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Azul Platino: a bluish granite from Extremadura (Spain) to be considered in the context of architectural heritage

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Granite quarrying is one of the main industries operating in Spain, and was severely affected by the economic crisis that began in 2008. Although the industry is slowly recovering from this event, new construction activity has not fully recovered. For a company to be competitive in the stone market, it must consider the overall characteristics of the materials it provides and their importance with regard to architectural heritage, with the aim of using original types of stone in restorations. In the area of Trujillo (Extremadura, Spain) a variety of striking bluish and secondary yellow granites outcropping within the Plasenzuela pluton have been analysed. These two varieties are quarried under different names and petrographically characterized by leucocratic minerals with a bluish phosphate dispersed throughout the rock. Their physical and mechanical properties make these granites a perfect option for most applications as ornamental rocks. The bluest variety, Azul Platino, has been used in local, national and international projects and fulfils the necessary requirements that would allow it to be considered a Global Heritage Stone Resource (GHSR).

Introduction

Azul Platino granite outcrops from the Plasenzuela pluton are located SW of Trujillo (Cáceres), between the municipalities of Plasenzuela and La Cumbre. They form an intrusion that together with other plutons (e.g., Trujillo, Albalá (Monteserín and Pérez Rojas, 1982) make up the Central Extremadura batholith in the southern Iberian massif (Ramírez, 1953; Castro and Fernández, 1998; Castro et al., 1999; Pereira et al., 2012) (Fig. 1). These plutons, with a clear crustal signature, intruded during the last stages of the Hercynian orogeny and are emplaced, cutting the Schist Greywacke complex metasediments (Pereira and Rodríguez Alonso, 2000, and references therein), causing a sharp contact metamorphism, as described in Monteserín and Pérez Rojas (1982). Both the granites and the affected metasediments have been the subject of different mining research projects, focusing on raw materials (e.g., Ag, Pb, U, Sn, W, Li (Guijarro et al., 1984; Lago et al., 1989), as well as ornamental stones, owing to their striking blue colour (Azul means Blue in Spanish). Hernández Sobrino and Higueras (1991) published data on the fractures and physical and mechanical properties of some of the bluish granites during their assessment of the economic possibilities of quarrying this rock. These authors suggested that the blue hue originates from the presence of quartz, similar to that of other bluish granites and volcanic rocks. Although this statement has traditionally been accepted, our work has determined that the colouring mineral phase is a phosphate, specifically baricite, as shown by microprobe analyses and x-ray diffraction of concentrates. This bluish phosphate accumulates in shear structures and rock and mineral fractures and is easily recognizable in thin sections.

Plasenzuela pluton is made up of granites of the alkaline series (Monteserín and Pérez Rojas, 1982) and is similar to Trujillo pluton, although their mineralogical and geochemical characteristics are slightly different. Both are characterized by an intense fluid activity during their final emplacement, which resulted in the accumulation of phosphates and borosilicates that gives these granites their appealing bluish colour. Fieldwork has shown that these granite outcrops are made up of very fresh rocks called Azul Platino and Azul Trujillo and slightly weathered rocks called Amarillo Platino and Amarillo Trujillo, which seem to represent a superficial layer of a few meters thick in some areas of the pluton (see below for other names). All varieties, fresh and more weathered, are commercialized, but in this work we will only refer to the characterization of Azul Platino, as this is the rock intended to be a candidate as Global Heritage Stone Resource (GHSR) at the moment.

Azul Platino as a Global Heritage Stone Resource

The essential characteristics of a Global Heritage Stone Resource (GHSR) were first published in Hughes et al. (2013). This concept was defined by the International Union of Geological Sciences (IUGS) Heritage Stone Task Group (HSTG, Cooper et al., 2013) and developed following the HSTG "Terms of Reference". The HSTG was promoted to the IUGS Subcommission (Heritage Stones Subcommission) and the updated Terms of Reference together with information on potential GHSR candidates and the already recognized and designated GHSR stones can be found at the Subcommission's webpage (http://globalheritagestone.com/other-projects/ghsr/).

A GHSR candidate must have a cultural history that encompasses a

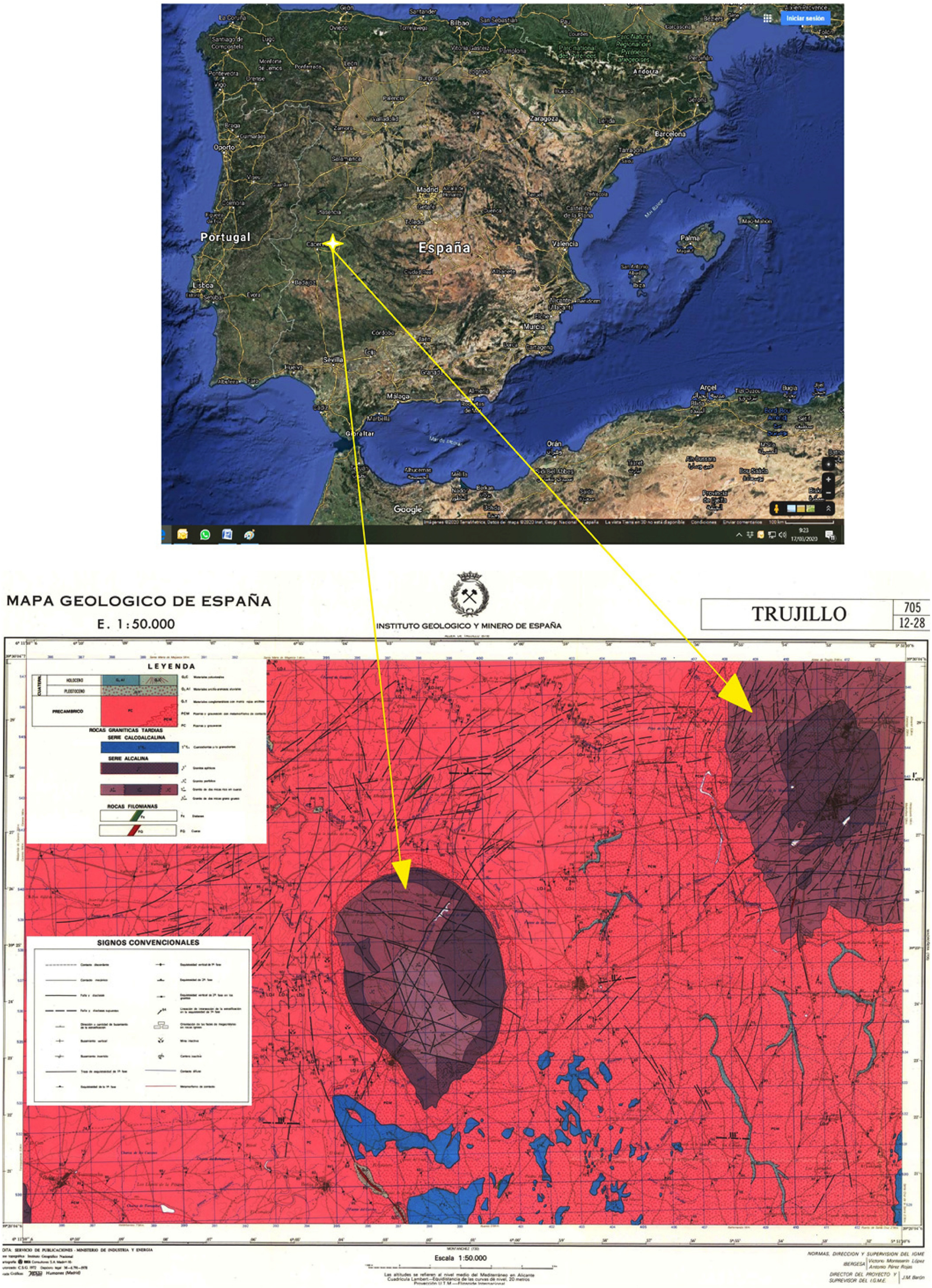

Figure 1. Location of Plasenzuela (left) and Trujillo (right) plutons. Modified from Monteserín and Pérez Rojas (1982).

significant period of time and used in major works for building, sculpture or utilitarian applications. Wide geographical use extending to several countries, if possible, is important, as well as recognition as a cultural icon, potentially including association with a national identity or a significant individual contribution to architecture. It is also recommended that a full description of the quality of the mineralogical, geochemical and physical and mechanical characteristics is included. As a result, the information of the cited stone becomes available to researchers, architects and all the possible stakeholders related to construction and restoration activities; in the case of Azul Platino all of these characteristics have been analysed. Contemporary quarrying and therefore the on-going availability of a GHSR for construction can increase the status of a GHSR, which is also beneficial. Because of its availability, technical investigations are encouraged and the continued use of the GHSR stone is promoted. With contemporary quarrying, GHSR designation may safeguard the resource from future inaccessibility resulting from quarry closure. Such inaccessibility has long been a problem given the sometimes very close proximity of dimension stone quarries to other human activities.

When nominating a particular stone as a potential GHSR, there is a procedure that includes a checklist with the main characteristics of the candidate stone. This checklist is normally included in a report that is published in a widely recognised international journal and can serve as the proposal itself. This step allows many stones from around the world described in obscure publications or in minority or inaccessible languages to reach wider audiences, allowing the specific stones to become better known worldwide.

Below is presented the checklist for Azul Platino with the most updated information:

Formal Name: Azul Platino.

Other Names: There are other names for similar stones quarried in areas nearby or even in the same quarry: Azul Trujillo, Violeta Trujillo, Amarillo Platino, Amarillo Trujillo. However, the stone described in this paper has the only formal name of Azul Platino (UNE EN 12440: 2008).

Place of Origin: Trujillo Region, province of Cáceres, in Extremadura, Spain.

Resource Location: Azul Platino is exclusively extracted in Extremadura (Fig. 2), with several quarries close by, and slight differences in colour can be observed.

Quarrying: Currently there are several companies operating in the Plasenzuela pluton extracting the Azul Platino variety: DFG Quarries (Group David Fernandez Grande), DFG-Deogracias, S.L., Granitos Tena, and Marcelino Martínez. Exact location of the quarries are:

DFG-Deogracias, S.L. (39.427477, -6.046319): 39°25'38.9"N 6°03'32.8"W
DFG Quarries (39.430593, -6.046319): 39°25'50.1"N 6°02'46.8"W
Granitos Tena, S.L. (39.413951, -6.067433): 39°24'50.2"N 6°04'02.8"W
Marcelino Martínez: (39.409707, -6.059107): 39°24'35.0"N 6°03'32.8"W

Quarrying this granite is one of the most important activities of the area (Fig. 3).

Heritage issues: The Azul Platino quarries are being considered within the European Quarry Landscape project that considers historic quarries and landscapes formed by quarrying across Europe (http://www.quarrylandscapes.teruel.es/). Although there is no published information on the historic quarries of Plasenzuela, there is a large compilation of data for historic quarries containing Trujillo granite (also commercialized as Azul Trujillo). In fact, Trujillo pluton has been designated as a Site of Geological Interest by the_Spanish Geological Survey (http://

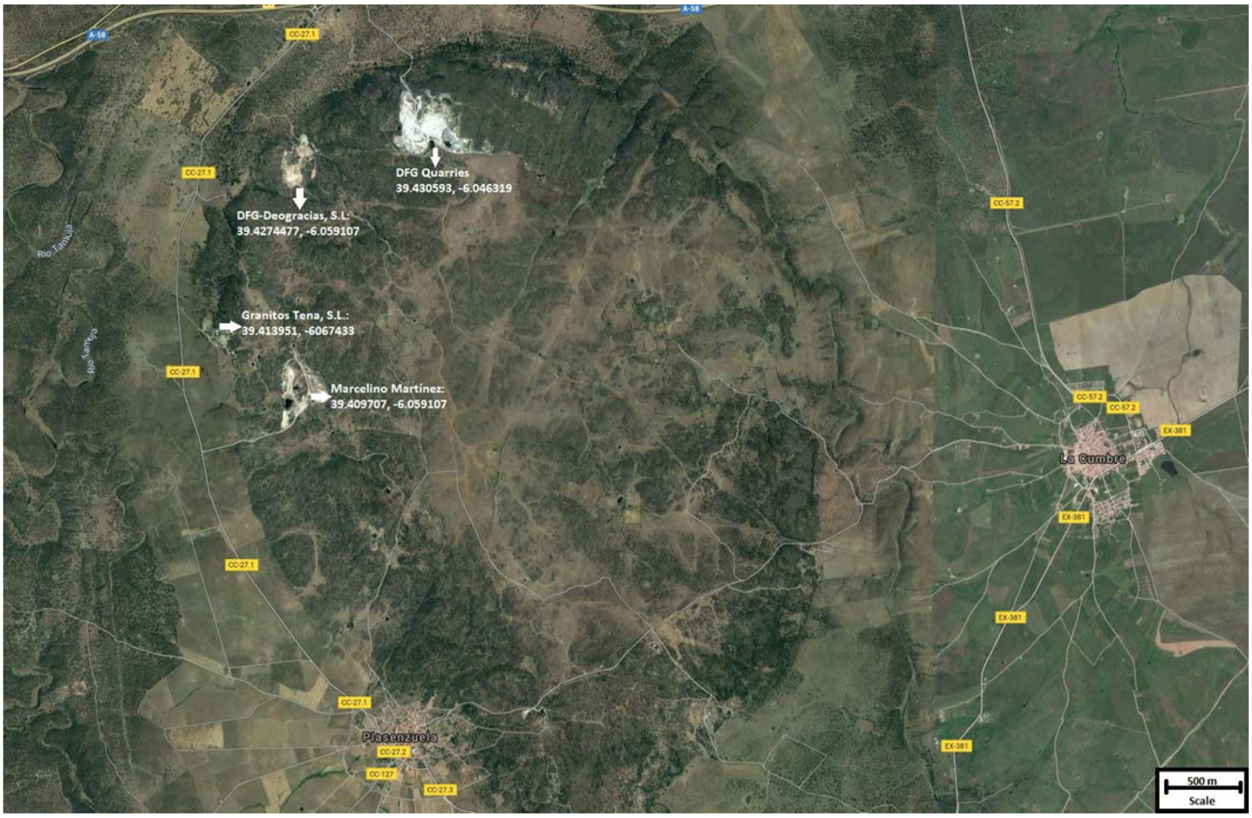

Figure 2. Location of Azul Platino quarries in Plasenzuela pluton. Satellite images are from Google Earth.

Figure 3. One of the quarries of Azul Platino in the Plasenzuela pluton.

info.igme.es/ielig/LIGInfo.aspx?codigo=CI178).

Petrographic Name: Two mica granite (Leucogranite in some cases)

Mineralogical composition: The granite has a medium-to-course granular texture with very few feldspar phenocrysts. Occasionally there is biotitic schlieren, although this is not generalized and would be considered an imperfection and an obstacle for commercializing the affected granite block. Azul Platino is made up of quartz, orthoclase and albite as essential minerals, with accessories such as muscovite, biotite (frequently chloritized), apatite, zircon, hematite, tourmaline and baricite. The latter is visible in the outcrop and in smaller specimens due to an intense blue colour.

Figure 4. Accumulation of baricite in a fracture affecting the Azul Platino granite. These crystals were manually separated for X-ray diffraction to identify the phosphate.

Baricite has a laminar texture, filling shears and microfractures (Fig. 4) and also within all the different mineral phases: feldspar, muscovite, tourmaline, and apatite (Fig. 5).

Colour: Azul Platino appears with different shades of colour, although the bluish colour is always conspicuous in various tones depending on the amount and the location of baricite present in the rock.

Natural variability: Azul Platino may differ in appearance, as its superficial layer can be weathered (Fig. 6). In fact, this weathered variety is also extracted and commercialized as Amarillo Platino granite (UNE EN-12440, 2008), which is very popular for achieving a rustic finish. The mineralogical composition of Amarillo Platino is exactly the same, but some sericite is found included in the feldspar, as well as some iron oxides, giving the yellowish colour. The many different possible finishes (polished, honed, aged, bush hammered, shot blasted, flamed, satin...) alter the appearance and the rock's colour. However, the polished finish is the preferred one for showing its characteristic colour (Figs. 7a, 7b).

Suitability: The high density and uniformity of the stone allows it to take on an excellent polish, making its use as a dimension stone highly versatile. It can be used in nearly every kind of application in building, garden and landscape architecture, decoration and sculpture. This stone becomes adaptable to all surfaces in inhabitable spaces and in interior (countertops, walls, floors) and exterior decoration (façades and floors).

Commercial name: Azul Platino is a stone included in Annex A, UNE EN 12440 (2008). This annex is a non-exhaustive list of most European natural stones and is the first attempt at listing the stones produced in Europe and their petrographical classification. The data

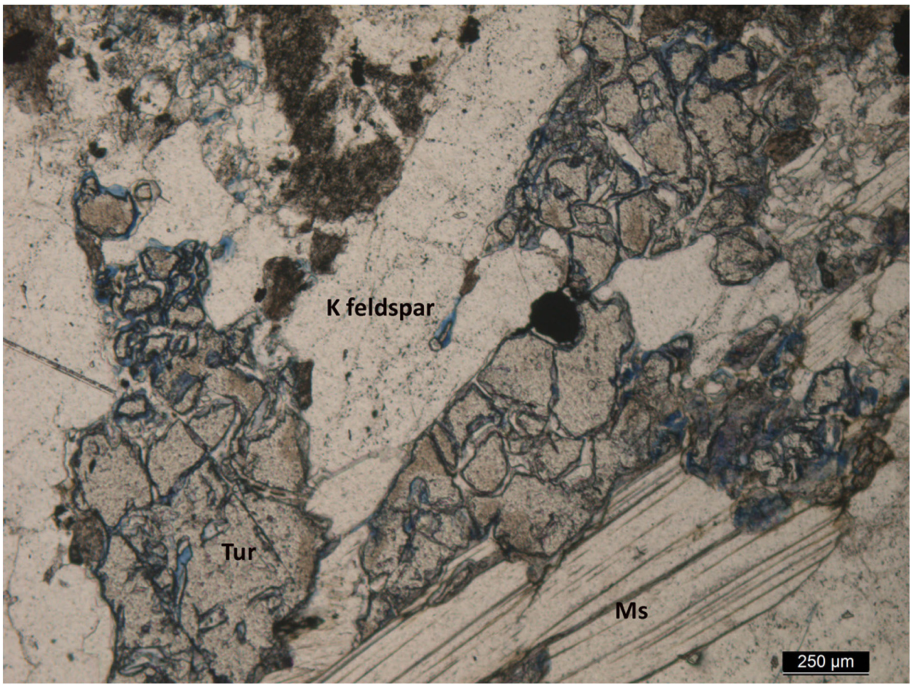

Figure 5. Baricite as blue inclusions in muscovite (Ms), tourmaline (Tur) and potassium feldspar (K feldspar). Symbols from Kretz (1983).

Figure 6. Transition from Azul Platino (right) to Amarillo Platino (left) in the quarry. The latter is the weathered facies of the first one.

on each stone variety is structured providing the following information: name or names (traditional name), petrological family, typical colour and place of origin, which in part coincides with the GHSR check list. We would like to point out that several mistakes have been detected in this Annex. For example, Azul Platino is described as a porphyric two mica granite, when we have demonstrated that the appearance of large crystals of feldspar is very unusual, and sometimes can be easily described as leucogranite, because the absence of melanocratic phases such as biotite.

Geochemistry: Major and trace elements were determined by ICP OES and ICP MS respectively. The composition of Azul Platino places this granite within the field of the alkaline series, as described by Monteserín and Pérez Rojas (1982). A detailed chemical description can be found in Pereira et al. (2012). The largest geochemical difference observed between Azul Platino and the weathered variety is reflected by the slightly higher LOI (Loss on Ignition) values for the latter, having very similar values for major and trace elements.

Physical and Mechanical Properties

Vulnerability and maintenance of supply: Azul Platino, together with other bluish ornamental granites quarried in Extremadura, is present in high amounts and the quarry fronts are the most extensive within the Iberian Peninsula. This granite industry is one of the economic bases of the region. Therefore, the proper characterization of these granites help in their exploitation and to maintain supplies for construction and restoration purposes.

Production figures: In 2016 the estimated production of Azul Platino in the quarry was approximately 60.000 Tons. In addition, 30 people are employed to work directly in the quarry and several other employees carry out different types of activities.

Historic Use: Azul Platino granite has been used for centuries, first within the area surrounding the extraction site and then subsequently in other areas, both nationally and worldwide.

The town of Trujillo was built as a fortress on top of a large pluton, the pluton of Trujillo. It has been the home of ancient cultures including the Roman and pre-roman cultures, Muslims and Christians. This rich heritage was built almost entirely around the granite massif on which the city sits and the nearby plutons, such as Plasenzuela, which mostly comprise two mica granites and leucogranites from the plutons of Trujillo and Plasenzuela.

Buildings: In addition to the heritage architecture built using this granite in the historic city of Trujillo and surroundings, Azul Platino granite was used in the construction of many important projects in Spain, Europe and all around the world. Examples of these include:

- La Guardia Airport (NYC, USA)
- Yokohama Bridge (Tokyo, Japan)
- European Parliament (Brussels, Belgium)

Table 1. Physical and mechanical properties of "Azul Platino"

Property	Value*	Recommended value**
Water absorption (%)	0.2	0.4 (max)
Density (kg/m^3)	2650	2560 (min)
Open Porosity (%)	0.8	n.a.
Mean Compressive Strength (MPa)	160	131 (min)
Mean Flexural Strength (MPa)	14.4	8.27 (min)
Wear resistance (mm)	19	n.a.

n.a. Not available
*Roc Máquina, 2008
**ASTM C-615 "Standard Specification for Granite Dimension Stone"

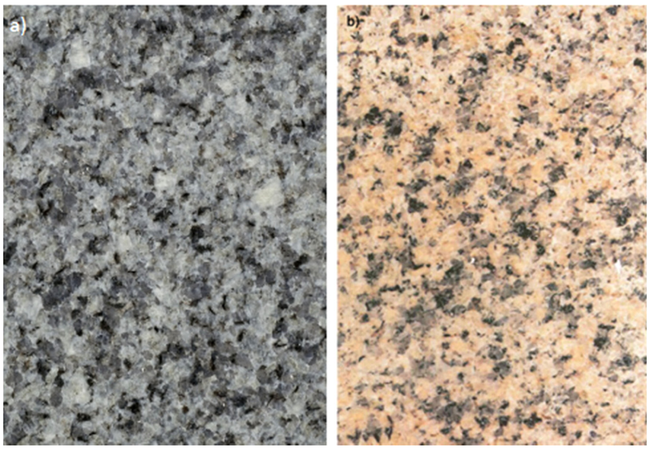

Figure 7. Polished plates of a) Azul Platino and b) Amarillo Platino.

- Planetarium (Valencia, Spain)
- Tenerife Auditorium (Tenerife, Spain)
- Suntec City Mall, (Republic of Singapore)
- MTR Kowlonn Station (Hong Kong, China)
- Citizens Centre (Hangzhou, China)
- O´Connel Street (Dublin, Ireland)
- Oficinas DFG (Monçao, Portugal)
- Plaza de San Marcos (León, Spain)
- New NATO offices building, interior and exterior (Brussels, Belgium)
- Plaza de la Estrella (Vigo, Spain)
- Lavacolla Airport (Santiago de Compostela, Spain)
- Aeropuerto de Bilbao (Bilbao, Spain)
- Haramain High-Speed Railway Station (Jeddah, Saudi Arabia)
- l'Assut de l'Or Bridge (Valencia, Spain)
- Agora (city of Arts and Science, Valencia, Spain)

Pictures for most of these buildings can be seen at: http://pavestone.es/pav/es/proyectos/azul-platino

Other characteristics: One important characteristic of this natural stone is the low radon exhalation produced by the different varieties, including the more weathered stones. This quality is particularly relevant when considering its use in interior spaces (Pereira et al., 2012).

Conclusion

Azul Platino has a striking bluish colour and its properties make this granite a perfect option for most applications as an ornamental stone, both in interior and exterior environments. Additionally, it has been used for centuries, first for building the architectural heritage in the area surrounding the extraction site, and then subsequently for carrying out many important projects in Spain, Europe and around the world.

Azul Platino fulfills all the necessary requirements for its consideration as a Global Heritage Stone Resource. Together with other local natural stones from Extremadura, Azul Platino could also form part of the designation of a Global Heritage Stone Province (Pereira and Cooper, 2014).

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