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ORIGINAL ARTICLE

The Historical Significance of the Welded Tuffs from Arucas, Canary Islands

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Abstract

Arucas Stone (*Piedra de Arucas*) is a welded tuff quarried in the town of Arucas, on the island of Gran Canaria in the Canary Archipelago. This rock has been quarried for centuries, not only for building but also for many other purposes, such as manufacturing water cisterns or conduits, and especially for carving. The quarrying and economic activity related to this stone have profoundly shaped the history and economy of the city of Arucas, in terms not only of extraction, but also of a highly valued local artisan tradition of stone carving. Immigrants from the Canary Islands even brought this stone to several countries in South America, where it was used to erect numerous important architectural heritage sites. Nowadays, this stone is only quarried in two areas, even though it is often required for the restoration and rehabilitation of historical buildings. Its special characteristics, and, above all, its historical importance, make this stone a prime candidate for Global Heritage Stone designation.

Keywords Tuff · Heritage stone · Architectural heritage · Canary Islands · Masonry

Introduction

Tuffs in Cultural and Architectural Heritage

Tuffs are igneous rocks with pyroclastic texture, mainly composed of pyroclastic fragments measuring less than 64 mm, along with up to 25% of other materials expelled by volcanoes. Freshly erupted tuffs are composed of volcanic glass, which soon after eruption undergoes a devitrification or early high-temperature crystallization process. Depending on the degree of consolidation, tuffs can be divided into non-welded, poorly welded, and welded. The first two sorts are extensively used as aggregates in construction, as they are easily cut, forming a light, solid, and easily workable material. On the other hand, welded tuffs, also known as ignimbrites, are formed when fine fragments of volcanic glass remain hot enough to fuse together, or simply consolidate due to the weight of the volcanic deposits (Le Maitre 2002). Welded tuffs are also used in construction, but outcrops are scarcer than the other two types mostly due to fracturing. During the cooling process, the welded tuff mass suffers internal contractions that tend to lead to an intense web of fractures, making the outcrop unsuitable for quarrying.

When welded, tuffs can be used as ashlars and also to carve intricate designs for decorative purposes. The constructive properties of tuffs have been known since Roman times (Heiken 2006). In fact, the term *tuff* comes from the rock's name in Italian, *tufo*, which makes reference to any rock that can be cut with a knife. This rock was extensively quarried in several places across the Roman Empire, such as the quarries of the Veii area, which provided raw construction materials for buildings starting in the Archaic period (Arizza 2018). Some other examples of tuff used in construction in the Italian Peninsula are the

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old towns of Pittigliano and Naples, made entirely of tuff. There, tuff mining spawned a complex web of social and economic relationships that became the main economic activity of the area. Nowadays, tuffs are still quarried as dimension stone in many areas of the world, in addition to being very common in architectural and stone heritage. However, as usually happens with historic quarries, it is difficult to find suitable stone replacements for heritage buildings made from rocks that are no longer quarried. Nijland et al. (2010) have dealt with this issue, evaluating the suitability of using several varieties of Italian tuffs (Neapolitan Yellow tuff, *tufo romano* and *tufo etrusco*) to replace Römer tuff, which was profusely used to build some of the most representative Dutch monuments of the Romanesque period (tenth to thirteenth centuries). The name of this tuff (*Römer* is German for Roman) makes direct reference to the civilization that introduced the use of tuff in the Netherlands. The Italian tuffs satisfactorily matched the aesthetic requirements, but their weathering behavior was inferior compared to the Römer tuff, due to the pore system, which for tuffs seems to be the main driver for durability. Maras et al. (2021) have found that water absorption, an indirect measurement of connected porosity, is inversely proportional to mechanical properties: the lower the water absorption (and hence the pore system), the higher the mechanical properties (elasticity modulus, seismic wave velocity, uniaxial compression). One of the tuff varieties considered in Nijland et al. (2010), Neapolitan Yellow tuff, was tested with an eco-sustainable treatment in order to enhance its durability. D'Orazio and Grippo (2015) have found an important improvement in weathering behavior by using nanocomposites, which mitigate the rock's speed of water absorption, thus making it less prone to damage by slat crystallization or freeze–thaw. These two weathering mechanisms are considered the main triggers for stone disintegration and are closely linked to the pore system (Cárdenes et al. 2014). In tuffs, connected porosity, rather than pore size, is the main factor behind weatherability, via a negative correlation: the higher the connected porosity, the lower the weathering potential. Tuffs, which usually have a medium–high connected porosity, are therefore relatively stable against these two mechanisms. Esaki and Jiang (1999) studied the weathering situation of a historic welded tuff bridge in Kagoshima (Japan). This 150-year-old bridge has suffered several floods since its construction. Its state of conservation was studied evaluating mechanical, chemical, and physical weathering with respect to depth from the surface. Mechanical and physical weathering, caused by pressures and stresses on the rock matrix, were found to reach up to 5 cm from the surface, while chemical weathering affected more than 10 cm. These results suggest that tuffs are more susceptible to chemical weathering than to mechanical and physical weathering.

Regarding the use of tuffs in cultural and architectural heritage, Zatler-Zupancic et al. (1992) studied the green andesite tuff from Gorenjska, Slovenia. As with other tuffs, the Gorenjska tuff was used to sculpt elaborate door and window frames, as well as ashlars. Again, the original quarries of this rock have been abandoned,

Table 1 Some of the most representative buildings of the architectonic heritage built with Arucas stone

Building	Place	Year
Santa Ana Cathedral	Las Palmas de Gran Canaria, Spain	1497
Triana and Vegeta districts	Las Palmas de Gran Canaria, Spain	fifteenth century
Nestor Alamo Museum	Las Palmas de Gran Canaria, Spain	seventeenth century
Canarian Museum	Las Palmas de Gran Canaria, Spain	1879
Military Goverment	Las Palmas de Gran Canaria, Spain	1888
Canarias Square	Caracas, Venezuela	nineteenth century
Santa Catalina Hotel	Las Palmas de Gran Canaria, Spain	nineteenth century
Old Courthouse	Las Palmas de Gran Canaria, Spain	twentieth century
Templo Parroquial San Juan Bautista	Arucas, Spain	1909
Heredad de Aguas de Arucas y Firgas	Arucas, Spain	1909
Orchilla lighthouse	Orchilla, Gran Canaria, Spain	1924
Capitolio de la Habana	La Habana, Cuba	1929
National Spanish Bank	Las Palmas de Gran Canaria, Spain	1948
Canarian Village	Las Palmas de Gran Canaria, Spain	1950
Canarian Botanical Garden	Tafira, Gran Canaria, Spain	1952
Alfredo Krauss Auditorium	Las Palmas de Gran Canaria, Spain	1997
Teror Auditorium	Teror, Spain	2006
Juan Grande Prison	Las Palmas, Spain	2011

and no suitable replacement material has been found so far, leaving the stone heritage in danger. Two other tuffs have been proposed as a Global Heritage Stone Resource (GHSR): Rochlitz porphyry tuff, from Germany (Siedel et al. 2019), and Sardinian 'trachyte', from Italy (Careddu and Grillo 2019). The Rochlitz porphyry tuff, of Permian age, has been used since the Neolithic, but it was during the beginning of the twelfth century when it became part of the heritage of the region between Leipzig and Chemnitz. The Oligo-Miocene Sardinian 'trachyte' has been used to build everything from prehistoric buildings known as *nuraghi* to wells, roads, bridges, and even Roman mosaics. Although this rock is actually a tuff of trachytic composition, commercially, it is referred to simply as trachyte. Both stones, Rochlitz and Sardinian trachyte, were listed as potential candidates for GHSR designation (Cooper 2010).

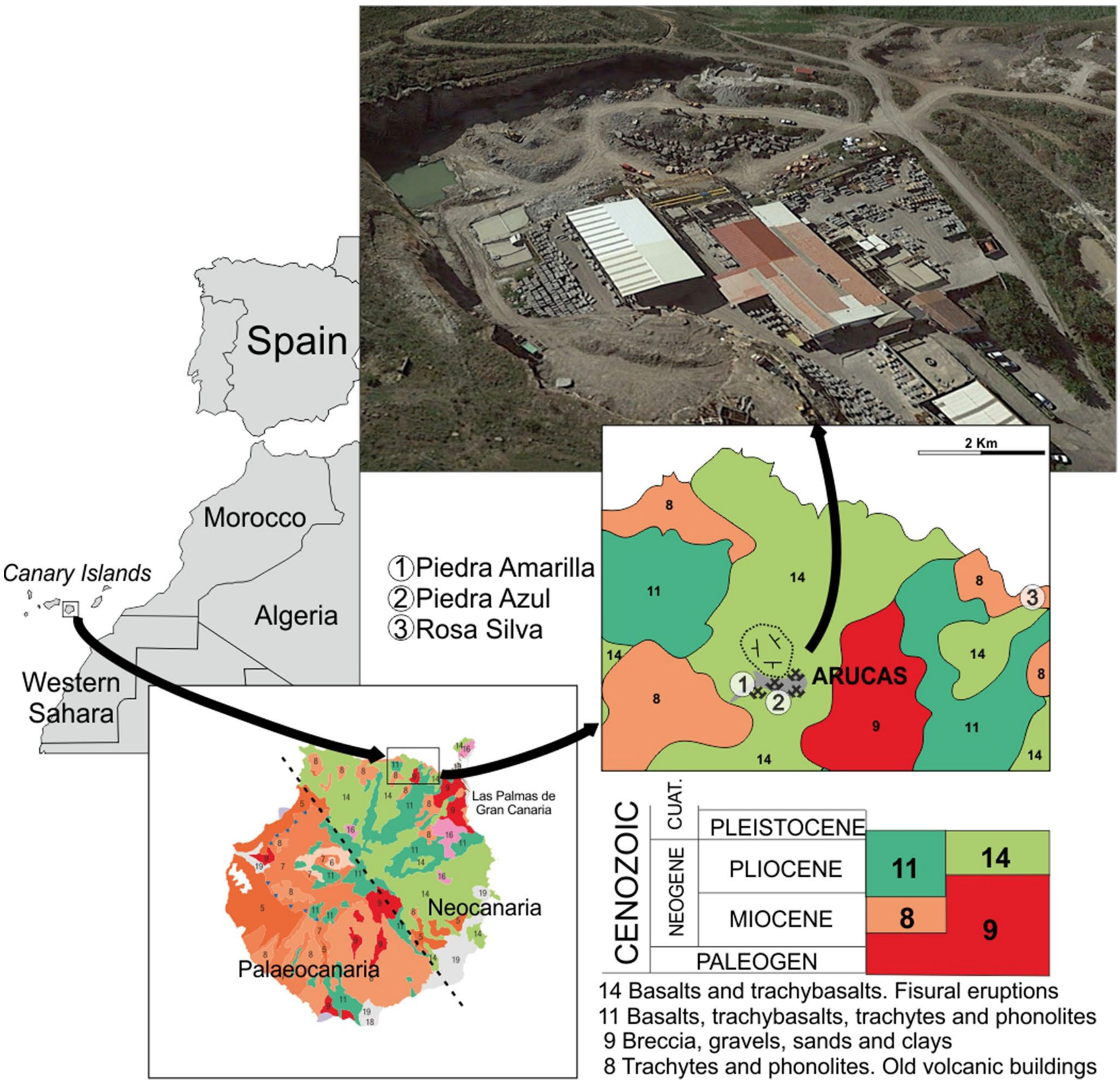

Fig. 1 Geological context, and situation of the Arucas stone quarries. Geological mapping: Spanish Geological Survey, IGME

The Historical Development of Piedra de Arucas

The people that lived in the Canary Islands before the arrival of the Spanish conquistadors were called Guanches. Nowadays, there are few remnants of this culture, since most of the heritage was lost along the centuries after the Spanish conquer. However, some relics have survived until our days, like the *Cueva pintada de Galdar*, where engraved tuff ashlars made by the Guanches have been preserved. Arucas is a small city a few kilometers west of Las Palmas, the capital of the Spanish province of Las Palmas de Gran Canaria, in the Canary Islands. The modern town was founded around 1479 over the remains of the pre-Hispanic town of *Arehuc*. The construction of the new Arucas required many artisans, most of them brought in by the Catholic Church, which had a major hand in the colonization of the Canary Islands. Among these artisans, the master masons had to cover a broad range of tasks, which involved not only cutting and formatting stone ashlars, but also producing millstones, which were indispensable to grind the salt and corn that would sustain the locals' diet. Three varieties of tuff have historically been quarried in Arucas: *Piedra Amarilla* (Yellow Stone), *Piedra Azul* (Blue Stone), and *Rosa Silva*, also known as 'Corea Stone'. The peculiar name of this rock makes reference to the Korea War. It seems that soon after the beginning of this conflict, someone went to the quarry, warning about the war. 'We already have a war with this stone' was the answer, so the quarry became known as the Corea quarry. The first documented Blue Stone quarry opened by the sixteenth century, and the master masons became known as *labrantes*, from the Spanish verb *labrar*, which means 'to cut' or 'to carve' (Cabrera Guillén 2007). By the seventeenth century, the work in the quarries became more specialized, with the emergence of different positions: *oficial* (officer), *pedrero* (stone provider), *maestro cantería* (carving master), and *maestro mayor de canteros* (general foreman). The economic growth of Arucas was boosted by the stone business as well as sugar cane and cochineal production. There were other professionals linked to the quarry work that provided all kinds of goods to the stone industry, such as blacksmiths, shoemakers, tailors, etc. During the nineteenth century, Arucas underwent even greater economic growth than the capital of the province, the neighboring Las Palmas de Gran Canaria. Almost every new house was built entirely with local stone, with ornamented ashlars wherein the *labrantes* showed off their skills, competing with one another. The year 1909 saw the construction of the offices of the *Heredad de Aguas de Arucas y Firgas*, the organization that regulates the distribution of water for farming. Soon after, the *Templo Parroquial San Juan Bautista* church was built. These two magnificent buildings are the most representative historical heritage of Arucas. In fact, the church is so impressive that it is often mistakenly referred to as a cathedral. The quarrying technique was rather simple, since the profitable beds are horizontal, due to the volcanic deposition. The average depth of the quarries was 10–12 m below ground level. The staff was divided into two main groups: the quarrying staff, which extracted and prepared the blocks, and the carving staff or master masons, who gave the blocks their final shape. In between these two groups, there was the *repartidor*, or dealer, who distributed the blocks to the master masons. The *repartidor* did his work sight unseen in order to ensure a fair distribution of the stone, without favoring any particular mason over the rest. Still, the master masons would often bribe him to secure the best stones for themselves. The quarries' distribution was simple: a shack to store the tools and a simple thatch roof to protect the master masons from the harsh sun. Some *labrantes* specialized in a rather difficult and dangerous technique, the *azufrado* ('sulfuring') of the stone. This technique was used to bind pieces of stone together, using a mixture of sulfur and stone powder, which was burned for several minutes. The difficulty was in choosing the correct proportions of stone/sulfur powder, and also in the timing of how the stones were joined together. The sulfur vapors were harmful and would usually irritate the workers' eyes and throat (Cabrera Guillén 2007). Starting in 1960, the new born tourism industry attracted many *labrantes*, who swapped their jobs in the quarries for construction work on hotels and other touristic infrastructures. Today, only three quarries remain active. While demand for Arucas stone remains high, there are various problems currently threatening the sector, such as a lack of skilled workers and competition from foreign stones, coming from other countries, such as China and India.

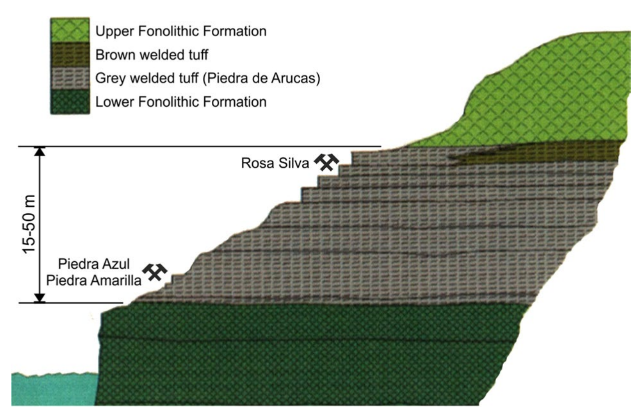

Fig. 2 Stratigraphic sequence of the productive levels. Modified from Mangas 2008

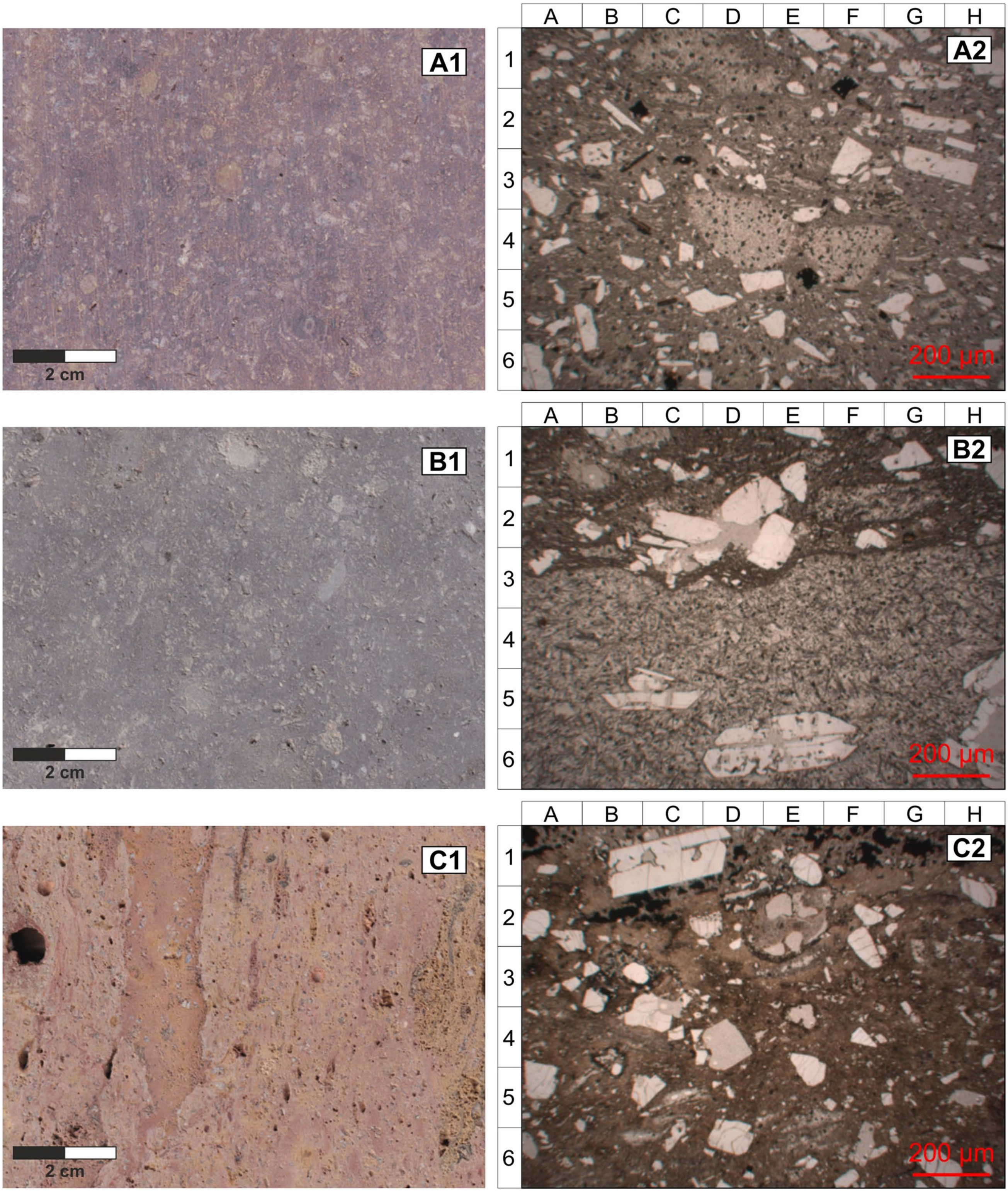

Fig. 3 View of hand specimen (left column) and transmitted light optical microscope (right column). All samples present aphanitic texture, with the development of feldspar crystals. **A** Rosa Silva, **B** Azul, **C** Amarilla

Arucas stone extraction and carving is closely linked to the history, traditions and heritage not only of Arucas, but surrounding villages as well. Most of the quarries are located outside of Arucas proper, but a few are located

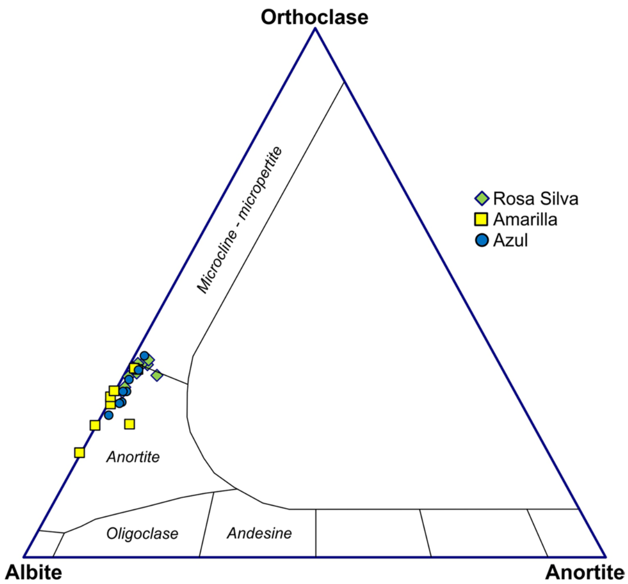

Fig. 4 Compositional ternary diagram for the feldspar. Anortite is dominant in the Amarilla and Azul varieties, while microcline is also presented in Rosa Silva Arucas's stone variety

within the historical town. Rome and Naples (Funiciello et al. 2006) also have tuff quarries located inside their old towns, some of which have been restored for touristic purposes. In Arucas, the space of one of these old quarries has been used to build the museum *La Cantera* (the quarry), opened in 2006 and owned by the local company Mecohersan. After the Spanish Civil War (1936–1939), there were only two job opportunities in Arucas: stone or bananas. Stone workers were by far the best paid, and enjoyed high social standing. Children started working in the quarry at the age of 10, carrying away stone waste for free, and depending on the *labrantes* for tips. If they had interest and skill, they could practice carving at lunch time. After some years of practice, they could try their hand at carving a *cantonera*, a stone conduit used to distribute water to each farming plot. Since water is scarce in the arid Canary Islands, a *cantonera* had to be extremely accurate so that each plot would receive its allotted share of water.

Most of the architecture made with this rock is in the Canary Islands, but there are traces of Arucas stone in the New World (Cuba and Venezuela), brought by the emigration of Canary Islanders (Table 1). Today Arucas stone is being replaced by foreign stones, especially from China, but the mark left by this stone on the history and shape of the region is indelible. However, it is necessary to highlight the value of Arucas stone and its associated heritage, which comprises an indispensable part of the history of the Canary Archipelago.

Geological Context

Gran Canaria and Tenerife are the two main islands of the Canary Archipelago, which forms part of Macaronesia, a group of four volcanic archipelagos in the North Atlantic Ocean, inside the African Plate. Canary Archipelago was formed by successive volcanic eruptions, according to a unifying model which combines the output of a hotspot together with a set of propagating fractures and the effect of tectonically uplifted crustal blocks (Anguita and Hernan 2000). Thus, the age of the islands increases toward the east as the recent eruption of *Cumbre Vieja* volcano also proofs. The younger western islands are still growing, with volcanic landforms of bare rock, while the older eastern islands have undergone significant erosive processes, and their relief is flat and smooth. Gran Canaria (14.6 million years old) is situated in the middle of the chain of islands. Geologically, it is divided into Neocanaria, the NE portion of the island, and Paleocanaria, the SW portion (Fig. 1). Welded tuff (or ignimbrite) quarries are located in Neocanaria, in the terrains created during the Holocene volcanism (Troll and Carracedo 2016). The quarries were located in the terrains formed during the alkaline decline stage, in the Middle Miocene. During this stage, a set of explosive eruptions emitted alkaline felsic magmas subsaturated in silica, forming several pyroclastic and lava deposits, grouped under the name *Phonolithic Formation* (Balcells et al. 1992). Up to 1000 km^3 of different trachytic volcanic materials were emitted, covering the NE portion of Gran Canaria.

Arucas Stone Quarries

Productive levels are located in between two lava flows of the Phonolithic Formation (Fig. 2), formed by stacks of 1- to 7-m-thick pyroclastic flows, together with sporadic few-decimeter-thick sedimentary levels. The rocks are made up of lithic fragments (< 50% abundance). These several-centimeter-long lithic fragments are mainly felsic rocks (phonolites, trachytes), with porphyric-aphanitic textures (Fig. 3). There are also dark-grey pumice fragments, in which it is sometimes possible to identify light and tabular feldspar crystals (Mangas and Solaz 2008), which can reach up to several millimeters in length. SEM analysis of the samples has shown that the mineralogy of these feldspars corresponds to anorthite (Figs. 4 and 5). The chemical composition of the samples is as to be expected for this kind of rocks (Table 2), with high silica and aluminum contents. The ocher color of the *Piedra Amarilla* is due to its high iron content as compared to the other two. Technical data from the three varieties available on the market show a difference between the *Amarilla* and *Rosa Silva* stones on the one hand, and

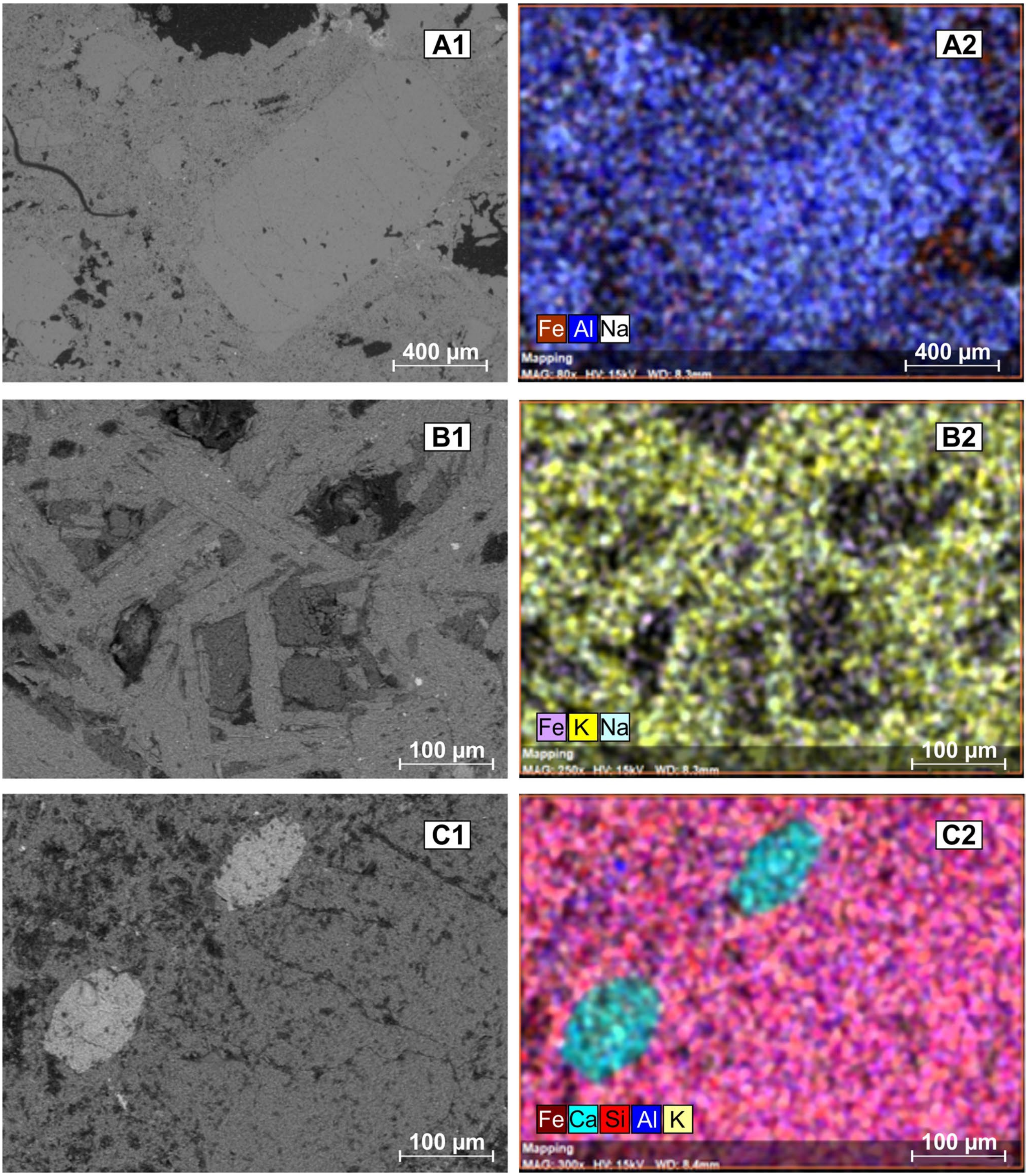

Fig. 5 SEM images and EDX mapping of the samples. **A** Rosa Silva, **B** Azul, **C** Amarilla

the *Azul* stone on the other. The first two have a lower water absorption and lower open porosity than the *Azul*, which in turn presents higher values for the test of salt crystallization (Table 3).

Current State of the Resource

The quarries are exploited using diamond wire combined with occasional powder blasts and expansive cement. Each

Fig. 6 1 view of the quarry *Lomo Tomás de León* (*Piedra Azul* variety); 2 abandoned quarry in the historical town of Arucas; 3 museum *La Cantera*, owned by the company M*ecohersan*, in Arucas; 4 A *cantonera*, for distributing the water to farms, carved in Arucas Stone; 5 The Church of *San Juan Bautista*, also known as Arucas Cathedral; 6 view of the *patio* of the Cultura House of Arucas, built with Arucas stone

Table 2 X-ray Fluorescence determination of the major elements of the three rock varieties. A representative specimen of each variety was analyzed

Sample	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	L.O.I	Total
Rosa Silva	62.46	17.77	3.63	0.21	0.87	0.79	6.43	4.7	0.89	0.14	1.85	99.75
Azul	61.21	17.81	3.85	0.18	0.57	0.48	6.43	5.39	0.9	0.06	2.27	99.16
Amarilla	66.3	13.22	5.29	0.65	0.28	0.16	5.82	4.16	0.99	0.07	3.05	99.99

Table 3 Technological properties of the Arucas stone varieties. Data provided by the companies Cantería de Arucas (Corea and Azul) and Mecohersan (Amarilla)

Sample	Bulk Density	Open porosity	Water absorption	Compressive strength	Flexural strength	Charpy impact test	Abrasion resistance	Slip resistance		Salt crystallization
								Dry	Wet	
Corea	2.45 g/cm^3	3,70%	1,00%	82.95 Mpa	16.9 Mpa	5.55 J	9.97 mm	83	80	1,00%
Azul	2.10 g/cm^3	19,68%	5,46%	74.66 Mpa	7.82 Mpa	3.87 J	19.87 mm	88	87	5,03%
Amarilla	2.15 g/cm^3	0,14%	4,50%	109.13 Mpa	12.50 Mpa	–	10.80 mm	85	92	0,58%

quarry front is cleaned and prepared according to the pyroclastic lava flow that created it. Each front is subdivided into several parts, from which blocks measuring between three and seven cubic meters are extracted and brought to the factory. The blocks are sawed using a multi-disc automatic block cutter. Nowadays, only three quarries are active: *Piedra Azul* (Blue Arucas Stone, Lomo Tomás de León, Canteria de Aucas company quarry), *Rosa Silva* (Pink Silva, Montaña Cardones, Canteria de Aucas company quarry), and *Piedra Amarilla* (Yellow Ayagures stone,Ayagures *Mecohersan* company quarry). Current production is mainly focused on restorations of historical buildings and to supply the Canary Islands' internal market (Fig. 6). The future of this stone is uncertain, since stricter environmental legislation does not provide exceptions for historical quarries and foreign material competition which have decreased the profitability of these centuries-old quarrying and masonry tradition.

Conclusions

Arucas stone is a good example of how a particular stone has shaped the historical development of a region. Becoming a *maestro cantero*, or master mason, was the highest achievement for a local worker. Even today, the figure of the *maestro cantero* has a special status on the island of Gran Canaria. This stone is a good example of how a community has developed and taken shape around the quarrying of a stone resource. Moreover, an important part of the historical and architectural heritage of the island of Gran Canaria has been built with this stone. And yet, the existence and viability of the quarries is threatened by new environmental legislation and, even more so, by competition from abroad. Its current situation, together with its historical significance, makes this rock a suitable candidate for Global Heritage Stone recognition.

Declarations

Competing Interests The authors declare no competing interests.

References

Anguita F, Hernan F (2000) The Canary Islands origin: a unifying model. J Volcanol Geoth Res 103:1–26. https://doi.org/10.1016/s0377-0273(00)00195-5

Arizza M (2018) Tuff quarrying in the territory of Veii. A 'status' activity of the landowning aristocracy of the archaic period, from construction to craft. Scienze dell'Antichitá 24:101–109

Balcells R, Barrera JL, Gómez JA, Hernán F, Schimincke HU, Cueto LA (1992) Mapa Geológico de España 1:100.000, hoja 21–21/21–22 (Gran Canaria). IGME

Cabrera Guillén D (2007) El oficio de la piedra en Arucas y su puesta en valor como recurso turístico.

Cárdenes V, Mateos FJ, Fernández-Lorenzo S (2014) Analysis of the correlations between freeze–thaw and salt crystallization tests. Environ Earth Sci 71:1123–1134. https://doi.org/10.1007/s12665-013-2516-7

Careddu N, Grillo SM (2019) “Trachytes” from Sardinia: geoheritage and current use. Sustainability 11:3706
Cooper BJ (2010) Toward establishing a “Global Heritage Stone Resource” designation. Episodes 33:38–41
D’Orazio L, Grippo A (2015) A water dispersed titanium dioxide/poly(carbonate urethane) nanocomposite for protecting cultural heritage: preparation and properties. Prog Org Coat 79:1–7. https://doi.org/10.1016/j.porgcoat.2014.09.017
Esaki T, Jiang K (1999) Comprehensive study of the weathered condition of welded tuff from a historic stone bridge in Kagoshima. Jpn Eng Geol 55:121–130. https://doi.org/10.1016/S0013-7952(99)00112-X
Funiciello R, Heiken G, Levich R, Obenholzner J, Petrov V (2006) Construction in regions with tuff deposits. In: Heiken G (ed) Tuffs. Their Properties, Uses, Hidrology and Resources. Special paper 408. Geological Society of America, pp 119–126
Heiken G (2006) Tuffs - their properties, uses, hydrology, and resources (GSA Special Paper 408)
Le Maitre RW (2002) Igneous rocks. A Classification and Glossary of Terms. 2nd edn. Cambridge University Press
Mangas J, Solaz I (2008) Rocas industriales de la Formación Fonolítica Miocena en Gran Canaria: puzolanas, áridos de trituración y rocas ornametnales. In: Pérez-Torrado FJ, Cabrera MC (eds) Geo-Guías. Itinerarios Geológicos por las Islas Canarias. Gran Canaria. Sociedad Geológica de España, Las Plamas de Gran Canaria, pp 137–152
Maras M, Kose M, Rizaoglu T (2021) Microstructural characterization and mechanical properties of volcanic tuff (Malatya, Turkey) used as building stone for the restoring cultural heritage. Periodica Polytechnica Civ Eng. https://doi.org/10.3311/PPci.16977
Nijland TG, Van Hees RPJ, Bolondi L (2010) Evaluation of three Italian tuffs (Neapolitan Yellow Tuff, Tufo Romano and Tufo Etrusco) as compatible replacement stone for Römer tuff in Dutch built cultural heritage. In: Přikryl R, Török A (eds) Geological Society, London, Special Publications, vol 333. pp 119–127. https://doi.org/10.1144/SP333.12
Siedel H, Rust M, Goth K, Krüger A, Heidenfelder W (2019) Rochlitz porphyry tuff (“Rochlitzer Porphyrtuff”): a candidate for “Global Heritage Stone Resource” designation from Germany. Episodes 42:81–91. https://doi.org/10.18814/epiiugs/2019/019007
Troll V, Carracedo JC (2016) Geology of the Canary Islands. Elsevier
Zatler-Zupancic B, Mladenovic A, Ramovs A, Vesel J, Avgustin C (1992) Andesite tuff in Slovenia: part of the cultural heritage of Gorenjska. In: 7th International Congress on Deterioration and Conservation of Stone, Lisbon, pp 99–108