.”

- "Piedra Jabaluna", a term used by the first stonemasons who arrived on the island to refer to a stone that must have been similar in appearance and properties to the dark-coloured slate quarried in Tarifa (Cadiz) known as "Piedra de Tarifa or Piedra Jabaluna". There is little documentation on the quarries where this type of stone was extracted. Some references mention the quarry "La Machada", possibly located in the ravine of "La Carnecería".

iv. *Trachytes and phonolites*

- “Piedra gris - dorada” (its light gray tone turns golden due to surface oxidation). The following quarries were mentioned: “El Viejo” (Tegueste), “Lomo Román” (Santa Úrsula) (Fig. 1), “Tigaiga” (Los Realejos) and “Buenavista del Norte”.

- “Piedra Azul”, of which the following quarries were mentioned in the surroundings of “La Laguna”; “Pedro Álvarez”. In the northern area; “Acentejo”, “El Esparragal”, “La Solitaria de Taco”, “Los Silos” and “Camino del Lugar” (Buenavista). In the southern area; mainly those of “Barranco de la Orchilla” (Abona) and those of “Sixto” (Granadilla), both in exploitation by “Talleres Sixto”.

Fig. 1 Quarry “Lomo Román” (Santa Úrsula)

On the basis of these initial data, significant heritage examples have been selected for each type of stone. In presenting them, the possibilities for sculptural work will be discussed. Images and descriptions of quarries will also be presented.

2. Geological context

The origin of the Canary Islands has been the subject of study since the 1970s, and several hypotheses have been put forward since then. In the case of Tenerife, the most accepted theory is that the island was formed from a Central Shield, "Roque del Conde" (11.9 - 8.9 Ma) and two later constructions that grew on its flanks, "Teno" (6.2 - 5.6 Ma) and "Anaga" (4.9 - 3.9 Ma) (Guillou et al. 2004), this stage is called "Serie Basáltica Antigua". After a period of inactivity, a new eruptive stage began, mainly marked by the "Las Cañadas" volcano (3.5 Ma) and in which three main cycles of activity can be distinguished, causing successive caldera collapses (Ancochea et al. 1990). This phase of formation is known as the "Edificio Cañadas". Subsequently, fissural volcanism initiated the construction of the "Edificio Dorsal" (1.0 Ma). After these formations, the first eruptions began, forming the "Complejo Teide-Pico" (0.2 Ma). The materials emitted during this period occupied a large part of the caldera and overlapped until they reached a height of 3718 metres, thus forming the Teide stratovolcano (third highest volcanic structure in the world).

i. Tuffs

The tuff quarries, from which the "Piedra Colorada" and "Piedra Blanca" were extracted, are mainly associated with the "Anaga" massif, although it is also possible to find some extraction areas in the "Teno" massif. This material occurs in levels interspersed between the basaltic lava flows. The lava flows being the most representative unit of this massif. Tuff is a pyroclastic rock formed by the lithification of lapilli and ash deposits (fall deposits) (de Vallejo et al. 2007), emitted in a volcanic eruption, usually of an explosive nature. This formation mechanism, typical of pyroclastic fall deposits, is equally valid for the "Piedra Tosca", as this is a type of tuff in which pumice fragments predominate (pumice tuff). This lithological unit, described on geological maps as "Undifferentiated felsic pyroclasts" outcrops mainly on the southern and south-western slopes, hence the extraction quarries are located in this area of the island.

ii. Ignimbrites

The ignimbrites of "San Juan de la Rambla" outcrop in the northern part of the island. With an estimated age of 1.24 Ma, they occur at depths of about 40 metres, forming poorly individualised beds with coarse columnar disjunction. The "Piedra Chasnera" belongs to the lithological unit "Arico ignimbrite’s" (0.65 Ma), because it is on the slopes of this municipality in the south of the island where they outcrop. The term ignimbrite is sometimes used as a synonym for welded tuff, while other authors propose that the tuff is a non-welded ignimbrite (Hernández-Gutiérrez, 2017). The ignimbrites mentioned in this study correspond to pyroclastic flow deposits in which the lithic fragments are crushed and stretched (fiamme) following the flow direction, as described by de Vallejo et al. (2007).

It should be noted that the lithological units to which the "Piedra Tosca" and "Piedra Chasnera" belong have been extensively studied in the field of volcanology and geology, as they constitute, together with other

deposits, what is known as the "Bandas del Sur Group" (Dávila-Harris et al. 2013).

iii. *Basalts and trachybasalts*

The historical quarries of “Piedra Molinera” have not been located exactly and although it is still marketed today, this stone material does not come from an active quarry but from occasional extractions taking advantage of the earthworks and clearings of large works. There is no doubt that the "Piedra Molinera" comes from basaltic lava flows (mainly of trachybasaltic composition), which are the most extensive lithological unit, so there can be outcrops of this stone in practically any area of the island.

Of the "Piedra Jabaluna", the only quarry of which we have reference is located on "aa" and "pahoehoe" type lava flows of porphyritic texture, fundamentally olivine-augitic or olivine.

iv. *Trachytes and phonolites*

The "Piedra gris - dorada" extracted in the "Tigaiga" quarry belongs to trachyte - mafic phonolite flows of porphyritic facies. These basaltic flows are of low power with a surface area typical of "aa" basaltic flow. The stone extracted in the "Lomo Román" quarry corresponds to a phonolitic flow that appears sporadically interspersed in the basaltic flows and in the case of the "Buenavista" quarry, the stone is associated with the mafic phonolitic flows of the "Montaña de Taco" (0.7 Ma). They are generally quite massive rocks, although they are sometimes more porous, being similar in appearance to some trachybasalts.

The "Barranco de la Orchilla" and "Sixto" quarries, from which the "Piedra Azul" is extracted, are located on flows of trachyte-phonolitic composition. The lava flows that outcrop in the "Barrando de la Orchilla" correspond to a fairly extensive unit that occupies a large area of the slopes of Adeje and Vilaflor, in fact, this lithological unit is called "Vilaflor Phonolite’s". In the "Sixto" quarry, the lava flows correspond to powerful phonolitic multi-lavic slabs that were emitted in the last phases of the "Edificio Cañada". The most notable difference between these two deposits arises at the mineralogical level. Most frequently, the stone that outcrops in "Barranco de la Orchilla" corresponds to a nepheline phonolite, while the outcrop where the "Sixto" quarry is located is composed of haüyne-phonolite.

3. Types of stone and their use in historical buildings

Depending on the characteristics of the volcanic stones in terms of hardness, density, colour, texture, etc., they were used to meet the aesthetic needs of their time. For example, if we look at the architectural elements that present ornamentation in the historic centre of “La Orotava”, we can see that a trachytic rock of a bluish grey colour, medium hardness and diffuse anisotropy predominates. It is a material that speaks to the cutting tool with good control over the material to be removed and responds to the different intensities of impact without conditioning. The shapes lend themselves to all types of finishes, both round and voluminous shapes and with wide or detailed enveloping shapes.

The anisotropy, being diffused and homogeneous, does not condition the way of directing. The cuts facilitate freedom of movement in the different tilling processes, although care must be taken with the finishing processes of the details.

The clearest example of the plastic possibilities of this type of stone can be seen in the ornamental repertoire, based on vegetal and animal motives, applied to the large corbel which gives the balcony a shape, located in the central part of the main doorway of the church of “Nuestra Señora de la Concepción” (Fig. 2), built in the 18th century by the master mason Patricio García (Tarquis, 1965).

Fig. 2 Ornamentation applied to the main doorway of the church of “Nuestra Señora de la Concepción” (La Orotava)

The quarries that supplied this type of stone material are located in the municipality of “Santa Úrsula”, bordering the south-western slope of the “La Orotava” municipality. This type of quarry corresponds to very powerful flows, derived from the high pressure that unfolds and opens the surface of the dome, causing the material to slide slowly until it comes to a standstill. This stone material was used for the elaboration of the most outstanding architectural façades for the nobility of “La Orotava”, being the means, to enhance their social power (Hernández, 2004).

Coarse-pored vacuolar basalt or "Piedra Molinera" was used for its characteristics of resistance to compression and abrasion for the manufacture of millstones and in construction, it was specifically used for buttresses, corners and foundations; although to a lesser extent we see it used to form prominent elements of a façade, such as the main doorway of a historical building. The main façade of the convent of “San Agustín” (La Orotava)

(Fig. 3) contains two doorways arranged at right angles, the entrance doorway to the convent made of millstone and the church doorway, the latter made of trachyte stone. Both façades were made in the 17th century by Juan González Agalet (Tarquis, 1965) and Lázaro de Miranda (Rodríguez, 2015), who were in charge of finishing the façade of the church of "San Agustín" as well as the doorway and bell tower of the convent. It is also known that part of the stonework was carried out by the official Diego Rodríguez (Hernández, 2004).

In this case, can the differences in colour, texture and even hardness between the two stones and their use be understood as an aesthetic resource. Since they were made at the same date and by the same craftsmen. Two architectural elements are shown, on the one hand the sober and rational image of the entrance doorway, marked by its compositional simplicity of broad, rounded forms, in contrast with the church doorway, which stands out for the beauty of its design and delicate ornamental decoration.

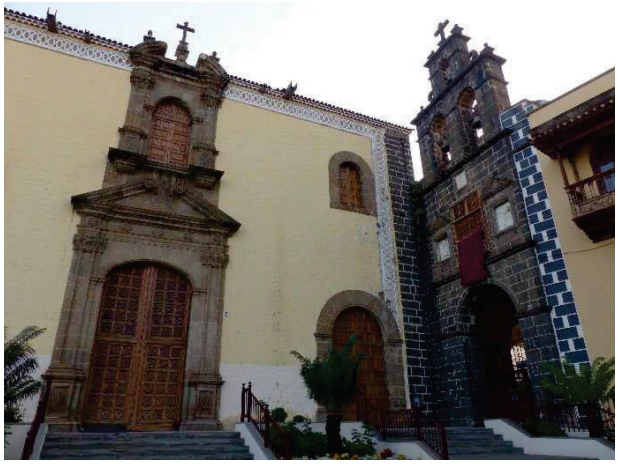

Fig. 3 Main façade of the convent of "San Agustín" (La Orotava)

The name millstone derives from the use that the aborigines gave to this lithic typology in the elaboration of mills and mortars to grind cereals.

Vacuolar basalt, compared to the tools of the time, lent itself, due to its hardness, to carving processes that resulted in broad and forceful shapes, in contrast to trachyte, which allowed all kinds of finishes.

In Tenerife this type of stone was quarried, according to the description of the stone used for the construction of the convent of "San Lorenzo" of "La Orotava", Hernández (2004) commented: Another element used was the burnt stone of the "aa" lava of "Puerto de La Cruz", with which they made the partitions of the dormitory and the new cells. We can deduce from this description that we are dealing with a vacuolar basalt. "Puerto de la Cruz" has been subjected to tourist construction overcrowding, which has limited the possibilities of exploiting this type of material.

Fig. 4 shows outcrops of vacuolar basalt which, when the time comes, could cover the need to replace losses in elements made of this type of stone.

Fig. 4 Vacuolar basalt outcrop (Buenavista del Norte)

Two types of stone are used in the Historic Centre of La Laguna. Most of the 16th century buildings were built with basaltic conglomerate extracted from the quarry on the "Nombre de Dios" (Fig. 5), in the village of "Tegueste"; it is a polychromatic stone reddened by the oxidation phenomena, its texture is irregular and the lithic fragments are welded together and have a good level of structural cohesion. It is a suitable material for carving, although in general it lends itself to large forms and a certain level of detail.

Fig. 5 Quarry on the "Nombre de Dios" (Tegueste)

Within the formal repertoire made in this type of stone, two façades stand out: the façade of the house of "Corregidor" (Fig. 6, left) from the mid-16th century and the façade of the "Alvarado Bracamonte's" house (Fig. 6, right) from the 17th century. Due to its chromatic and textural characteristics, this type of stone has historically been given different names: "Encarnada", "Roja" and "Bermeja" stonework. Martín (1978) commented on the façade of "Corregidor's" house in his book "Arquitectura Doméstica de Canarias" as follows: The only thing that remains of the original building is its excellent façade of coloured stonework - the oldest example of Plateresque

architecture on the islands - and the best, together with the “Cabildo de Santa Cruz de La Palma".

Almost all of the “Lagunera” doorways of the 17th and 18th centuries were made of trachybasalt from the “Pedro Álvarez” quarry, also in “Tegueste”. The material is bluish in colour, has uniform grain, is dense and compact, although relatively soft against the tool, lending itself to detailed forms.

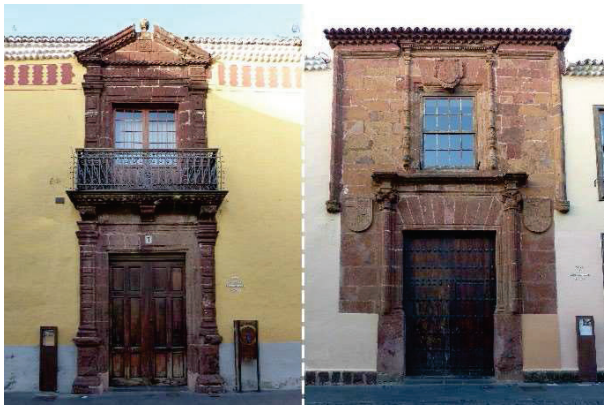

Fig. 6 “Corregidor’s“ house (left) and “Alvarado Bracamonte’s” house (right) (San Cristóbal de La Laguna)

There are several outstanding examples of façades made with this type of stone in “La Laguna”, such as the main façade of the “Salazar Palace” (Fig. 7), made entirely of stonework. It is known that its construction began around 1629, with the last building work in the middle of the 17th

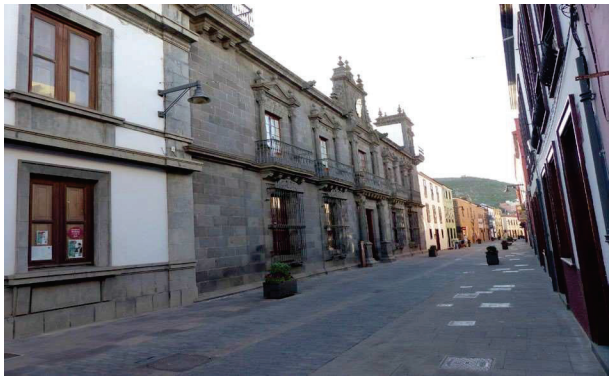

Fig. 7 Façade of the “Salazar Palace” (San Cristóbal de La Laguna)

Another example that maintains formal and ornamental parallels with “Palacio Salazar” is undoubtedly the “Palacio Nava” (Fig. 8), whose main façade is also entirely covered in stonework. Its construction underwent various modifications between the end of the 16th century and the middle of the 17th century.

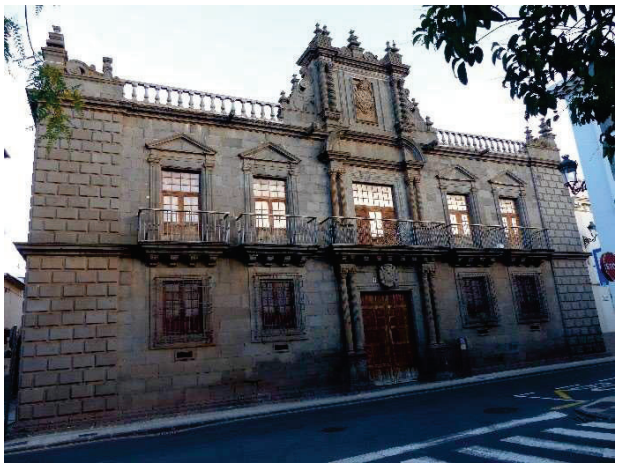

Fig. 8 Main façade of the “Palacio de Nava” (San Cristóbal de La Laguna)

We can see that the stone material used in the elaboration of both portals lends itself to detailed finishes as well as to blunt and rationed forms.

In the municipalities of “Buenavista del Norte” and “Garachico” there are two doorways made of dark grey trachyte stone: the entrance doorway to the Convent of “San Francisco” (Buenavista del Norte) (Fig. 9, left), founded in the first half of the 17th century, and the doorway of the main façade of the palace of the Marquises of “Adeje” and Counts of “La Gomera”, built in the second half of the 17th century and known as the “Casa de Piedra” (Fig. 9, right).

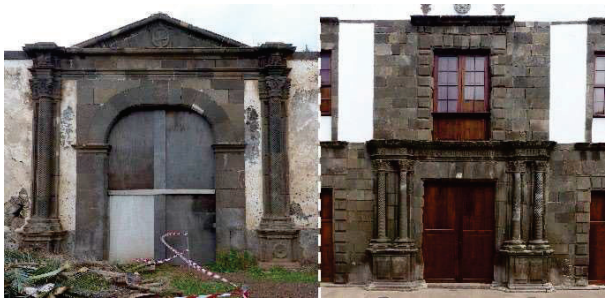

Fig. 9 Main façade of the “Casa de Piedra” (left), Main façade of the convent of “San Francisco”

The trachyte used in these two doorways is an excellent stone for carving, it lends itself to all kinds of finishes, its low hardness facilitates a smooth and soft cut that allows modeling without difficulty. In “Buenavista”, the best stone was found between the “Cejas” ravine and that of “Don Bartola" (Ruíz-Martín 2009) (Fig. 10)

Fig. 10 Quarry in "Buenavista del Norte"

The main doorway of the church of "San Antonio de Padua" (Fig. 11) in the municipality of "Granadilla de Abona", dating from the early 17th century, is made entirely of phonolite stone, extracted from the "Sixto" quarry located in the same municipality (Fig. 12). This stone is of medium-hardness, which requires a slow and careful process to withstand the impacts of the tool, resulting in less control when it comes to fitting the shapes, but in terms of modeling it offers good qualities.

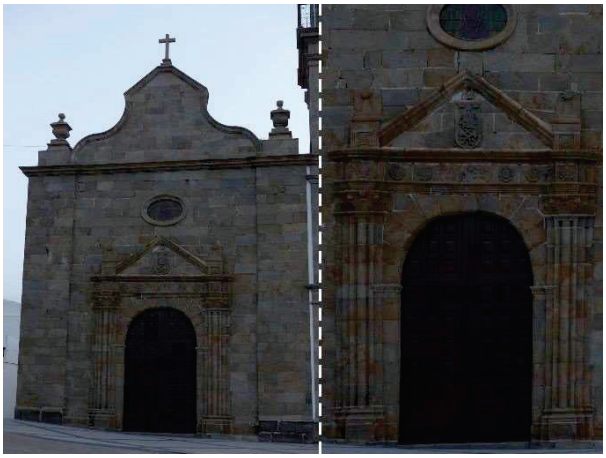

Fig. 11 Façade of the church of "San Antonio de Padua"

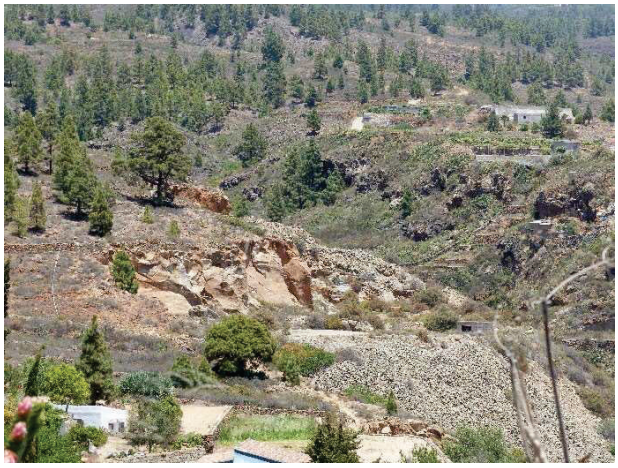

Fig. 12 Sixto Quarry (Granadilla de Abona)

4. Deterioration

The aspects that influence the repertoire of lesions affecting the stone range from its own composition, the quarry, the construction systems, its environmental context and the evolution of the cultural property to which it belongs. In other words, intrinsic and extrinsic factors. Other elements that must be taken into account in the conservation of cultural property built in stone are the mechanisms of alteration, which can be chemical, physical or biological in nature (Gómez de Terreros and Alcalde, 2000; Alonso et al., 2006; Prado, 2019). The set of deterioration agents can trigger lesions of different nature. In this way, the main groups of damage are described from the point of view of the practice of conservation-restoration of cultural property (CNR-ICR, 1990; Garcia de Miguel, 2011; Laborde, 2013):

i. *Lesions due to loss of matter*

Erosion involves a reduction of the primitive surface, with a smoothing of forms due to chemical, physical and/or biological processes. Similarly, dissolution is mainly due to chemical processes that separate certain components without generally causing the surface to decohere. If the condition persists over time, selective dissolution phenomena may occur. In disintegration, there is an obvious detachment of particles from the substrate. Detachments involve a separation of material with various morphologies (blistering, exfoliation, etc.) and causes (soluble salts, defects in the stone, static problems, rusted iron elements, etc.). Finally, missing material is a localized and appreciable loss.

ii. *Material-induced lesions*

This group of lesions includes surface deposits (accumulations of foreign matter) and alteration of products (as a result of the interaction between extrinsic agents and the constituent material). In this sense, they cause both morphological changes and surface chromatic alteration.

iii. *Superficial lesions of colour or gloss*

In these pathologies, in which chromatic changes occur, no losses are perceptible and the possible contribution of matter is hardly noticeable. There is a change in the tone or intensity of the colour. On the other hand, discolouration is a loss of colour vibrancy and implies an increase in clarity. Further, stains are a circumstantial and localized variation of colour on the surface. They may be due to humidity, contact with metals, other organic substances, etc. Likewise, graffiti (with or without historical relevance) are chromatic alterations of anthropic origin.

iv. *Damage due to deformation and breakage of the material*

Stone materials can fracture without externalizing deformation, although, depending on their nature or geometry, they can develop a low degree of deformation. Thus, these deformations are associated with flat or linear constitutions and can be distinguished by buckling, warping and twisting. On the other hand, increasing stresses, whether natural or due to structural loads, can lead to cracking. The rupture is generated in the direction(s) of weakness of the material, and can be seen from discontinuities. Similarly, their orientation will depend on their textural components and/or structural stresses. Their size defines the terms fissure, fracture and crack.

5. Conclusion

The different types of stone used in the Artistic Heritage of the island of Tenerife are the result of responses in terms of their performance or complexities that may have been experienced in the working processes, a conditioning factor that has defined the choice of each type of stone for the execution of the carved elements.

The specific objective is the identification of the materials used in each heritage element, as well as the location of historical quarries or geological outcrops that show the viability of obtaining materials compatible with those used in the heritage assets in future restorations.

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Acknowledgments: The author J.A. Valido has carried out this study with the support of the Spanish Ministry of Universities, through a pre-doctoral contract (FPU16/05739).