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QUARRY IDENTIFICATION AND CHARACTERIZATION OF 2nd CENTURY A.D. ROMAN GRANITE COLUMNS FROM ECIJA (SPAIN)

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ABSTRACT

Rock column is one of the most representative structural elements used in Roman buildings. Its main section is the shaft, a cylindrical conduit between the base and the chapiter. Their decontextualization sometimes makes it difficult their provenance. This is the case of granite shafts coming from the ancient *Colonia Augusta Firma Astigi*, nowadays Écija (Seville, Spain).

In this paper, 52 pieces of granite shafts preserved both along the streets and in the Municipal History Museum of Écija have been studied, to understand the provenance of the granite used in its construction and the type of building where they were employed. An approximation of the granite composition based on the quantity of the main minerals was carried out by digital image analysis. This non-invasive technique allows us to identify the main characteristics of the granites according to their provenance. Additionally, the column heights were calculated according to Roman treatises of architecture.

The combination of these techniques allowed us to determine the quarries of the granite columns. The results showed that 20 shafts may come from the Troad region (Turkey), which granite was one of the most commonly used in the Roman constructions on the provinces; although granite from other quarries, i.e. Gerena (Spain) or Forum (Egypt), might have been used in this city during the 2nd century AD too. The relationship between provenance of the granite and height of the column allows us to specify aspects referred to the magnification of buildings or the sponsors of the monumentalization of public spaces carried out in time of the Roman emperor Hadrian.

KEYWORDS: Characterization, Columns, Écija, Granites.

1. INTRODUCTION

Columns are one of the most employed supports in Ancient Rome, and even became a purely architectural element for decoration. At the beginning of the 2nd century AD, a special predilection for the use of granite shafts was developed (Lazzarini, 1987). The extraction of the stones from the quarry and their polishing required a high skill, especially in the case of big shafts, because geometrical regularity is one of the main characteristics in the Roman architecture (Fig.1).

Granites, porphyries, basanites, breccias and marbles mainly came from Imperial quarries -*patrimonium caesaris*- (Padilla, 2000). These stones were exported from there to the most important cities of the empire (Pensabene, 2006). This Imperial interventionism favoured a higher supervision in the supply and quality of materials in the most relevant construction projects.

The main granite quarries used in the Roman empire were Troad (Turkey), Elbe and Giglio (Italy) and Mons Claudianus or granite of the Forum (Egypt), together with the quarries of Misia (Turkey) and the Spanish granite Types I, II and III, the latter named with these nomenclatures after Williams-Thorpe and Potts (2002) according to their main characteristics (Fig. 1). All these stones were seaborne through the empire. Pliny the Elder and Ammianus Marcellinus (according to Padilla (2000)) described the use of *naves lapidariae*, ships specially designed to transport marble and other stones to the main imperial ports. From these ports, stone materials were distributed with lighter ships or boats to the places where they were needed.

Figure 1: Main granite quarries used by the Romans during the 1st-2nd centuries AD (red points) and main ports related to the distribution of granites to Astigi (blue points).

One of the most important Roman cities in the Iberian Peninsula was *Colonia Augusta Firma Astigi*, now Écija (Seville, Spain). This city, founded about 25-22 BC by emperor Augustus, is placed in a rich agricultural area and in the crosspoint between one of the most important roadways in the ancient Hispania -*Via Augusta*- and the river *Singilis* (now Genil, main tributary of the river Guadalquivir) which was navigable at that time. The trade and the exportation of products, especially olive oil, supported a rapid growth of the city. All these reasons determined *Astigi* to be appointed as the capital of one of the four *conventus iuridici* (*conventus Astigitanus*) in the Roman province of *Baetica* (Carrasco and Jiménez, 2017).

Augustus designed a new city with an extension about 49 ha. The city was populated by veteran military from the Roman Legions *II Pansiana*, *IV Macedonica* and *VI Victrix* that took part in the *deductio*. They were assigned to the *Papiria* tribe (Ordóñez, 1988).

The city developed an important economic and social growth in the 1st-2nd centuries AD. During the rule of the Emperor Hadrian, the city was embellished with several architectural projects. Buildings materials from other parts of the Mediterranean basin were imported to *Astigi*, especially granites (Lazzarini, 2002; Márquez, 2002), being this stone more resistant than marble for the construction of building structures (Felipe, 2013; 2014).

Nowadays, a wide variety of archaeological remains are preserved both along the streets and in the Municipal History Museum of Écija. These remains confirm the prestige achieved by the city during the Roman empire. Some researchers have previously made slight approaches to ascertain the provenance of these materials, especially in the case of columns, by morphological studies (Felipe, 2008; 2013; 2014), or non-destructives techniques, i.e., portable gamma ray spectrometry (Williams-Thorpe and Potts, 2002).

In this study, 52 granite shafts from Écija (Seville, Spain) were studied in order to analyse their quarry provenance and original building context. Shafts have commonly been reused for churches, palaces or house, so they are rarely found in the original archaeological site. Visual inspections and petrographic studies are well-extended methodologies to identify quarries (Columbu et al. 2018) and the use of digital image analysis is helpful to estimate granite composition. Additionally, the reconstruction of the size and shape of the shaft pieces from Écija has allowed us to make an interpretation of the Roman buildings which they could belong to. This approach and the quarry identification allows us to identify origin and sponsors of the monumental period of Écija during the 2nd century AD.

2. MATERIALS AND METHODS

52 pieces of granite shafts conserved in the historic centre of Écija and its Municipal History Museum were studied (Fig. 2). Additionally, 16 samples from columns with similar characteristics were included in the study as patterns of different quarries. These columns are dated in the 1st-2nd centuries AD and are placed in Hadrian's Villa (Tivoli, Italy), the Pantheon pronaos (Rome, Italy), the Birds house (Itálica, Spain) and columns placed in Alemanes street, Mármoles street and Alameda de Hércules in Seville (Spain).

Figure 2: Examples of columns and shafts coming from Écija. (a) ECI-F-12 and ECI-F-13, façade of Santa Bárbara church. (b) ECI-F-42, Santa Florentina street. (c) ECI-F-16, San Pablo gardens. (d) ECI-F-2, ECI-F-32 and ECI-F-38, Municipal History Museum of Écija.

The methodology used to determine the quarry of the granite shafts is based on the correlation between the architectonic inventory and the mineralogical characterization of the granites, comparing the results with previous studies about the possible quarries used and samples of shafts made with their stones (Antonelli and Lazzarini, 2004; Antonelli, Lazzarini and Cancelliere, 2010; Bruno, 1998; De Vecchi et al., 2000; Lazzarini and Sangati, 2004; Ponti, 2002).

2.1. *Mineralogical and petrographic characterization*

Granite is an igneous rock formed by mafic and felsic minerals with a high colour contrast. The identification of the samples was made by visual inspection, Zarbeco handheld digital microscope and petrographic analysis. The quantification of mineralogical components was studied by digital image analysis.

70 granite shafts from Écija and the selected monuments as prototypes of quarries were studied[1]. Samples were taken to 19 shafts, following the recommendation of CNR-ICR NORMAL 3/80 (1980) for sampling in monuments. These 19 samples were studied by optical and/or petrographic microscope. Petrographic thin sections of samples were made

[1] There is a large shaft reused in the 16th-century stables of Palacio de Valdehermoso which we could not access for this study.

with an epoxy resin (Technovit® 4004) and analysed under a petrographic microscope Motic BA310Pol.

Digital image analysis has become a useful tool for the study of cultural heritage, i.e., cave paintings (Domingo, 2014), characterization of archaeological ceramics (Campos et al., 2003; Reedy et al., 2014) or evaluation of weathering form in historic buildings (Rogerio-Candelera, 2016; Ortiz et al., 2017). In this case, the digital image analysis was employed to decrease the uncertainty caused by visual inspections. The quantification of the major minerals in each granite allowed to make a comparison between the quarries and the Écija shafts. For that, 20 photographs were taken to each shaft, taking into consideration the lens distance to avoid possible deformations in the image and focusing through a window of constant dimension. The images were scaled to centimetre and converted into grayscale using the software GIMP®.

Digital image analysis was made with the software Image Pro-Plus®. According to Becerra et al., (2020), the images were segmented using the histogram tool in three different ranges of colour. Each colour range corresponds to one of the major minerals present in granite stones: quartz, feldspar and biotite. The percentage of each mineral was calculated in based of the number of pixels that form each colour area in comparison with the total pixels of the image. These quantifications were calculated with the count/size and range statistics tools of the software. The samples were classified according to the percentage of each mineral in five compositional groups:

- Group 1: Granites with a high content of biotite (>40%) and a content of quartz and feldspar lower than 60%.
- Group 2: Granites with a content of quartz higher than 80%, biotite between 20-40% and feldspar lower than 50%.
- Group 3: Granites with a content of quartz higher than 60%, and a low content of biotite (<20%) and feldspar (<40%).
- Group 4: Granites with a content of quartz between 30-60%, feldspar between 20-70% and biotite lower than 20%.
- Group 5: Granites with a high content of feldspar (> 50%) and low presence of quartz (<30%) and biotite (<40%).

2.2. *Morphological characterization*

According to Vitruvius' canons of aesthetic proportion (Vitruvio, 2001), the column was the architectural element that defines the building proportion in Roman architecture. The imoscape diameter, that is the diameter of the shaft base, was the module of the building and was calculated according to the façade width (Esteban, 2001). Furthermore, shafts were characterized by a slimming towards the top (sumoscape). The proportion between imoscape and sumoscape was related with the column height (Table 1).

Table 1. Proportion between imoscape, sumoscape and column height according to the canons of Vitruvius (2001).

HEIGHT (Roman feet)	HEIGHT (m)	PROPORTION Imoscape:Sumoscape
<15	<4.43	6:5
15-20	4.43-5.91	6 1/2: 5 1/2
20-30	5.91-8.87	7:6
30-40	11.87-11.82	7 1/2: 6 1/2
40-50	11.82-14.78	8:7

A theoretical reconstruction of the columns based in the pieces of shafts was carried out according to the interpretation of the Vitruvius' canons made by Jones (2003). Shafts were classified in 3 groups. The first one is shafts that only conserve its imoscape. The reconstruction was made according to the relation imoscape-column height, as these shafts do not conserve its sumoscape. It was used as general rule the proportion 1/8, where 1 was the module and 8 the shaft height. This is the most usual proportion in Écija, according to Felipe (2006). Next, the size of the base and capital was calculated according to Jones (1989). The height of the column was calculated as the addition of the base and capital height to the shaft height. The second group includes shafts that conserve the sumoscape instead of the imoscape. In this case, the module was calculated using a theoretical approximation. Thus, shaft heights were established comparing the shaft pieces with real columns that have similar sumoscape diameter and same order. As the shaft pieces are attached to the Corinthian order, the proportions of this order according to Jones (1989) were taken into consideration. Finally, the third group gathers shafts that do not conserve either imoscape nor sumoscape, and only allow an approximation of their diameters. In these cases, the column height was calculated by comparison with columns of similar shaft diameters analysed in the previous cases.

The shafts were classified in 11 groups according to the calculated module (diameter of the imoscape measured in Roman feet):

- 1 1/3
- 1 2/5
- 1 1/2
- 1 2/3
- 2
- 2 1/5
- 2 1/2
- 2 3/5 or 2 3/4
- 2 4/5
- 3
- 5

Finally, in all the cases, column heights were converted from centimetres to Roman feet, and next Roman feet were converted to fractional values to be compared with the Vitruvius' patrons. This analysis allowed to classify the columns in 4 groups according to their height:

- Group A: shafts with a diameter among 36-52 cm and the column height is lower to 15 Roman feet (< 4.45 m).
- Group B: shafts with a diameter among 52-68 cm and the column height is among 15 and 22 Roman feet (4.45-6.50 m).
- Group C: shafts with a diameter among 68-83 cm and the column height is among 22 and 27 Roman feet (6.50-8.00 m).
- Group D: shafts with a diameter among 83-92 cm and the column height is about 27 Roman feet (8 m).

3. RESULTS

3.1. *Characterization of granites from historical quarries*

Table 2 shows the characterization of the granite shaft used as patterns from different historical quarries with provenances determined in previous studies (Beltrán, 2012; Felipe, 2013; Márquez, 2002; Peacock, 1994; Pensabene, 2006; Scaife, 1953; Williams-Thorpe and Potts, 2002). These samples were studied by visual inspection and petrographic analysis, and the results were used to compare the Écija shafts and determine its provenance.

Table 2. Mineralogical and morphological characterization of the shafts used as patterns.

CURRENT LOCATION	REFERENCE NUMBER	PROVENANCE (according previous studies)	SAMPLING	COMPOSITIONAL GROUP	PROVENANCE (Quarry)	MODULE (Roman feet)
Quarry of Proserpina			X		SPANISH I	
Cathedral of Seville (Alemanes street)	SEV-CAT-F-02	Spanish II (Williams-Thorpe and Potts, 2002)		2	SPANISH II	1 2/3
Quarry of Gerena	ECI-R-C01 ECI-R-C02 ECI-R-C03		X			
Three-exedra building, Hadrian's Villa	VILL-EXE-F-01	Forum		5	FORUM	1 1/2
Three-exedra building, Hadrian's Villa	VILL-EXE-F-03	Forum		5		
Three-exedra building, Hadrian's Villa	VILL-EXE-F-04	Forum		5		
Three-exedra building, Hadrian's Villa	VILL-EXE-F-02	Forum		5		2
Alameda de Hércules, Seville	SEV-F-01	Troad/Forum/Spanish II (Beltrán, 2012; Pensabene, 2006; Williams-Thorpe and Potts, 2002)	X	N.D.		3
Pantheon, Rome	ROM-F-01	Forum (Peacock, 1994; Scaife, 1957)		4		5
Pantheon, Rome	ROM-F-02	Forum (Peacock, 1994; Scaife, 1957)		4		
Mármoles street, Seville	SEV-F-MAR	Forum/Spanish II (Márquez, 2002)		N.D.	N.D.	2 4/5
Peristyle of Bird's house, Itálica,	ITAL-F-01	Troad (Williams-Thorpe and Potts, 2002)		4	TROAD	1 1/3
Peristyle of Bird's house, Itálica,	ITAL-F-02	Troad (Williams-Thorpe and Potts, 2002)		4		
Golden square, Hadrian's Ville	VILL-P-F-01	Troad (Felipe, 2013)		4		1 2/5
Golden square, Hadrian's Ville	VILL-P-F-02	Troad (Felipe, 2013)		2		
Golden square, Hadrian's Ville	VILL-P-F-03	Troad (Felipe, 2013)		5		

Golden square, Hadrian's Ville	VILL-P-F-04	Troad (Felipe, 2013)	5	
Cathedral of Seville (Alemanes street)	SEV-CAT-F-01	Misia (Williams-Thorpe and Potts, 2002)	4	1 2/3

The main characteristics of the granite from each quarry are the following:

Granite from Troad (Turkey): this granite is classified as quartz-monazite, with a similar amount of potassium feldspar of dark violet colour (porphyloblasts with 2-3 cm of diameter) and white oligoclase. Its violet colour has originated its name of *violetto* granite. In its mineralogical composition we can find plagioclase, hornblende and black biotite with a grey quartz (Lazzarini and Sangati, 2004; Lazzarini, 2010).

The usual weathering in this granite, just like granite from Misia, is peeling around the grains, powdering on the surface and decolouration. Furthermore, water favours the iron lixiviation from the mafic components of the granite (biotite and hornblende) to the stone surface, generating a brown patina (Lazzarini, 2010).

Examples of this type of granite may be the shafts from Itálica (Seville). While the sample ITAL-F-01 was clearly identified by the content of violet feldspar, the sample ITAL-F-02 was more difficult due to the low amount of this mineral. These results match those of Williams-Thorpe and Potts (2002). The columns from Golden Square (Hadrian's Villa) also come from this quarry (Felipe, 2008).

Granite from Misia (Turkey): the composition of this granite is principally biotite-hornblende and granodiorite (34-53%), potassium feldspar (24-35%), anhedral quartz (21-29%), brown biotite (5-10%) and green hornblende (8%). This granite has a pale grey colour and a homogeneous isotropic holocrystalline texture with fine grains (1-5 mm) (De Vecchi et al., 2000). The macroscopic characteristics are similar to the granite from Elba and Giglio islands, although the last one does not have hornblende (De Vecchi et al., 2000).

Granite from Elbe/Giglio (Italy): the Elbe granite is principally composed of granodiorite and has a grey colour plenty of small black grains. It looks similar to Misian granite, with the difference that Elbe granite has white porphyloblasts (Bruno, 1998; Felipe, 2008).

The Giglio granite has a grain thicker than Elbe granite, and a grey colour with slightly brown tone (Borghini, 1998; Felipe, 2008). The main rock-forming minerals are tourmaline and chlorite sometimes mixture with limonite. The presence of crystal quartz is common, but it seldom appears aligned, and has a low content of mica. These rock-forming minerals sometimes appear covered by a fibrous mineral.

The asignation between Elbe and Giglio granite is difficult. Thus, these granites usually are considered as coming from a unique quarry (Lazzarini, 1987). The main difference with respect the Misian granite is the absence of hornblende (Lazarrini, 2010).

Granite of the Forum (Egypt): this is a tonalite-gneiss with white-grey colour. This granite stands out for quartz crystals and plagioclases of few millimetres, sometimes oriented in parallel. The holotypes have an average size of 1.4-2.0 mm. The black grains are composed of biotite and hornblende. In some cases, it is possible to find clusters of leukocratic (light) and mafic (dark) that cause a different foliation (Antonelli, Lazzarini and Cancelliere, 2010).

An example of the use of this granite may be the columns of the Three-Exedra Building (Hadrian's Villa). Most of them were restored, what favours the determination of their quarry. The presence of grains around 1.4-2.0 mm and their colour, composed of a white-grey background with crystals oriented in parallel and black grains, makes its dating easy. Nevertheless, Williams-Thorpe (2008) states that this quarry was not used in Roman Spain. The study carried out on one of the shafts from Alameda de Hércules (SEV-F-01) might confirm the employment of this granite in its construction (Beltrán, 2012), although it has been linked to the Troad quarry (Márquez, 2002) or the Spanish granite Type II (Williams-Thorpe and Potts, 2002). In this case, the absence of violet feldspar, smaller grain size and a low contrast between dark and pale components discard the attribution to Spanish granite Type II. Additionally, several similarities were found with the columns of the Three-Exedra Building.

Spanish granites Types I, II y III: the Spanish quarries used during the Roman empire have not been studied in depth as they were mainly employed for local supply. One of the first studies was carried out by Williams-Thorpe and Potts (2002). This author classified Spanish granites in three groups: Types I, II and III. This study can be used as a slight approximation due to the absence of comparisons between archaeological features and quarries. The quarry of granite Type I is commonly placed in the Proserpina reservoir (Merida), the granite Type II in Gerena (Seville) and the granite Type III near Córdoba (Williams-Thorpe and Potts, 2002). The last granite has very similar characteristics to the granites from Corsica and Sardinia.

Regarding the granite descriptions, Type I is composed of thick grey grains and large crystals. In fact, Pizzo (2011) described the granite used in the construction of Emerita Augusta as a granite composed of two micas of pale grey colour, medium-thick grain with frequent presence of large crystals of potassium feldspar. In many cases, the oxidation of biotite is observed, as well as ochre and reddish spots in the feldspars. The result of the petrographic analysis of the Proserpina quarry sample agrees with Williams-Thorpe and Potts' descriptions (2002) for this granite.

The mineralogical components of the granite Type II are quartz, acid plagioclase, microcline and brown-reddish biotite. Muscovite, zircon, apatite, garnets and/or other opaque minerals can appear in amount less than 1%. Although this rock is classified as granite, it has a granodioritic trend. Its texture is holocrystalline and granular hypidiomorphic (Simancas, 1981). The sample SEV-CAT-F-02 can correspond to this description.

The granite Type III has a white-black colour, with a high content of biotite (Williams-Thorpe and Potts, 2002), and can correspond to the description of the Córdoba granite made by Pensabene (2014).

The Spanish granites have thicker grains than the other granites (Williams-Thorpe and Potts, 2002). Additionally, some differences were observed among the Spanish granites, for example, granite Type II has the highest contrast between mafic and felsic minerals, with a reddish biotite, whereas granite Type III has less contrast of colours among components and the biotite has a brown tone.

The exportation from Spanish quarries was limited, and only the fossil rock named *brocatello* (Tortosa, Spain) was commercialized in Rome and north Africa (Mayer and Roda, 1999). The rest of marbles and granites may have only been employed in the Iberian Peninsula (Mayer and Roda, 1999). For example, Pensabene (1998) described granites Types I, II and III used for constructions in Itálica and *Hispalis* (Seville), although there is no mention to the city of Écija.

3.2. *Characterization of Écija shafts*

Following the scheme employed for the granites used as patterns, Table 3 shows the results of the Écija shaft characterization and their provenance assignation.

Table 3. Mineralogical and morphological characterization of the Écija shafts.

<table>
<tr><th>CURRENT LOCATION</th><th>REFERENCE NUMBER</th><th>PROVENANCE (according previous studies)</th><th>SAMPLING</th><th>COMPOSITIONAL GROUP</th><th>PROVENANCE (Quarry)</th><th>MODULE (Roman feet)</th></tr>
<tr><td>Façade of Santa Bárbara church, right side. Possible column from the temple of the Forum.</td><td>ECI-F-12</td><td>Elbe/ Giglio (Williams-Thorpe and Potts, 2002) or Misian (Padilla, 2000)</td><td>X</td><td>4</td><td rowspan="3">ELBE/GIGLIO</td><td>2</td></tr>
<tr><td>San Pablo gardens, next to the river.</td><td>ECI-F-15</td><td>Elbe/ Giglio (Felipe, 2008; Williams-Thorpe and Potts, 2002)</td><td></td><td>2</td><td>2 1/2</td></tr>
<tr><td>San Pablo gardens, next to the river.</td><td>ECI-F-16</td><td>Elbe/ Giglio (Felipe, 2008; Williams-Thorpe and Potts, 2002)</td><td></td><td>4</td><td>2 3/4</td></tr>
<tr><td>Roadside post in Cordero street corner to Platería street.</td><td>ECI-F-18</td><td>Spanish II (Felipe, 2008; Williams-Thorpe and Potts, 2002)</td><td></td><td>2</td><td rowspan="11">SPANISH II</td><td rowspan="2">N.D.</td></tr>
<tr><td>Arco de Belén street.</td><td>ECI-F-22</td><td>Unidentified</td><td></td><td>2</td></tr>
<tr><td>Guerrero street corner to San Francisco street.</td><td>ECI-F-35</td><td>Unidentified</td><td></td><td>4</td><td>1 1/3</td></tr>
<tr><td>San Francisco church, corner.</td><td>ECI-F-34</td><td>Unidentified</td><td></td><td>2</td><td rowspan="3">1 2/5</td></tr>
<tr><td>Descalzos church. Corner, inner piece.</td><td>ECI-F-48</td><td>Unidentified</td><td></td><td>4</td></tr>
<tr><td>Guerrero street corner to San Francisco street.</td><td>ECI-F-36</td><td>Unidentified</td><td></td><td>4</td></tr>
<tr><td>Cintería street.</td><td>ECI-F-44</td><td>Unidentified</td><td></td><td>2</td><td rowspan="2">1 1/2</td></tr>
<tr><td>Caballeros street (Emilio Castelar) corner to Garcilópez street.</td><td>ECI-F-3</td><td>Spanish II (Felipe, 2008; Pensabene, 2006; Williams-Thorpe and Potts, 2002)</td><td></td><td>4</td></tr>
<tr><td>Virgen mármoles street corner to Arco de Belén street</td><td>ECI-F-37</td><td>Unidentified</td><td></td><td>4</td><td rowspan="2">1 2/3</td></tr>
<tr><td>Historic Municipal museum of Écija</td><td>ECI-F-47</td><td>Unidentified</td><td></td><td>2</td></tr>
<tr><td>Roadside post in Emilio Catelar street corner to Arcipreste Aparicio square.</td><td>ECI-F-4</td><td>Spanish II (Felipe, 2008; Pensabene, 2006; Williams-Thorpe and Potts, 2002)</td><td></td><td>2</td><td>2</td></tr>
</table>

Roadside post in Jesús sin soga street corner to España square.	ECI-F-9	Spanish II (Felipe, 2008; Williams-Thorpe and Potts, 2002)		2		2 1/5
San Pablo gardens, next to the river.	ECI-F-17	Spanish II (Felipe, 2008; Williams-Thorpe and Potts, 2002)		2		2 1/2
Roadside post in Arco de Belén street corner to Olivares Street.	ECI-F-25	Forum o Spanish II (Felipe, 2008)		3		1 2/5
Roadside post in Estepa street corner to San Bartolomé street.	ECI-F-23	Spanish III (Felipe, 2008)		4		1 2/3
Padre García Tejero street corner to Mas y Prat street.	ECI-F-26	Spanish III (Felipe, 2008)		5		
Façade of Santa Bárbara church in Jesús sin Soga street, right side. *Possible column from the temple of the Forum.*	ECI-F-10	Spanish III (Felipe, 2008; Williams-Thorpe and Potts, 2002)		5	SPANISH III	2 1/5
Façade of Santa Bárbara church in Jesús sin Soga street, left side. *Possible column from the temple of the Forum.*	ECI-F-11	Spanish III (Felipe, 2008; Williams-Thorpe and Potts, 2002)		2		
Historic Municipal museum of Écija. *Archaeological excavation of the España square.*	ECI-F-38	Unidentified	X	5		2 1/2
Historic Municipal museum of Écija. *Archaeological excavation of the España square.*	ECI-F-32	II (Felipe, 2008; Pensabene, 2006; Williams-Thorpe and Potts, 2002)	X	5		2
Historic Municipal museum of Écija. *Archaeological excavation of the España square.*	ECI-F-2	Forum (Pensabene, 2006)	X	2		
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes street.*	ECI-F-51	Unidentified		4	FORUM	2 1/5
Near to the façade of the Cárdenas palace.	ECI-F-28	Forum or Spanish II (Felipe, 2008)		2		2 1/2
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes street.*	ECI-F-50	Unidentified		4		
Descalzos church. Corner, upper piece.	ECI-F-49	Unidentified		4		1 1/2
Historic Municipal museum of Écija. *Archaeological excavation of the Virgen de la Piedad street.*	ECI-F-1	Misian (Pensabene, 2006)	X	4	MISIAN	2 3/5
Historic Municipal museum of Écija. *Archaeological excavation of the España square.*	ECI-F-52	Unidentified		3		2 1/5
Andalucía avenue, nº 5, *coming from Santa Barbara church.*	ECI-F-20	Troad (Felipe, 2008)		N.D.	N.D.	2 4/5
Roadside post in Emilio Castelas street corner to Virgen de la Piedad street.	ECI-F-27	Unidentified				N.D.
Hacienda Building	ECI-F-33	Unidentified		4		
Roadside post in Virgen de la Piedad street corner to Olivares street.	ECI-F-24	Unidentified	X	4		1 2/3
Roadside post in Puerta Cerrada square, nº 8.	ECI-F-19	Troad (Felipe, 2008)		4	TROAD	
San Francisco church.	ECI-F-31	Troad (Felipe, 2008)		3		
Façade of Santa Bárbara church, left side. *Possible column from the temple of the Forum.*	ECI-F-13	Troad (Felipe, 2008; Pensabene, 2006; Williams-Thorpe and Potts, 2002)		4		2 1/5
Entrance to San Francisco church.	ECI-F-30	Misian/Elbe/Giglio (Felipe, 2008)		4		

Roadside post in Arcipreste Aparicio square corner to Emilio Castelar street.	ECI-F-5	Troad (Williams-Thorpe and Potts, 2002)	X	4	2 1/2
San Pablo gardens, next to the river.	ECI-F-14	Troad (Felipe, 2008; Pensabene, 2006; Williams-Thorpe and Potts, 2002)		3	
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes street.*	ECI-F-46	Unidentified	X	5	2 3/5
Santa Florentina street, nº 9A	ECI-F-42	Unidentified		4	
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes street.*	ECI-F-45	Unidentified		4	
Façade of Valdehermo-so palace in Arcipreste Aparicio square.	ECI-F-7	Troad (Pensabene, 2006; Williams-Thorpe and Potts, 2002)	X	2	2 4/5
Roadside post in Santa Florentina street corner to José Canalejas street.	ECI-F-29	Unidentified		5	
Façade of Valdehermo-so palace in Arcipreste Aparicio square.	ECI-F-8	Troad (Pensabene, 2006; Williams-Thorpe and Potts, 2002)	X	5	
Municipal storehouse. *Archaeological excavation of the España square.*	ECI-F-39	Unidentified	X	2	
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes street.*	ECI-F-41	Unidentified		4	
Historic Municipal museum of Écija. *Archaeological excavation of the Fray Carlos Amigo Vallejo street corner to Miguel de Cervantes stree).*	ECI-F-40	Unidentified	X	4	3
Tolerancia square, next to the river, *coming from Santa Cruz square.*	ECI-F-21	Troad (Felipe, 2008)		3	
Roadside post in the façade of Valdehermo-so palace in Arcipreste Aparicio square.	ECI-F-6	Troad (Pensabene, 2006; Williams-Thorpe and Potts, 2002)	X	2	
Historic Municipal museum of Écija. *Archaeological excavation of the Galindo street.*	ECI-F-43	Unidentified	X	3	

We could not assign any studied shaft as Spanish granite Type I (quarry of Proserpina reservoir, Mérida). The sample ECI-F-1 has similar characteristics with the pattern of Gerena granite, that is, Spanish granite Type II. Other samples that could be classified as Spanish granite Type II are ECI-F-04, ECI-F-09, ECI-F-17, ECI-F-18, ECI-F-22, ECI-F-34, ECI-F-35, ECI-F-36, ECI-F-37, ECI-F-44, ECI-F-47 and ECI-F-48. These samples have a high contrast between the dark and light components, and some traces of reddish biotite (Figure 3.a). Nevertheless, the patterns come from a quarry located in Genera, but there is not any finding of historical marks reported. Perhaps, Romans used another outcrop related with the same facies. Additionally, these samples are similar to the sample SEV-CAT-F-02, coming from the Cathedral of Seville, and classified as Spanish granite Type II by Williams-Thorpe and Potts (2002).

The samples ECI-F-10, ECI-F-11, ECI-F-23, ECI-F-25, ECI-F-26 and ECI-F-38 may be classified as Spanish granites Type III, because they have a white-black colour (Fig. 3.b) due to the white matrix of quartz and feldspar and the presence of black biotite (Fig. 4).

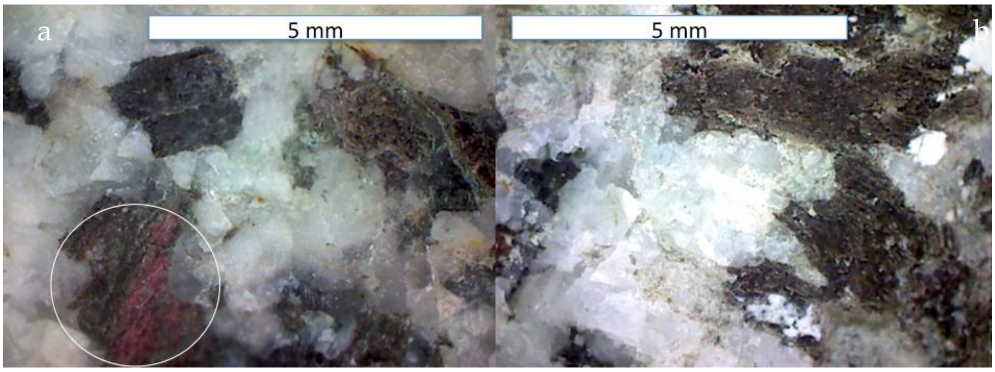

Figure 3. Images from digital microscope of the samples (a) ECI-F-35, identified as Spanish granite Type II with presence of reddish biotite, and (b) ECI-F-23, identified as Spanish granite Type III.

Figure 4: Petrographic image of sample ECI-F-38 at a magnification of 2.5X. (a) Parallel light allows to observe the quartz matrix (white colour) and feldspar (grey colour), and a biotite grain with brown-greenish tone in tabular section with presence of cleavage on the right. (b) Crossed nicols allows to see a quartz macla.

The Misian granite has a thin grain (1-5 mm), homogeneous texture and pale colour. The samples ECI-F-1, ECI-F-49 and ECI-F-52 may come from this quarry because they do not have white porphyloblasts. Furthermore, these shafts show powdering, a typical weathering form of Misian granite. The shaft catalogued as sample ECI-F-1 was previously classified as Misian granite by some authors (Pensabene, 2006; Felipe, 2008), although its size is outside the range of shaft diameters of granite columns from this quarry (Williams-Thorpe and Potts, 2002).

Many of the studied samples have been linked to the Troad quarry (Table 3). These samples have potassium feldspar that gives them a violet tone (Fig. 5), together with white oligoclase, plagioclase, hornblende and black biotite with grey quartz (Yavuz, 2014). The visual inspection carried out on-site allows us to confirm that these shafts show powdering on the surfaces, a typical weathering form of this kind of granites. Furthermore, the hornblende and biotite show a brown patina (Fig. 6).

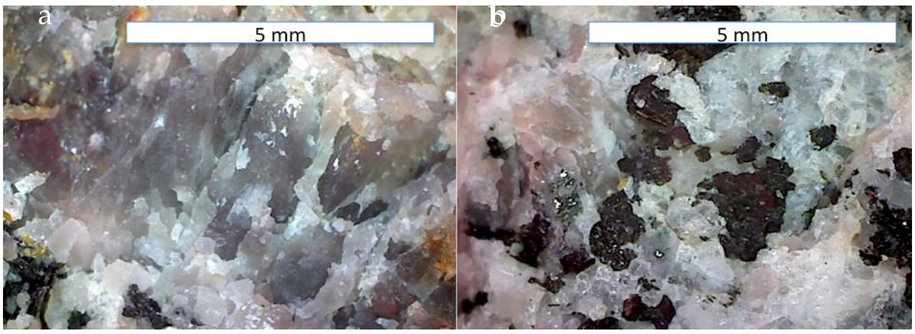

Figure 5: Images from digital microscope of samples (a) ECI-F-24 and (b) ECIF-19 classified as Troad granite. It is highlighted the violet tone due to the presence of potassium feldspar.

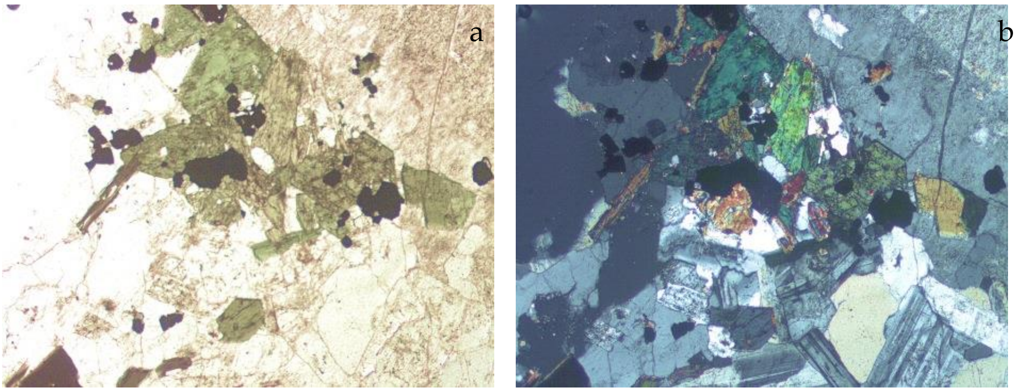

Figure 6: Petrographic image of sample ECI-F-05 at a magnification of 2.5X. (a) Parallel light allows to observe the hornblende (green colour) with its typical prismatic form. (b) In the crossed nicols image it is possible to see visible quartzes of low relief with the absence of macla and alterations (white colour).

The granite of the Forum is similar to the Spanish granite Type II (Fig. 7). The main difference is that Forum granite shows a higher presence of crystals oriented in parallel. The shafts identified with this quarry (ECI-F-2, ECI-F-28, ECI-F-32 ECI-F-50 and ECI-F-51) displayed exfoliation and surface erosion of the mineral constituents. These weathering forms favour the formation of coving, common weathering pattern in granites coming from this quarry. The provenance for the samples ECI-F-2, ECI-F-28 and ECI-F-32 matches those of previous studies (Pensabene, 2006; Felipe, 2008).

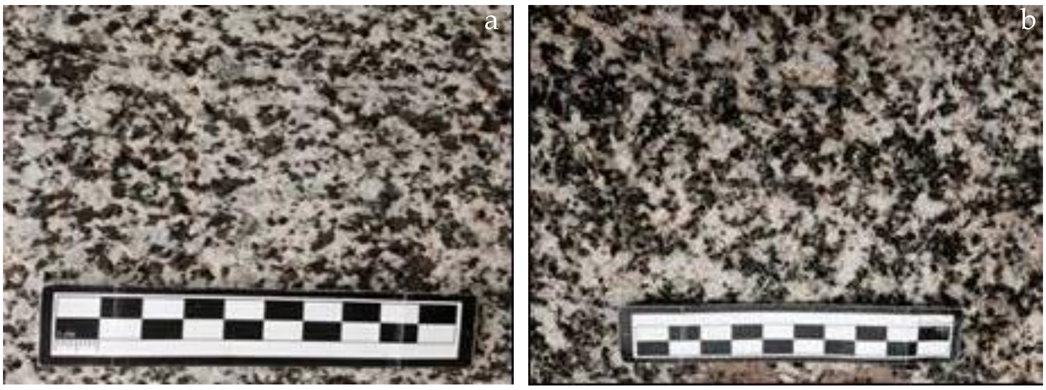

Figure 7. Photographs of (a) a granite classified as granite of the Forum (ECI-F-2), with the typical crystals orientation in parallel and (b) a Spanish granite Type II.

The Elbe/Giglio granite is similar to Misian granite, although without hornblende. Samples ECI-F-15 and ECI-F-16 may come from this quarry. Sample ECI-F-16, where no petrographic analysis could be carried out with sampling, we agree with Williams-Thorpe and Potts classification (2002), although it also has similarities with the granite of the Forum and the Spanish granite Type II.

Finally, samples ECI-F-02 and ECI-F-03 could not be classified from any quarry because they do not have any similarities with the available patterns.

In summary, the granites most employed in *Astigi* came from Troad (38.46%) and Spanish Type II (25%). Spanish granite Type III (11.54%) and granite of the Forum (9.62%) also were used in the construction of Roman buildings, while only 6 columns have been assigned to granites from Elbe/Giglio or Misia, so these quarries might not be commonly used in this city.

3.3. Mineralogical characterization

Digital Image Analysis was used to make a second approximation based on the presence of quartz, feldspar and biotite, main minerals in the studied granites. For that purpose, the images were segmented with the histogram function, and the percentage of each mineral was calculated. Fig. 8 shows an example of Digital Image Analysis executed in samples ECI-F-1 (Misian granite) and ECI-F-17 (Spanish granite Type II). The sample ECI-F-1 has a high content of quartz (47.2%) and feldspar (40.5%), while the presence of biotite is lower than 12.3%, so this shaft was classified in the Group 4. The sample ECI-F-17 is a clear example of granite of the Group 2 because it has a higher content in biotite (31,5%) and the presence of feldspar (21.3%) is lower than the quartz (47.2%).

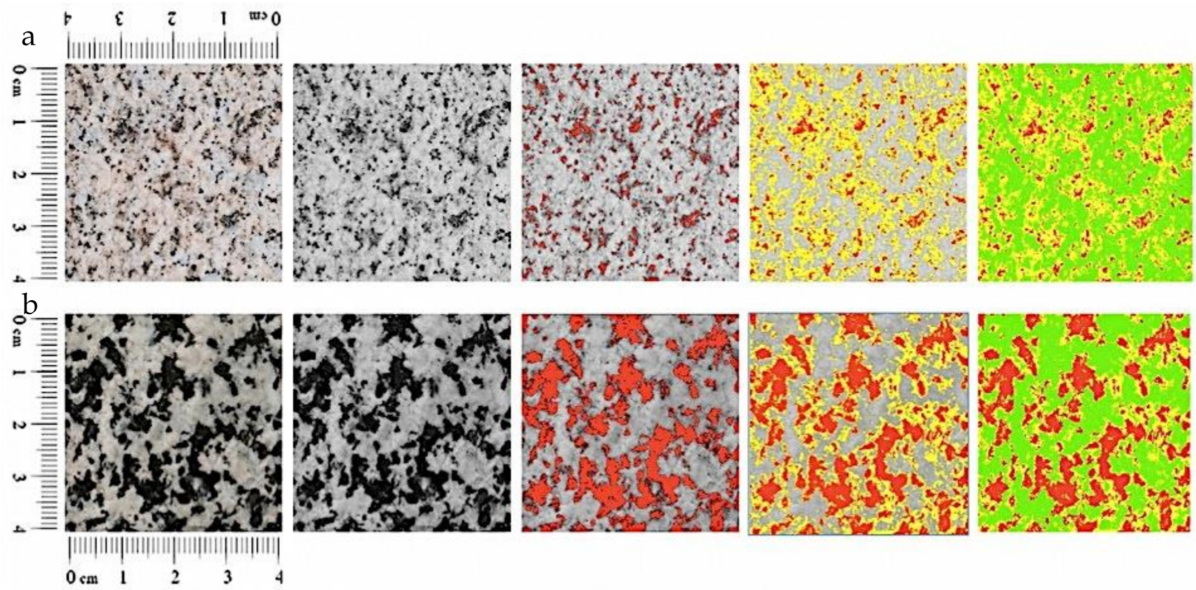

Figure 8: Digital Image Analysis of the samples (a) ECI-F-1, classified as Misian granite, and (B) ECI-F-17, classified as Spanish granite Type II. The analysed minerals are biotite (red colour), feldspar (yellow colour) and quartz (green colour).

The classification of the pattern samples (Table 2) allowed an approximation to the mineralogical characteristics of each granite without sampling. For example, the granites of the Forum have a higher content in feldspar. Similar content of feldspar has the Troad samples, although some samples were classified in the Group 2 due to its high content in biotite. Similar content of biotite was observed in the samples of Spanish granites Type II. Taking into consideration the studied monuments, the different analysed samples of each building were classified in the same Group, so that Digital Image Analysis would help to reduce the uncertainty associated to the determination of the granite provenance. Only in the case of Golden Square (Hadrian's Villa), the analysed samples were classified in different Groups due to the difference in the feldspar content, perhaps due to the presence of different maclas in the outcrop.

In the case of the Écija samples, the samples classified in a same quarry presented a heterogeneous percentage of minerals (Table 3). This is shown in Figure 9 where the different samples are represented in a triangular diagram. The results showed that samples do not belong to Group 1, as they do not have a biotite content higher than 40%. The contents of quartz and feldspar were often similar, between 30-60% in many of the samples (Group 4). Only in some samples it could be observed a higher content in feldspar (Group 5), especially in the case of the granites of the Forum and Spanish granites Type III.

The percentage of samples classified in each compositional group according to its quarry has been represented in Fig. 10a, while Fig. 10b shows the location of the columns according to the quarry. Although granite is a very heterogeneous stone in its composition and the percentage of minerals varies among facies in the same quarry, it was still possible to broadly approach the composition of each quarry. The Elbe/Giglio granites and Spanish granite Type II have compositions with a similar presence of quartz and feldspar. In the case of Spanish granite Type II, the results achieved match the classification of the pattern samples (Table 2). The Misian granite is characterized by a rich content in quartz. The granites from Forum, Troad and Spanish III have more heterogeneous compositions. In the case of Forum and Troad granites, it was possible to observe a trend between Groups 4 and 5, as they share a high presence of feldspar.

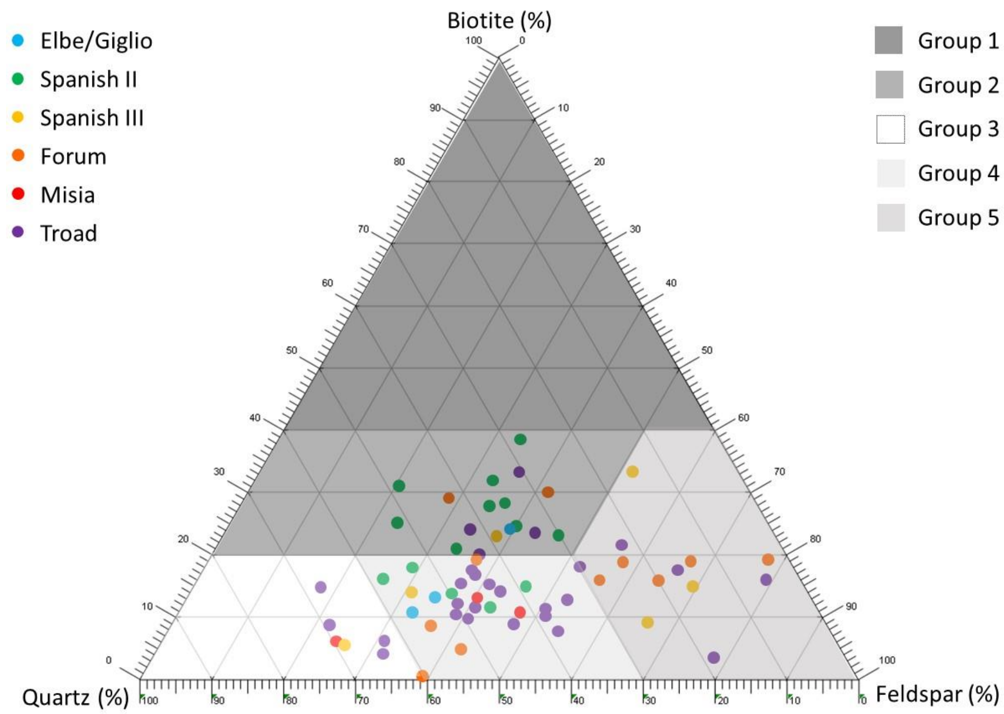

Figure 9: Triangular diagram about the composition of the Écija shafts according to the percentage of minerals (quartz, feldspar and biotite) calculated by Digital Image Analysis and classified in function of their quarries.

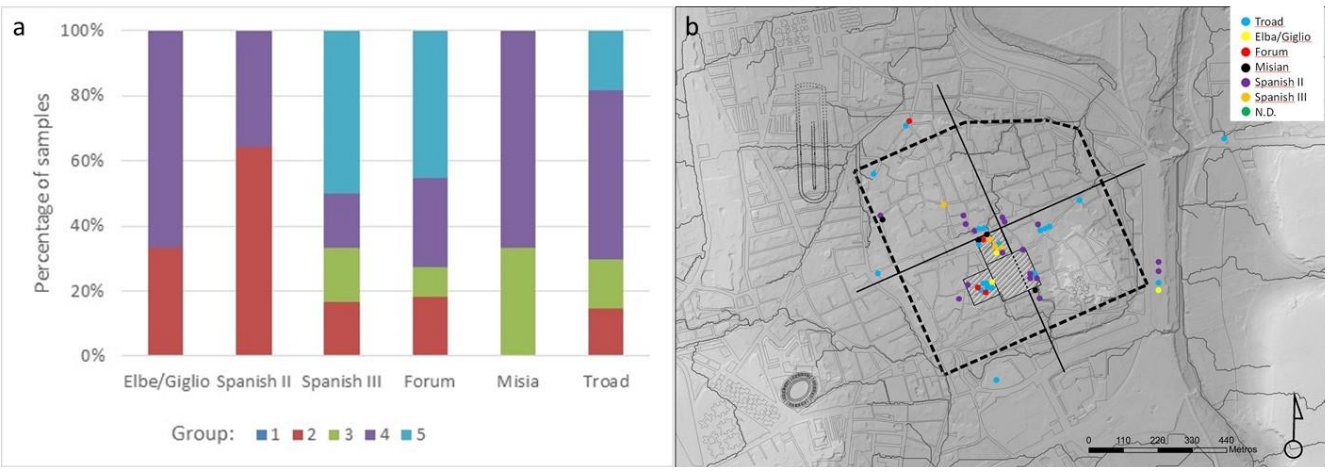

Figure 10: (a) Approximation to the mineralogical composition of each quarry according to the groups made after Digital Image Analysis. (b) Location of the columns where were discovered according to their quarry in the map of Écija. Discontinuous black lines are the limit of the Roman city of Astigi, continuous black lines are the principal road of the Roman city (Cardo Maximus and Decumanus Maximus) and the striped square correspond to the Roman forum and its and its successive extensions.

3.4. Morphological characterization

A reconstruction of the Ecija shafts was made in accordance to the imoscape or sumoscape size. This reconstruction is based on the calculation of the module of the shaft. Tables 2 and 3 show the classification of the shaft in function of their modules. The most used modules in Écija shafts are 1 2/3, 2 1/2 and 3.

Fig. 11a shows the size of columns related with the quarries. An approximation to the size was made in shafts without imoscape and sumoscape. Columns were classified in four groups. The higher columns come from the Troad quarry, while the smaller ones come from Spanish quarries. This result may be due to the use of imported materials for monumental or important civil constructions, maybe fund by Roman emperors (Felipe, 2008). On the other hand, the construction of buildings of lower relevance in the civil life may have generally used more economic materials coming from nearby quarries (Spanish granites). These buildings would have been funded by the local higher social classes. Regarding the granites of medium size (about 20 Roman feet, Group II) they may be employed in the monumentalization of the Écija forum carried out during the Hadrianic period (Fig. 11.b), where granites coming from Misia, Elbe/Giglio, Troad and Spain might be used (Felipe, 2014).

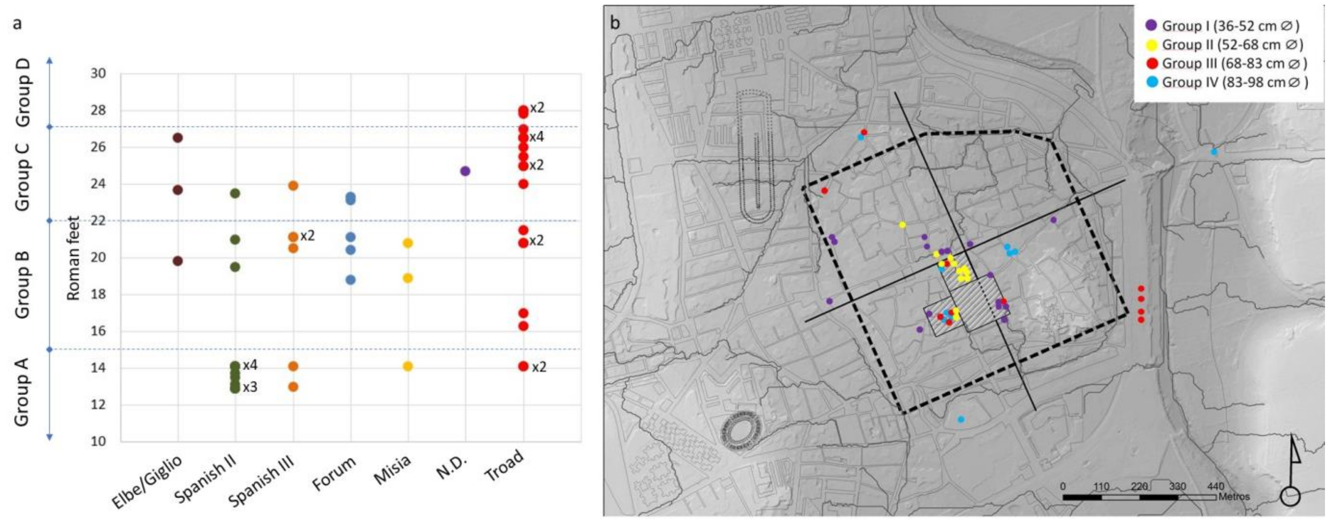

Figure 11: (a) Column heights measure in Roman feet according to the granite quarry. The columns have been classified in four groups: Group A, height lower to 15 Roman feet (< 4.45 m); Group B, height between 15 and 22 Roman feet (4.45-6.50 m); Group C, height between 22 and 27 Roman feet (6.50-8.00 m) and Group D, height higher than 27 Roman feet (>8.00 m). (b) Location of the columns where were discovered according to their diameter in the map of Écija. Discontinuous black lines are the limit of the Roman city of Astigi, continuous black lines are the principal road of the Roman city (Cardo Maximus and Decumanus Maximus) and the striped square correspond to the Roman forum and its and its successive extensions.

4. CONCLUSIONS

The knowledge about the provenance and shapes of the stone columns used in the Roman city of *Astigi* (present Écija) allows to confirm the period of splendour lived in the 2nd century AD. The comparison between granite shafts conserved in the city and shafts whose quarries have been previously identified has allowed us to determine the possible origin of the granites used in Écija during the Roman empire. The quarries are placed both in the Iberian Peninsula and all around the Mediterranean basin.

A total of 52 shafts from ancient *Astigi* have been studied. The results showed that 20 shafts were made of granite from the Troad region, one of the most imported quarries for Roman construction. 13 shafts have been identified as Spanish granite Type II (Gerena quarry) and 6 as Type III (near Córdoba). The other shafts may be imported from Egypt (granite of the Forum), Italy (Elbe/Giglio) and Turkey (Misia).

Digital Image Analysis useful technique to approach the quantification of mineral components of the granites. The percentage of quartz, feldspar and biotite varies among quarries. Although the samples were heterogeneous in the mineral quantification, there are trends that allows to limit the uncertainty associated to the identification process.

The classification of shafts according their shape or height, supplements the information obtained from the quarries employed in Écija in order to understand the role of the city in the Roman Empire. Thereby, the combination of the granite provenance and the study of the column size allows us to understand the relevance of building sponsors that asked to bring columns from Troad region (Turkey). The beautification of *Astigi* during the 2nd century AD was funded by the Roman emperors as suggested by employment of Imperial quarries, while the growing local high classes might employ the nearby quarries in their constructions.

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