Journal of Roman Archaeology 35 (2022), 848–875
doi:10.1017/S1047759422000447

Marble trade in the Roman Mediterranean: a quantitative and diachronic study

Devi Taelman

Department of History, Archaeology, Arts, Philosophy and Ethics, Vrije Universiteit Brussel
<devi.taelman@vub.be>

Abstract: Marble provenance studies in archaeology have become increasingly popular in recent decades. This has resulted in a large quantity of analytical data becoming available for archaeological marbles. This article presents the results of a quantitative study of the distribution of white marble in the Mediterranean based on an analysis of the available provenance data for the Roman period. The study shows increased distribution of white marble between the late 1st c. BCE and the end of the 2nd c. CE. A decline in distribution from the 3rd c. CE was less abrupt than traditionally believed and shows object-, material-, and region-specific trajectories. The marble distribution data is finally evaluated within a wider socio-economic frame, considering factors such as the marble trade system and broader Roman economy, changes in cultural practices related to statue erection, importance of reuse and recycling, growing ruralization, and reduced interest of the elite in urban capital investment in the later Roman periods.

Keywords: White marble, marble provenance, Roman economy, quantification, architecture, sculpture

Recent decades have witnessed a growing importance of archaeological data in studies of how past economies functioned and evolved through time. Much of this progress results from advances in scientific (provenancing) techniques, the application of (geo-)statistical methods, and increased interest among archaeologists and historians in what the material record can tell us about past socio-economic systems.[1] Commonly used archaeological proxies for the economy of the Roman period include amphorae, various kinds of fineware pottery, shipwrecks, wine and olive presses, and fish-salting infrastructure.[2] While studies of high-quality raw materials, such as marbles, are not uncommon in archaeology, the full potential of this material category as proxy data for the Roman economy has not yet been fully explored in the field of economic archaeology/history.

Roman society was highly stratified, and the upper classes were constantly striving to showcase, maintain, and increase their power and prestige. Monumental architecture and sculpture, in both public and (semi-)private contexts, were among the most powerful means of doing this. The grandeur of monumental architecture was expressed not only by the sheer investment of energy, manpower, or funds involved in the building of its structural components, but also by its elaborate decor; in essence, the scale and elaboration of monumental buildings largely exceeded their functional requirements.[3] Ancient cities were lavishly adorned with marble statuary and marble(-clad) architecture, mainly through benefaction by members of the elite.[4] Architectural and sculptural decoration were considered integral parts of any monumental building, contributing to the message the building

1 Verboven 2018, 346.

2 Wilson 2014.

3 Abrams 1989; Trigger 1990, 119.

4 Jongman 2007b.

conveyed as a whole. As such, Roman architectural and sculptural decoration was highly functional. It served as an organizing and structuring element within a building,[5] providing the physical setting where people lived, met, and interacted. This function is evident for public buildings, but elite housing also served a public purpose as a location of contact between the elite owners and their clientele. More fundamentally, decor had a distinct social function. It was intended to be seen by visitors. Lavish decor displayed wealth and prestige, and was associated with the Roman elite, who had substantial financial means to acquire luxury materials. It acted as a social marker with a clear communicative effect on outsiders. It was used to express and reinforce membership of the elite, as well as to display, perpetuate, and increase the political, social, and economic power and status of the resident/benefactor.[6] Monumental marble statuary and marble(-clad) architecture were therefore an essential part of the Roman urban environment, and their study can contribute to our understanding of the level of urban investment by the upper classes. Roman cities were adorned to celebrate and reinforce the power of benefactors. As such, marble decoration can, in addition to building histories, function as an indicator for the level of urbanization. In addition, the act of monumental building shows the presence of a societal class that had the necessary means to mobilize and coordinate the manpower required for construction. Monumental architecture thus serves also as an indicator of social complexity and hierarchy.[7]

The Mediterranean basin has abundant attractive white marbles, many of which were exploited in the Roman period. The distribution of these marble resources is, however, very uneven, with the major exploitation districts clustered mainly in the Italian Peninsula, mainland Greece, the Aegean Islands, and Asia Minor. Smaller production centra can be found, for example, in the Iberian Peninsula (Fig. 1). This uneven distribution of resources means that trade in marble was unavoidable. Marble objects were traded in enormous quantities and over long distances in the Roman period, much like other objects (wine, olive oil, pottery, etc.), and as such reflect wider economic practices.[8] The importance of marble for Roman society, combined with its durability, provenancing potential, and chronological resolution – marble objects (e.g., building elements, sculpture, sarcophagi) are generally well dated – make it a very promising subject of research for archaeologists and historians interested in the economy of antiquity.

Since the mid-1980s, when scientific marble provenancing in archaeology started, research has concentrated mainly on developing techniques and methodologies for material characterization and provenance determination.[9] Advances in petrographic and archaeometric methodologies, in combination with extensive quarry sampling, have in recent years allowed marble artefacts to be provenanced with high reliability. Typically, archaeologists have explored the Roman marble economy through case studies, that is, individual monuments, collections, or archaeological sites. While this case study-based approach is undeniably valuable, there are certain questions that can only be answered by studying

5 DeLaine 1997, 72–73.

6 Taylor 2003, 214.

7 Abrams 1989; Verboven 2018, 358.

8 Russell 2013b.

9 For example, Lazzarini 2004; Attanasio et al. 2006; Antonelli and Lazzarini 2015. See also the various conference proceedings of the Association for the Study of Marble and Other Stones in Antiquity (ASMOSIA).

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

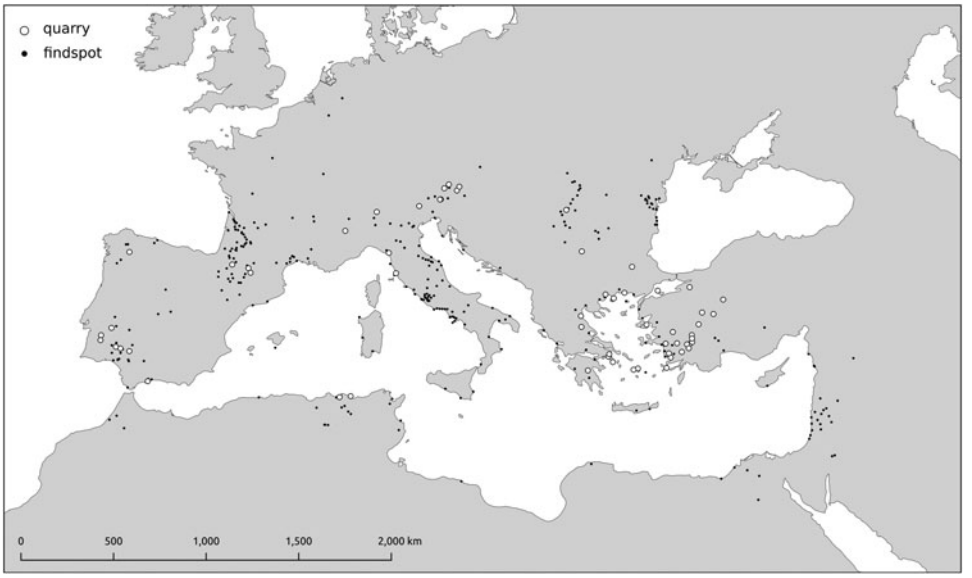

Fig. 1. *Geographical distribution of the marble quarry districts and Roman sites with white marble provenance determinations of objects dated between 200 BCE and 500 CE. (D. Taelman.)*

the marble provenance data in its entirety. Such synthetic, regional, or supra-regional research is still scarce.[10] In particular, quantitative approaches to the Roman marble economy are still lacking, despite the general consensus on the value of more and better quantification and the need to reach firmer, falsifiable hypotheses in the understanding of ancient economies.[11]

In this article, I focus on published white marble provenance data of quarry districts that exported on a supra-regional scale in the Roman Mediterranean (200 BCE–500 CE). Thanks to the rising popularity of white marble provenance studies in recent years, there are now sufficient reliable provenance determinations for white marble, with a large enough regional and chronological spread, to allow for quantification on a large scale. As a result, provenance determinations for white marble can now serve as a meaningful proxy indicator for studying long-distance trade, changes in urbanization, and elite urban investment in the Roman world, as well as for examining the structure, behavior, and performance of the wider Roman economy. Analysis of the data focuses on revealing and visualizing general trends, patterns and associations in the rise and fall of market shares and the distribution of individual marble resources across the Mediterranean. Without ignoring the effect of taphonomic processes, changes in consumption and distribution patterns are charted here with the aim of identifying relative changes in the volume of marble traded throughout the Roman Mediterranean. Distribution patterns of white marbles are compared diachronically through standard descriptive and exploratory quantitative methods, looking specifically at similarities and dissimilarities between regions and object categories. Finally, the quantitative data are discussed with the aim of identifying the mechanisms that may have produced the observed patterns and trends. Changes in

[10] Notable exceptions are Fischer 1998; Russell 2013b; Taelman et al. 2021; Taelman 2022.

[11] See the edited volumes by Bowman and Wilson 2009b; de Callataÿ 2014.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

production systems of quarries, changes in the exchange system (level of market integration, regionalization of the markets, etc.), and changes in the consumption patterns of marble (consumer taste, urbanization rates, etc.). are considered.

Materials and quantitative approach

White marble provenance dataset

Data from 417 publications with provenance determinations for archaeological white marble have been collected, resulting in a corpus of 8,722 records of individual white marble artefacts from 434 archaeological sites, mainly around the Mediterranean Sea. Marble objects were only added to the database if their provenance determination was considered reliable, that is, based on a generally accepted multimethod approach combining at least mineralogic-petrographic and archaeometric analysis.[12] The topic of this article is the Roman Mediterranean between 200 BCE and 500 CE. All marble objects that fall within these chronological and geographical limits were extracted from the dataset for further analysis. This constituted a subset of 7,017 objects from 350 Roman sites, provenanced to different 65 quarry districts (Fig. 1). The dataset was then further refined to focus on the quarry districts that exported mainly on a supra-regional scale in Roman times. Quarry districts included in the analysis are Aphrodisias, Carrara, Dokimeion, Ephesos, Göktepe, Naxos, Paros (Paros-1, Paros-2(3)), Pentelikon, Prokonnesos and Thasos (Thasos-1(2), Thasos-3).[13]

Each database entry represents an archaeological marble artefact, and the record includes findspot, storage location, object type, chronology, analytical data, material provenance, laboratory, and literature reference, as well as the immediate and wider contexts of the object (e.g., historical background of the site, building or monument). Chronology was assessed on the basis of the information presented in the literature. Objects were typologically classified into six main classes: architectural elements (ashlar, veneer, column elements, etc.), sculptural objects (statuary, relief sculpture, etc.), epigraphic documents, utilitarian objects (vases, plates, chandeliers, cosmetic plates, etc.), sarcophagi, or undefined (Fig. 2A). The two most frequent functional classes, that is, architectural and sculptural white marble objects, were a further focus.

While the strengths of marble as a proxy indicator for the Roman economy have already been highlighted (popularity, durability, provenancing potential, quantity of available data, and chronological and geographical resolution), the material is obviously not free of biases that typically affect the amount and type of archaeological information at hand. These are primarily related to depositional and post-depositional processes, as well as research and publication history. Understudied (or underpublished) regions are certainly the Eastern Adriatic and the Balkans, North Africa, the inner Iberian Peninsula, northwestern

[12] Correct macroscopic characterization, identification, and provenancing of white marble is a difficult task, as variations in visual characteristics such as color, texture, and structure frequently occur within single outcrops. Moreover, inter-quarry similarities are frequent, and many white marbles have (near-)identical macroscopic and microscopic appearances. As result, identifications of white marble based on macroscopic and microscopic observations alone are highly problematic. See Lazzarini 2004; Antonelli and Lazzarini 2015 for a detailed discussion of marble provenance methodology.

[13] Examples of quarry districts not included in the study because of their reduced distribution in Roman times are Denizli, Hierapolis, Hymettos, Lesbos, Tinos, and Uşak.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

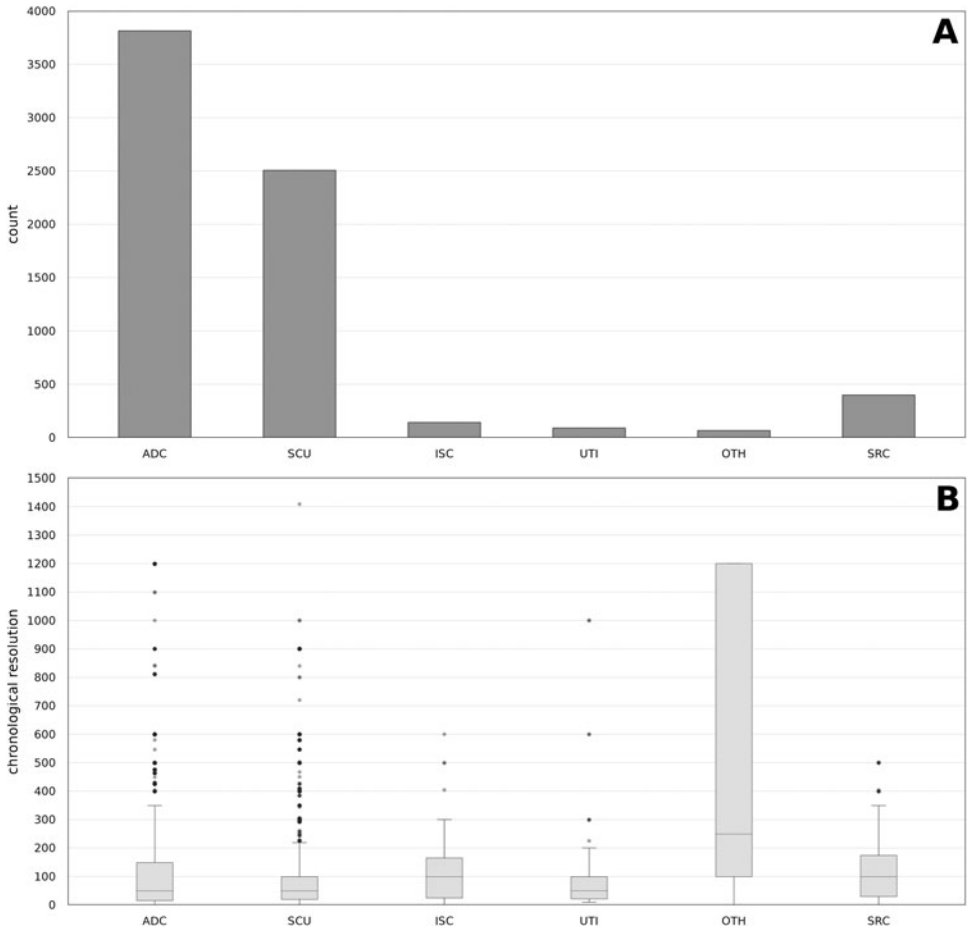

Fig. 2. *White marble object categories included in the study: (A) count per object category; (B) chronological resolution per object category. Object type abbreviations: ADC = architectural element, SCU = sculptural object, ISC = inscription, UTI = utilitarian object, OTH = undefined type, SRC = sarcophagus. (D. Taelman.)*

Europe, and inner Asia Minor. Nonetheless, the database for this article represents the most complete overview of white marble in the Roman Mediterranean currently available.

Biases that relate specifically to marble essentially involve reuse/recycling/redistribution, as well as differential sampling strategies and intensities. Differential sampling strategies and intensities relate primarily to the geographical and chronological spread of case studies and to the choice and number of objects analyzed. The most common approach to sampling in marble provenance studies has been to maximize the lithological variation of marble types at each findspot. Quantification of absolute counts of provenanced marble objects is, therefore, not always straightforward, representative, and/or comparable between findspots. While less problematic from a production perspective, this is a significant issue when focusing on distribution and consumption patterns. It must also be noted that differences in the quantity of provenance determinations available for certain findspots are related not only to differential sampling intensities, but also indirectly to differences in the quantities of marble material imported, and therefore to historical realities. This is particularly the case for Rome, where without doubt significantly more marble was imported than at most other sites in the Mediterranean. The site of Rome, for example, accounts for

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

almost 1,300 provenanced marble objects in the database. Other sites with high levels of marble use in the Roman period, such as Constantinople, Leptis Magna, etc., are, however, less well represented in the database due to different research focuses and/or different sampling strategies and intensities. To counter these effects of research focus and sampling strategies and intensities, this article concentrates on the presence/absence of marble varieties at findspots in a particular period instead of looking at the total sample count for findspots.[14]

Because of the physical properties and intrinsic value of the material, life histories of marble objects can be complex, sometimes with several cycles of reuse, recycling, and redistribution. Much of the material, especially in the Late Empire and Late Antiquity, was salvaged and reused or recycled for re-application, recarving, or use in lime production.[15] Where the context of the objects indicates signs of reuse/recycling, this was accounted for upon entry in the marble database by focusing on the earliest identifiable date for the object.

While these biases surely affect the dataset, I believe that its size, the focus on presence/absence counts, and having accounted for the immediate and wider context of the sampled objects reduces the effect of these weaknesses to a large extent.

Chronology and temporal uncertainty

The chronology of the marble objects under study is derived either from their stratigraphic context or, where the objects originated from open contexts or secondary depositions, from stylistic characteristics. Regardless of depositional context, exact dates of production and/or consumption are generally not available. As in most archaeological material studies, chronology is normally given using date ranges. Apart from the intrinsic temporal uncertainty of the collected archaeological material, we are confronted with objects that have different levels of temporal uncertainty. While some marble objects can be dated very narrowly (e.g., Imperial portraits, inscriptions), others can only be assigned to cultural periods (e.g., Early Empire, Late Roman, Hadrianic) or centuries (e.g., 1st c. CE). Figure 2B, shows, however, that with the exception of the undefined object types, it safe to say that all object categories show a relatively narrow chronological resolution, with mean values generally well below 100 years. Figure 3 further displays the relation between the temporal resolution of the marble objects included in the study and their distribution over time, using an alternative visual method known as the MR-diagram (midpoint-radius diagram), developed by Zenon Kulpa.[16] Here, every marble object is represented as a point in time on the basis of its date range (x-axis) and temporal resolution (y-axis). Using this method, it is possible to represent visually how many objects are dated to a particular time period and also what objects have relatively higher or lower temporal reliability. Figure 3A, for example, shows that most architectural marble objects date from 50 BCE to 250 CE, with most having a temporal resolution below 100 years. For the period after the 3rd c. CE, dating of the objects becomes less precise, as illustrated by the higher values on the y-axis.

[14] For example, if ten objects dated to the second half of the 1st c. CE at site A have been identified as Pentelikon marble, and five objects from the same period as Carrara marble, site A is counted once for Pentelikon and once for Carrara for the second half of the 1st c. CE.

[15] Barker 2020.

[16] Kulpa 1997a; Kulpa 1997b; Kulpa 2006.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

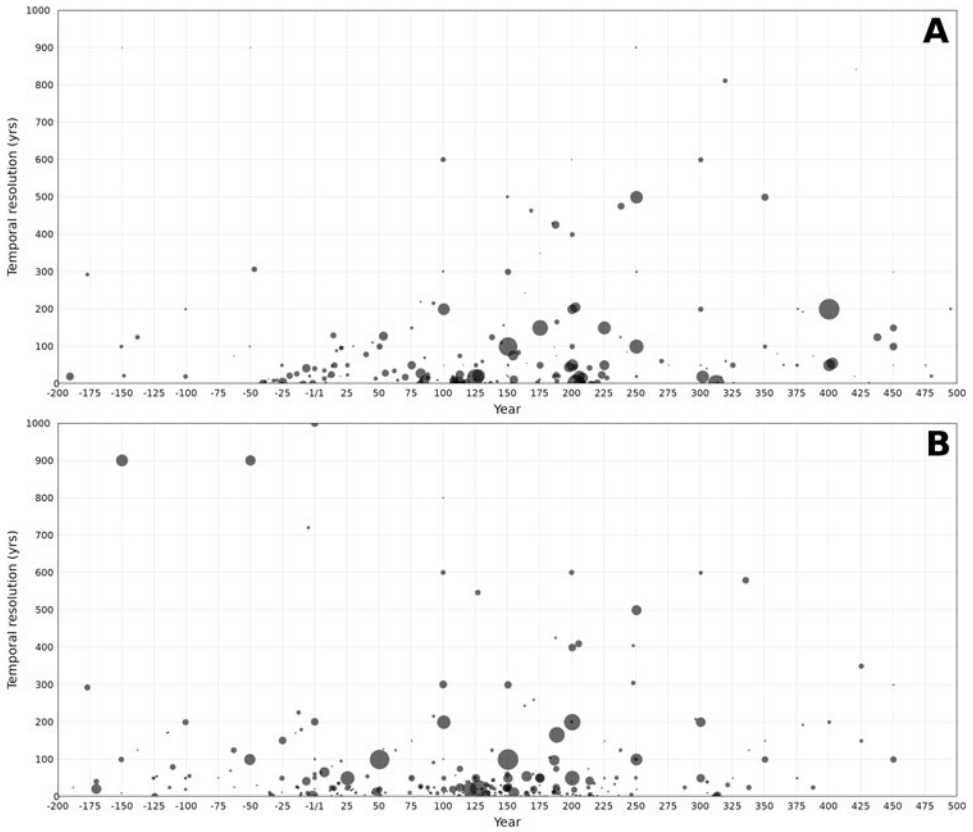

Fig. 3. *Chronological resolution of the white marble objects included in the study, as calculated using the midpoint-radius method. The size of the points represents the number of objects: (A) architectural objects; (B) sculptural objects. (D. Taelman.)*

Figure 3B illustrates that sculptural marble objects included in the study from the 2nd/1st c. BCE have varying temporal resolutions, and that most of the sculptural objects date from the late 1st c. BCE to the middle of the 3rd c. CE. In this period, temporal resolutions for most objects are below 50 years. For both material categories, the data for the Late Imperial period and for Late Antiquity are less abundant, but overall chronological reliability remains relatively high.

The problem of temporal diagnosticity remains pressing, however, when looking at medium- and long-term trends in the rise and fall of market shares of marble resources, and when aiming to compare the trade in marble with that of other (archaeological) proxies for the Roman economy. To deal with the issue of temporal uncertainty, and to enable graphing the variability in the objects' distribution over time with different levels of chronological resolution, a chronological distribution method has been applied to the objects in the marble dataset. For archaeological studies, several chronological distribution methods have already been proposed, the principal of which are midpoint chronology and aoristic weighting.[17] The idea behind these methods is that they apply a probability

[17] For example, Fentress and Perkins 1988; Fentress et al. 2004; Wilson 2011b; Crema 2012; Roberts et al. 2012; Willet 2014; Wilson 2014; Crema 2015.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

distribution over an object's date range to assign the object to a particular temporal block. Both methods assign a temporal probability weight to a specific event of unknown exact date, based on its potential start and end dates. They differ in how they distribute date probability over the object's time span, with each approach having its own strengths and weaknesses (e.g., computational requirements and robustness to outliers, that is, objects with very low chronological resolution). Midpoint chronology assumes that an object was produced exactly in the middle of its presumed date range,[18] while aoristic weighting applies a probability curve over the object's time span. Different probability curves can be applied; for example, a linear distribution, which assumes an equal probability over the object's date range, or a normal (bell-shaped) distribution, which assumes a higher likelihood in the middle of the object's date range than towards the start and end dates.[19]

For this article, marble objects were chronologically assigned to a particular period using aoristic weighting with a linear distribution. This method was chosen to reduce interpretational difficulties, as we generally have very little or no archaeological indication of the probability distribution of the production/distribution of marble objects within their date ranges. The timeline was divided into time blocks of 25 years, a choice that was based on and can be justified by the chronological resolutions of the objects under study (Fig. 2B). However, instead of summing the aoristic weighting results per time block, a simulation approach was applied to the distribution method with the goal of accounting for the probabilistic nature of the temporal distribution. This approach involves the creation of multiple possible "scenarios" of results, in this case 10,000 simulation runs, with the probability of occurrence for each trajectory being defined by the aoristic probabilities.[20] In this way, the difference between higher and lower temporal intervals (e.g., time blocks of 50 years instead of 25 years) has less influence on the results of the object chronology distribution. Raising or lowering the length of the time blocks will mainly affect the uncertainty level for that particular block. The chosen time interval, therefore, principally only affects the coarseness of the final curves.

White marble distribution trends and patterns

An initial exploration of the marble distribution graphs of Figure 4 shows a steady rise in the number of sites at which white marble has been attested in the Late Republic, with a minor peak in the first half of the 1st c. CE. A more pronounced peak can be observed for the 2nd c. CE, a period in which both architectural and sculptural marble had their widest distribution, but overall slightly more so for sculptural marbles: sculptural marbles are attested at more sites than architectural marbles. A gradual decrease in the distribution of architectural marbles followed during the Late Empire, and there was a stable period in Late Antiquity, with distribution figures similar to those of the early 1st c. CE. For sculptural marble, a significant decline set in at the beginning of the 3rd c. CE and distribution virtually halted in the mid-4th/5th c. CE.

---

[18] Using midpoint chronology, an object with a production date range of 115–165 CE is placed at 140 CE.

[19] Orton 1980, 99–101; Willet 2014; Crema 2015. Using linear distribution, an object with a production date range of 115–165 CE has an equal probability of being produced in any year between 115 and 165; that is, a probability of 2%.

[20] Crema 2012, 450–51; Crema 2015.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

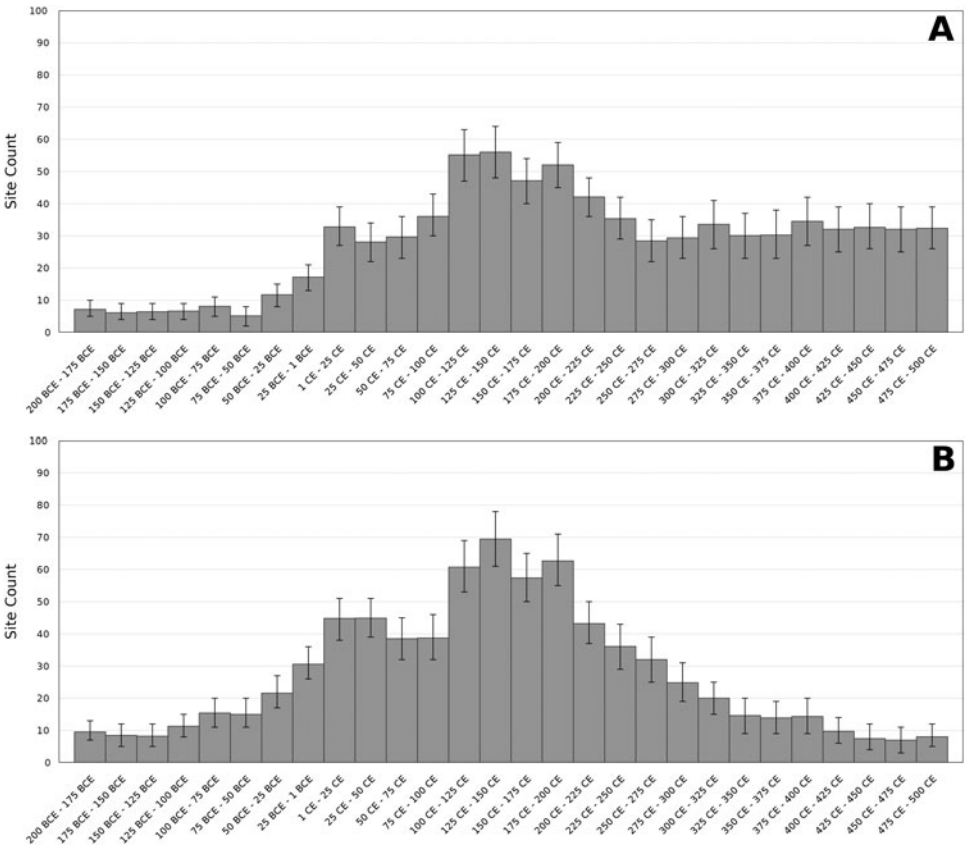

Fig. 4. *Number of sites per 25-year period at which white marble objects have been attested (bar height represents the mean number of sites, error bars the 95% confidence interval of the 10,000 simulations): (A) architecture; (B) sculpture. (D. Taelman.)*

While Figure 4 shows a relatively straightforward pattern, with a peak in distribution for both architectural and sculptural marbles in the 2nd c. CE, the graphs in Figures 5, 6, and 7 display a more diverse and complex picture, with marble-, object-, and region-specific distribution patterns, and with significant overlap in the distribution areas of different marble varieties.[21]

The general chronological picture is one in which Carrara, Prokonnesos and, to a lesser extent, Pentelikon dominated the market for architectural marble, while other marble varieties were either not used or only occasionally used for architecture. Carrara had by far the widest distribution of all marbles during the Late Republic and Early Empire, with a peak throughout the 1st c. CE and the first half of the 2nd c. CE, followed by a relatively stable number of site attestations up to the early 3rd c. CE (Fig. 5A). This peak results from a rapid rise in distribution in Italy and to some degree the Western Mediterranean (Fig. 6). Similar patterns can be detected for Pentelikon, Paros-2(3), and Dokimeion marble, albeit with lower distribution levels. In the Eastern Mediterranean, there are almost no attestations of architectural applications of Carrara marble. From the second quarter of

[21] For evaluating the region-specific distribution, a distinction is made between Italy, the Eastern Mediterranean, and the Western Mediterranean.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

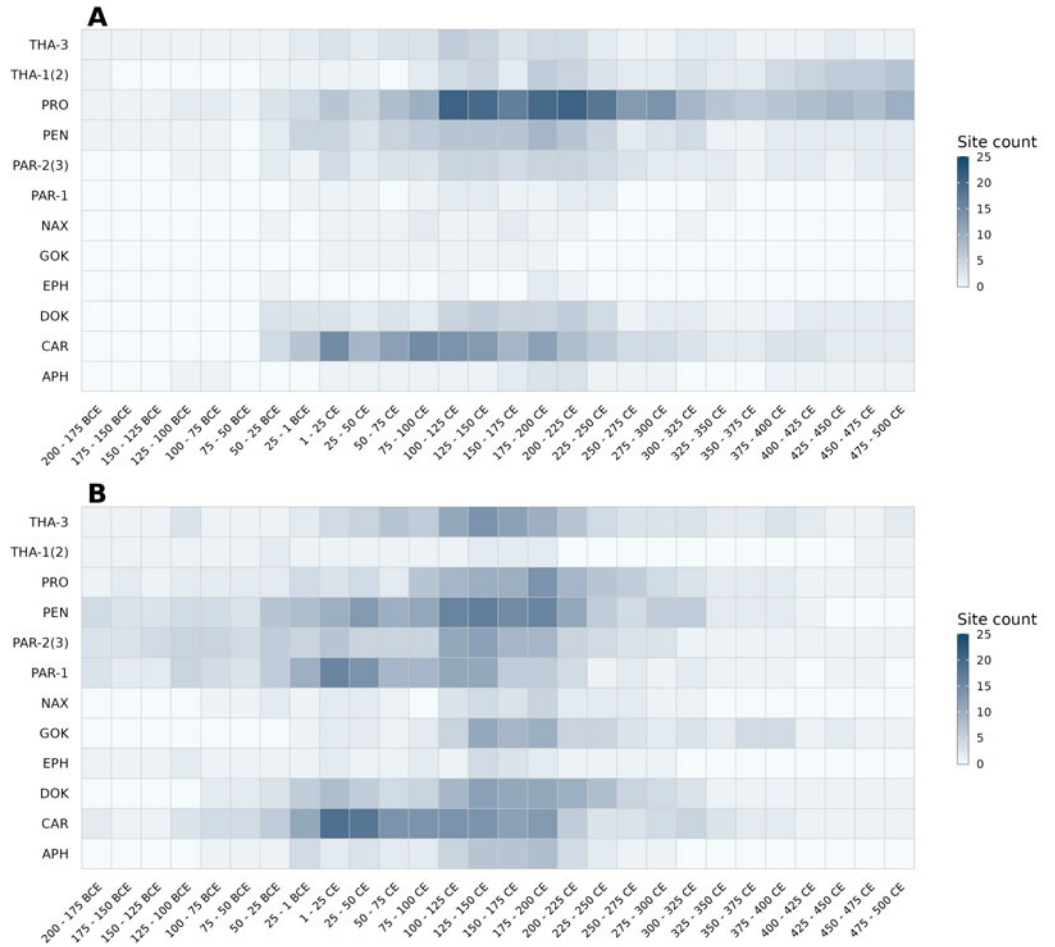

Fig. 5. *Number of sites per 25-year period and per marble variety at which white marble objects have been attested (site count represents the mean number of sites of the 10,000 simulations): (A) architecture, (B) sculpture. Quarry abbreviations: APH = Aphrodisias, CAR = Carrara, DOK = Dokimeion, EPH = Ephesos, GOK = Göktepe, NAX = Naxos, PAR-1 = Paros-1, PAR-2(3) = Paros-2(3), PEN = Pentelikon, PRO = Prokonnesos, THA-1(2) = Thasos-1(2), THA-3 = Thasos-3. The underlying data are provided in the Supplementary Materials accompanying this article. (D. Taelman.)*

the 3rd c. CE onwards, the importance of Carrara for architectural purposes diminished. While Carrara was the dominant supplier for architectural marble in the Mediterranean, mainly Italy, up to the end of the 1st c. CE, this role was gradually taken over by Prokonnesos in the 2nd c. CE. In Italy, Proconnesian marble shows a clear co-occurrence with Carrara marble from the 1st c. CE. Prokonnesos consolidated its role as prime architectural marble in Italy and the Eastern Mediterranean throughout the Middle and Late Empire, and in Late Antiquity. Despite Prokonnesos being the dominant architectural variety, we can discern a reduction in distribution in the 4th c. CE, followed by a modest recovery in the 5th c. CE, particularly in the East (Fig. 6). At present, only very few attestations of Proconnesian architectural marble are known from the Western Mediterranean (i.e., in southern Gaul, the Iberian Peninsula, and western North Africa). Noteworthy for Late Antiquity is the rise, albeit rather limited, in the number of sites at which Thasos-1(2), that is, the calcitic marble variety from Thasos, has been attested for

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

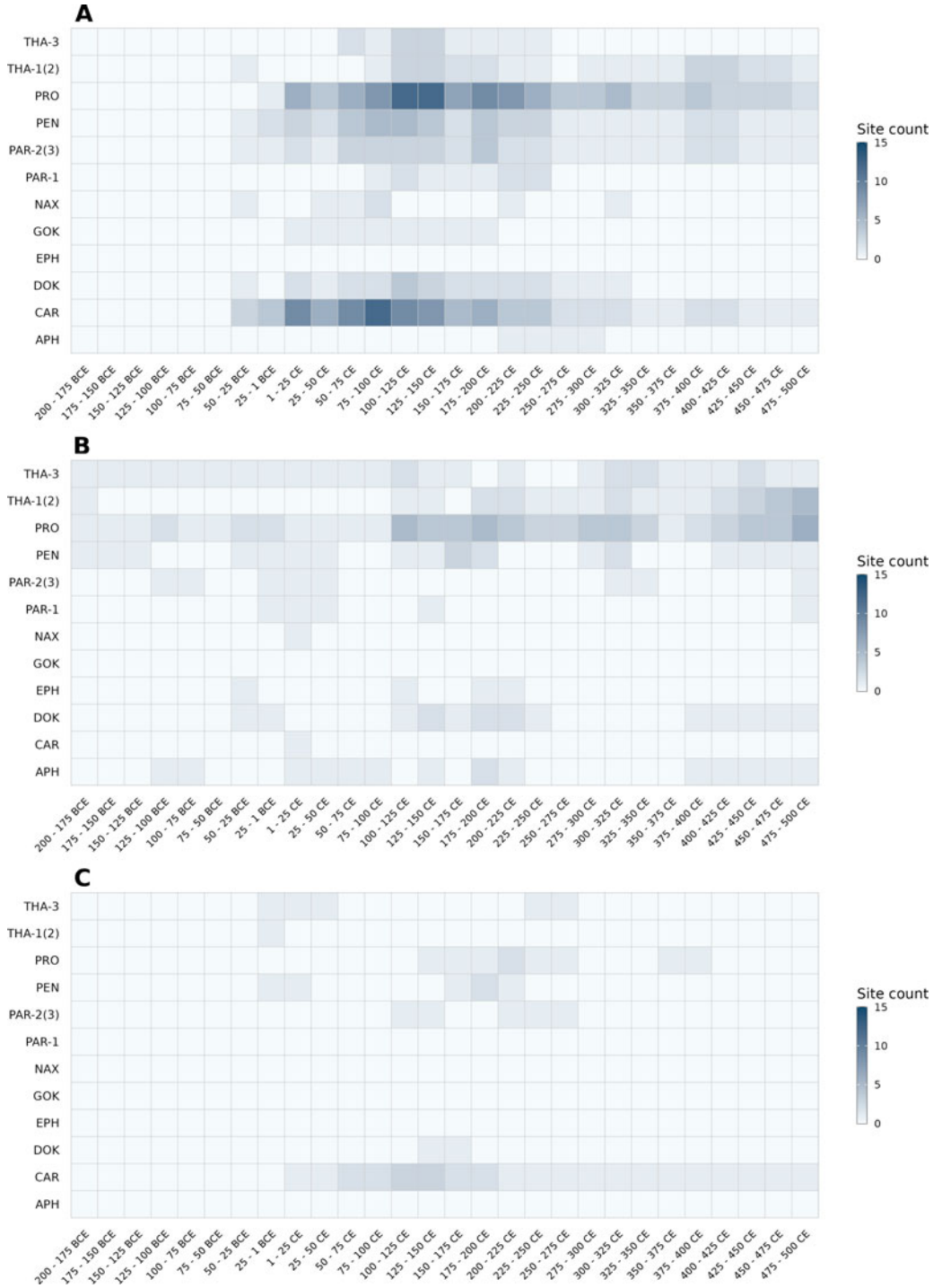

Fig. 6. *Number of sites per 25-year period, marble variety, and region at which white architectural marble objects have been attested (site count represents the mean number of sites of the 10,000 simulations): (A) Italy, (B) Eastern Mediterranean, (C) Western Mediterranean. Quarry abbreviations: APH = Aphrodisias, CAR = Carrara, DOK = Dokimeion, EPH = Ephesos, GOK = Göktepe, NAX = Naxos, PAR-1 = Paros-1, PAR-2(3) = Paros-2(3), PEN = Pentelikon, PRO = Prokonnesos, THA-1(2) = Thasos-1(2), THA-3 = Thasos-3. The underlying data are provided in the Supplementary Materials accompanying this article. (D. Taelman.)*

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

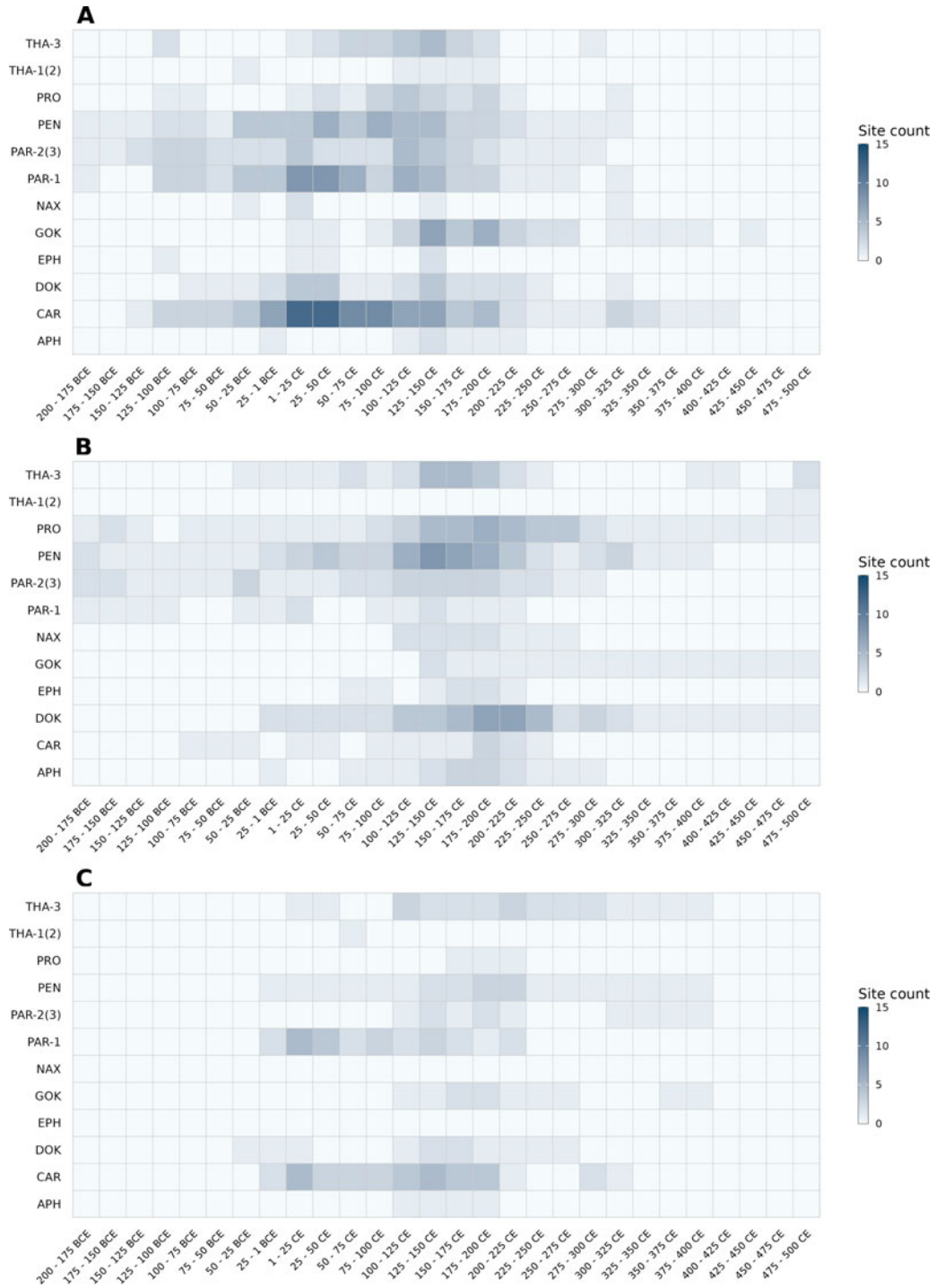

Fig. 7. *Number of sites per 25-year period, marble variety, and region at which white sculptural marble objects have been attested (site count represents the mean number of sites of the 10,000 simulations): (A) Italy, (B) Eastern Mediterranean, (C) Western Mediterranean. Quarry abbreviations: APH = Aphrodisias, CAR = Carrara, DOK = Dokimeion, EPH = Ephesos, GOK = Göktepe, NAX = Naxos, PAR-1 = Paros-1, PAR-2(3) = Paros-2(3), PEN = Pentelikon, PRO = Prokonnesos, THA-1(2) = Thasos-1(2), THA-3 = Thasos-3.The underlying data are provided in the Supplementary Materials accompanying this article. (D. Taelman.)*

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

architectural purposes. The Late Antique rise is related to attestations of the material mainly in Italy and the Eastern Mediterranean.

While the market for architecture was dominated by essentially two white marble varieties, the market for sculpture was much more divided (Fig. 5B). Marbles from Aphrodisias, Ephesos, Göktepe, Naxos, and Paros-1 were almost exclusively used for sculpture, an observation that has already been made by some scholars.[22] Overall, the entire Mediterranean shows a similar distribution pattern but with diverging chronologies, with a wide variety of marble being used for sculptural production. In the East, the practice of erecting statues was already underway in the 2nd/1st c. BCE. For Italy and the West, sculptural marble was introduced only in the Late Republic and the Early Empire respectively, but the phenomenon spread quite rapidly there. The peak of sculptural marble distribution in the East can be dated to the middle and late 2nd c. CE, while for Italy and the West, it had already occurred between the 1st c. CE and early 2nd c. CE (Fig. 7). Greek marbles (Pentelikon, Paros-1, Paros-2(3)), together with Carrara, prevailed in the market in the Late Republic, predominantly in Italy and the East. The late 1st c. BCE and the 1st c. CE show a sharp rise in the distribution of Carrara and Paros-1, followed by a period of slightly reduced popularity in the 2nd c. CE. At the peak of sculptural marble distribution, the market was essentially dominated by Pentelikon, Carrara, Thasos-3, Paros-2(3), Prokonnesos, and Dokimeion. Regional differences mainly relate to a focus on Prokonnesos, Pentelikon, and Dokimeion in the East, and Carrara and Paros-1 in Italy and the West. For example, the use of Paros-1 and Carrara in the Eastern Mediterranean has been attested in only a few, isolated cases. Worthy of mention is the almost complete disappearance of Carrara for sculptural purposes after the mid-3rd c. CE; this is in contrast with the more gradual decrease of Carrara marble in architecture. Particularly interesting is the curve of Göktepe marble, which had only a relatively short period of popularity around the middle and later 2nd c. CE, with a distribution essentially confined to Italy (mainly Rome). Two remarkable cases of Göktepe marble are its large-scale use for private and imperial statuary at the Roman villa of Chiragan (Martres-Tolosane, France) during the 2nd and 3rd c. CE,[23] and its use for a 4th-c. CE sculptural group found at the rural villa of Quinta das Longas in inland Lusitania.[24]

Overall, the image of the Roman marble trade is that it started in the Late Republic and experienced its heyday in the course of the 2nd c. CE. The decline of the 3rd c. CE is particularly visible in sculptural marble applications, while it appears less pronounced for architectural purposes. The market for architectural marbles was dominated by Carrara and Prokonnesos, as well as Thasos-1 in Late Antiquity. For sculptural purposes, Carrara, Pentelikon, Paros-1 and Paros-2(3) were the main marble varieties until the middle of the 1st c. BCE. Most sculptural marbles (Aphrodisias, Dokimeion, Paros-2(3), Pentelikon, and Thasos-3) show similar distribution patterns, with a low peak in the early 1st c. CE and a second, higher peak around the middle and during the late 2nd c. CE. Regions of distribution for the marbles, however, diverged. Pentelic marble made its appearance in the Eastern Mediterranean during the Late Republic. In the late 1st c. BCE, it was introduced

[22] For example, Germann et al. 1988; Maniatis and Polikreti 2000; Lazzarini et al. 2002; Russell 2013b; Attanasio et al. 2015; Bruno et al. 2015a; Al-Bashaireh 2021.

[23] Prochaska 2015; Attanasio et al. 2016; Attanasio et al. 2018; Attanasio et al. 2021.

[24] Nogales Basarrate et al. 2004; Lapuente et al. 2021.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

in Italy, first for sculpture. In the early 1st c. CE, it was widespread throughout the Mediterranean region, essentially for sculpture, while its architectural use was limited primarily to Italy. Well-known marbles like Ephesian and Naxian seem to have had only a restricted distribution.

Carrara appears to have been the dominant player in the market until the late 1st c. CE, with distribution mainly in Italy and the West. Its position as the leading architectural marble was taken over in the course of the 2nd c. CE by Prokonnesos, which remained the primary architectural marble until at least the end of the 5th c. CE. The decline of Carrara from the 3rd c. CE can be observed mainly for sculpture; for architecture, it is much less pronounced. It is often argued that the distribution and consumption of Carrara decreased principally from later 3rd and 4th c. CE onwards, mainly due to the gradual silting of the Luna harbor, the port from which the marble was shipped in Roman times, and the consequent transport difficulties.[25] The data presented here, however, show that the importance of Carrara marble had already decreased in the early 3rd c. CE, well before the silting of the Luna harbor, which has been dated to the 4th/5th c. CE by recent geoarchaeological studies.[26] These studies have shown that the coastal area near Luna was a geomorphologically very dynamic region, with frequent shifts in coastline controlled by changes in the sediment supplied by the rivers and streams descending from the Apuan Alps. Moreover, it has been demonstrated that this was a non-continuous process, already underway in the pre-Roman and Roman periods but becoming continuous only from the 5th–6th c. CE. Building activity in the 3rd/4th c. CE in Luna, the installment of a bishop's see in the town in 465 CE, and the role of the town as an important trading center in Byzantine times, in the latter half of the 6th c. CE,[27] all point to relative prosperity well after Carrara's marble output was reduced and suggest that the decrease in its distribution was not related to the silting of the town's harbor. Exhaustion of the marble resources does not explain the sudden fall in distribution either, given the later revival of extraction in the 12th c. CE using similar techniques to the Romans. These elements, together with different trends for Carrara architecture and sculpture, point towards market-driven processes behind its decline and the preference for Proconnesian marble in the Late Empire and Late Antiquity, especially in Italy. We should not ignore, however, that a reduction in the available labor force, resulting from a general population decrease in the region,[28] could also have played a role in the downfall of Carrara as a center of marble production.

Within this general image of quarry districts that exported on a supra-regional scale, we should not forget the importance of certain regional marbles. This is particularly the case for the Iberian Peninsula, which has several high-quality white marble resources, such as those from the Estremoz Anticline, Almadén de la Plata, and Mijas,[29] as well as the marble from Saint-Béat.[30] The presence of these high-quality white marbles resulted in distinct

[25] Walker 1988; Fazzini and Maffei 2000, 257.

[26] Bini et al. 2009; Bini et al. 2012; Bini et al. 2013.

[27] Busch 1991.

[28] Palmisano et al. 2017.

[29] Lapuente 1995; Lapuente and Turi 1995; Lapuente et al. 2000; Lapuente and Blanc 2002; Ontiveros Ortega et al. 2012; Taelman et al. 2013.

[30] Royo Plumed et al. 2015; Royo Plumed et al. 2018. The quarries of Saint-Béat are located on the northern sides of the Pyrenees; that is, in France, just outside of the Iberian Peninsula.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

marble consumption patterns for the region, in which imported Mediterranean marbles from Italy and the East were used in combination with regional material.[31] In the coastal parts of northeastern Tarraconensis, architectural objects were carved predominantly in Carrara, while Greek marbles (particularly from Paros, Pentelikon, and Thasos) together with Carrara were popular for statuary.[32] Inland, mainly along the Ebro Valley, Pyrenean marble from Saint-Béat was the preferred material for architectural and sculptural purposes, with Mediterranean imports arriving there only in reduced numbers. For Baetica, the districts of Almadén de la Plata and Mijas, and to a lesser extent Estremoz, were the prime suppliers for both architecture and sculpture. Imported Mediterranean marbles, essentially from Carrara and sometimes Paros, are attested only in a few cases.[33] The situation was similar for western North Africa, where marble for architecture was imported from both Hispanic (Malaga, Almadén de la Plata, and Estremoz) and Mediterranean sources, while statuary used exclusively Mediterranean material (Parian, Thasian, and Pentelic).[34] For Lusitania, and northwestern and central Tarraconensis, the Estremoz Anticline provided the bulk of the marble. Imported white marbles (Carrara, Pentelikon, Aphrodisias, and Paros) are currently attested only at Emerita Augusta, the capital of Lusitania, and this is mainly for high-status sculptural objects and buildings that are linked to the Imperial family.[35] Overall, the Estremoz Anticline seems to have been the regional marble with the widest distribution. Exports have been attested along the entire Atlantic side of the Iberian Peninsula, parts of inner Iberia, as far east as Caesaraugusta (Zaragoza, Spain), and at Banasa (Sidi Ali bou Djenoun, Morocco) in Mauretania Tingitana.[36]

The Roman white marble trade in a wider economic and societal perspective

It has long been the consensus among historians and archaeologists that the Roman economy experienced growth in the Late Republic and Early/Middle Empire, followed by decline in the Late Empire and Late Antiquity.[37] Recent studies, however, illustrate that this general pattern was locally much more diverse. There were clear regional differences, with decline setting in during the 3rd c. CE in the West (including Italy and Greece), while the East and North Africa experienced growth until the 4th–6th c. CE.[38] Much more central to today's scholarly debate is whether this growth was limited to aggregate growth or also included per capita growth. Positions in this debate largely align with academic

[31] See Pensabene 2004; Gutiérrez Garcia-Moreno and Rodà de Llanza 2012; Nogales Basarrate et al. 2015; Rodà de Llanza 2020; Taelman 2022 for a detailed discussion of the marble trade in the Iberian Peninsula.

[32] No provenance studies have been carried out for the southeastern coastal part of Tarranconensis thus far.

[33] For example, the use of Carrara marble for the Traianeum of Italica (Santiponce, Seville). Becerra-Fernández et al. 2021.

[34] The number of sculptural objects analyzed here is, however, very limited.

[35] For example, several statuary fragments from the theatre, the Colonial Forum, and the temple of Diana in Carrara and Paros-1 marble, as well as a statue of Aesclepius from the Mithraeum House in Aphrodisian marble. Lapuente et al. 1999; Lapuente et al. 2000; Lapuente et al. 2014.

[36] Antonelli et al. 2015; Lapuente et al. 2016.

[37] For example, Jongman 2007a.

[38] For example, Erdkamp 2020.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

background: archaeologists generally advocate for overall increased welfare and per capita growth, as evidenced by the unprecedented expansion of traded archaeological material around the Mediterranean between the 1st c. BCE and the 2nd c. CE; historians, on the other hand, tend to argue that the aggregate growth of the Roman economy, as illustrated by the archaeological evidence, was to a large extent outbalanced by demographic growth, resulting in only limited per capita growth or even decline.[39]

As an object of trade and an indicator for urbanization, the marble data presented in this article can contribute to this debate about the performance and structure of the Roman economy. Roman culture is well known for its impressive architectural realizations. The use of stone in ever-increasing quantities was emblematic of Roman architecture and urbanization; monumental marble(-clad) architecture and statuary were an essential part of the Roman urban environment. While urbanization and economic performance might not be connected in a straightforward manner,[40] there is no doubt that town development had a considerable effect on the Roman economy. More and larger towns meant higher urban populations and more people to be active in non-agricultural labor, such as crafts, manufacturing, and services.[41] Moreover, the foundation of new towns and the expansion of existing towns, with the erection and marble embellishment of monumental architecture, gave rise to large-scale building activity. This required efficient coordination and information exchange, and engaged workers with different professional backgrounds and specializations, including architects and builders as well as people involved in the production of building materials (quarrymen, carvers, sculptors, etc.) and in trade (merchants, shippers, transporters, etc.).[42]

Marble distribution, of course, does not directly reflect the foundation or expansion of towns; it can, however, be used as an indicator of elite capital investment in the urban fabric. Higher levels of marble distribution suggest increased financial means among the elite for investing in urban embellishment and therefore indirectly illustrate economic growth.[43] The town was the typical setting wherein the Roman elite spent the income of surplus production from their estates to perform their social role, amongst other ways, in the form of architectural munificence ranging from gifting entire buildings to donations of individual architectural elements such as marble decoration, columns, or statuary.[44] In view of this, increased marble distribution can be seen as a reflection not only of increased trade (and the related growth of markets) but also of increased urbanization, greater enrichment of elites, shifts in capital and labor from agriculture to non-agricultural economic sectors, social complexity, and higher living standards. Whether this increased investment in marble decoration resulted from the upper elite investing more (indicating increased social inequality and thus extensive economic growth), or it resulted from a larger fraction of the elite having access to luxury material (indicating increased living standards for a larger part of the population and thus intensive economic growth) is less

[39] See Scheidel 2009; Wilson 2009; Erdkamp 2016 for discussions on this topic.

[40] Morley 2011.

[41] Lo Cascio 2009.

[42] Abrams 1989; Trigger 1990; Erdkamp 2020.

[43] See Wu 2012; Dutta et al. 2018 for discussions of the relationship among economic performance, living standards, and the increased consumption of luxury goods.

[44] Zuiderhoek 2009.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

clear. Data from Pompeii and Herculaneum, however, seem to point in the direction of the latter. At these sites, a growing number of non-public buildings were being decorated with an increasing variety of marble in the 1st c. CE. This is particularly visible in marble insert and opus sectile pavements in residential structures, and in the marble-clad counters of bars, thus illustrating that increased marble consumption was not only restricted to the upper elite.[45] As such, increased marble distribution can point to real, per capita, intensive economic growth.

The distribution patterns of white marble in the Roman Mediterranean discussed in the previous section illustrate a start to the marble trade in the Late Republic, with its heyday in the 2nd c. CE. The decline that set in during the 3rd c. CE is particularly visible for sculptural marble. The distribution of architectural marble shows only a minor drop, followed by a relatively stable level of distribution throughout the Late Empire and Late Antiquity, with figures still higher than those for the Late Republic and Early Empire (that is, up to the 1st c. CE). The continued distribution of architectural marbles is mainly observed in Italy and the Eastern Mediterranean. The divergence between architectural and sculptural marbles suggests that reduced marble distribution in the Late Empire and Late Antiquity is not necessarily the result of a declining Roman economy, but rather points towards changes in the cultural practices related to statue erection in this period.[46] This is also illustrated by the fact that we can observe this phenomenon for all marble varieties and throughout the entire Mediterranean. The observations for marble data are very much in line with those for building inscriptions, which show a similar trend up to the end of the 2nd c. CE and early 3rd c. CE.[47] For the Late Empire and Late Antiquity, however, the building inscriptions show a drastic decline, which is not so marked in the marble distribution data. This might indicate that the urbanization decline after the 3rd c. CE was less pronounced than suggested by the building inscription record and is more related to changes in the epigraphic habit than to reduced elite investment in the urban fabric.

The decline in urbanization in the Later Roman period, albeit with notable regional chronological differences, that is advocated by several scholars[48] seems only partly supported by the marble distribution data. While it is certainly true that large-scale building activities in the Western Mediterranean in this period were less frequent, and several towns diminished in size or even disappeared, the reduced urbanization seems less valid for Italy and the East, or at least presented itself in a different manner. In the East, large-scale building projects and marble embellishment were still being undertaken in several regions.[49] In Italy, marble embellishment in urban centers seems to continue until Late Antiquity, albeit

---

45 Fant et al. 2013; Barker and Fant 2018; Barker and Taelman 2021. In the cases of Pompeii and Herculaneum, we must acknowledge the importance of reuse and salvaging of marble made available by the dismantling of ruined buildings following the earthquake of 62 CE. This has been illustrated, for example, by Fant et al. 2013, and Barker and Fant 2018. While the use of salvaged marble was without doubt cheaper than the importation of new material, marble maintained its intrinsic value and remained a luxury good.

46 Machado 2021.

47 Wilson 2009, 74–75; Wilson 2011a, 163–67.

48 Erdkamp 2012, 262–63; Erdkamp 2016, 11–12; Erdkamp 2020, all with references therein.

49 Bowman and Wilson 2009a, 51; Erdkamp 2012, 262–63. See also the work of Al-Bashaireh and Al-Housan 2015; Al-Bashaireh and Dettman 2015; Al-Bashaireh and Al-Housan 2019 on marble provenance of 4th-c. CE Christian architecture in the Levant.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

at a lower level than during the 2nd c. CE. This reduced investment in urban architectural marble seems to go hand in hand with a growing ruralization and reduced effort by the elite in using the town as the place to express their social and political roles. While urbanization levels were certainly lower in the Late Empire and Late Antiquity than in the Late Republic and Early Empire, the decline, as shown by the marble data, seems less pronounced or at least much more gradual than traditionally believed. And, it is not (only) the consequence of economic decline, but rather, at least partly, the result of changes in cultural practices and the way in which the Roman elite spent their money. The phenomenon of ruralization can also be seen clearly, for instance, in the province of Lusitania, where the 4th c. CE witnessed the development of several large and monumental villa estates, such as the villa of Quinta das Longas and Torre de Palma, at the expense of the main urban centers. Marble was common at these sites, sometimes even importing material from the East, as was the case for Quinta das Longas, which was decorated with statues carved from Göktepe marble.[50] These estates progressively acquired more land and gradually evolved into local centers where religious, funerary, social and economic aspects of society were concentrated. A focus on town contexts in marble provenance studies might thus partly explain the lower marble distribution numbers for this period.

Finally, we cannot ignore the importance of the reuse and recycling of marble architectural elements and marble sculpture in the Later Roman period. While this phenomenon was not uncommon already in Late Republican and Early Imperial times, and was not limited to marble,[51] it is generally associated with Late Antiquity. The purchase of heavy and bulky stone material was an expensive affair in pre-industrial times, as it involved the costs both of the raw material and of the quarrying, carving and transport.[52] For the Later Roman periods, it was often more economical to salvage the large quantities of marble that were available from demolished or abandoned pre-existing structures, thus reducing the costs related to long-distance transport. From this perspective, reuse can be considered simply as the use of an object because its properties are suited for its new function, beyond the one for which it was originally intended. Marble retained its value as raw material, making it unlikely that the resource would have been discarded if it could be usefully re-employed. The adoption of the practice of reuse can therefore not simply be considered an indicator of economic decline. On the contrary, the act of marble salvaging and reuse is a clear sign of continued investment in monumental building and of wider economic investment, albeit not at the scale of building activity in the Late Republic and Early to Middle Empire. Marble salvaging not only involved considerable organizational and infrastructural investments for material storage, but also required labor, including craftspeople for demolition and recarving, transporters (for local transport), and merchants of the second-hand material, as well as people involved in restoration or building.[53] Both growing ruralization and the practice of reusing/recycling marble elements fit into a wider phenomenon of the redefinition of urban public space in the Late Empire and Late Antiquity. It is within this frame that we need to interpret the marble distribution figures.

---

50 Nogales Basarrate et al. 2004; Lapuente et al. 2021.

51 Barker 2010; Barker 2012; Fant et al. 2013.

52 DeLaine 1997, 85; Russell 2013b, 95.

53 See Barker 2020 for a detailed discussion of the economics of marble salvaging and marble reuse in Late Antiquity.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

Because of the uneven geographical distribution of marble resources in the Roman Mediterranean, marble objects generally had to be traded over long distances. The traditional view is that marble exploitation and trade were associated with the emperor or the state. Most quarries are believed to have been part of the *patrimonium Caesaris*, especially after 17 CE, with the alleged confiscation of all principal mines and quarries by the emperor Tiberius.[54] The exploitation and distribution of the material were controlled by a centralized marble administration, the so-called *ratio marmorum*.[55] More recent studies however, have illustrated that this was not necessarily so, and that even at the "imperial" quarries, the presence of private and municipal ownership and production seems to have been the norm.[56] Even though the state was closely involved in the exploitation of (certain) marbles, most material entered the non-imperial market through market-focused trade and not through state redistribution. Looking at the enormous volumes of marble consumed in the Roman world, it seems unlikely that state redistribution was the main mechanism through which the material was exchanged. The overlapping distribution patterns of the different white marble varieties of the 1st and 2nd c. CE, particularly for sculpture, show a well-integrated, inter-regional market for Italy and the East. While imported material from Italian and Eastern quarries was not absent in the Western Mediterranean, the ample availability of regionally available marble resources, especially on the Iberian Peninsula, resulted in a much more complex picture. For Spain and Portugal, clear regionally distinct marble consumption patterns can be observed in which, in broad terms, sites in coastal Tarraconensis obtained regular imports from the Carrara quarries (and also from Greek quarries for sculpture), while inland Tarraconensis, Baetica, and Lusitania were oriented more towards regional marbles, with Mediterranean imports being used more scarcely and generally for prestigious projects.

Finally, comparing the marble distribution trends with the evidence obtained from shipwrecks on which stone cargoes were being transported further highlights some interesting points about the organization of the trade in white marble. The shipwreck evidence suggests that most distribution of marble in the Mediterranean dates to between the 1st and 3rd c. CE, with a peak in the 3rd c. CE.[57] The graphs provided in the current article, however, illustrate that the 3rd c. CE was a period with somewhat lower distribution, especially for sculpture but also to a lesser degree for architecture. Focusing on white marble, the somewhat later chronology of the shipwreck evidence probably has to do with a dominance of Eastern marbles in the cargoes. Most shipwrecks for this period have been encountered along Italian coasts, carrying Eastern marbles (Table 1[58]). The discrepancy between the two datasets is related to the fact that in the 3rd c. CE, although less marble was distributed, Eastern marbles, in particular from Prokonnesos, were still popular in Italy. Provenance studies illustrate that large-scale building and restoration projects by the Severan emperors in Rome in the early 3rd c. CE relied heavily on Proconnesian marble, giving rise to intensified maritime transport between Rome and the East in this

[54] Ward-Perkins 1992.

[55] Fant 1988; Fant 1993.

[56] Russell 2013b.

[57] Russell 2012; Russell 2013a; Russell 2013b, 112–39.

[58] Information in the table comes from: Calia et al. 2009; Carlson 2009; Gabellone et al. 2009; Aylward et al. 2012; Giannotta et al. 2015; Beltrame et al. 2016; Beltrame et al. 2019; Antonelli et al. 2020; Beltrame et al. 2020; Beltrame and Antonelli 2022.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

Table 1.
List of Roman shipwrecks with provenanced white marble cargoes. Cargo type abbreviations: ADC = architectural element, SCU = sculptural object, SRC = sarcophagus. Cargo provenance abbreviations: CAR = Carrara, DOK = Dokimeion, PAR-2(3) = Paros-2(3), PEN = Pentelikon, PRO = Prokonnesos, THA-1(2) = Thasos-1(2), THA-3 = Thasos-3.

Shipwreck	*Date*	*Cargo type*	*Cargo provenance*
Kızılburun	50 BCE–1 BCE	ADC, SCU	PRO
Punta del Francese	69 CE–96 CE	ADC	CAR
Secche della Meloria	1 CE–200 CE	ADC	CAR
Cala Cicala	175 CE–225 CE	ADC	THA-1(2), THA-3
Porto Cervo	175 CE–225 CE	ADC	CAR
Torre Sgarrata	180 CE–225 CE	ADC, SRC	THA-1(2), THA-3
Punta Scifo D	200 CE–250 CE	ADC	DOK, PEN, PRO
Capo Granitola	200 CE–300 CE	ADC	PEN, PRO
Marzamemi	200 CE–300 CE	ADC	PEN, PRO
San Pietro in Bevagna	200 CE–300 CE	SRC	THA-3
Isola delle Correnti	100 CE–300 CE	ADC	CAR, PRO
Marzamemi Church	500 CE–540 CE	ADC	DOK, PAR-2(3), PRO, THA-1(2)

period.[59] Moreover, Proconnesian marble is also found at several other sites in Italy in architectural contexts dated to the late 2nd and 3rd c. CE.[60] The intensified trade, together with the longer voyages (especially in comparison to Carrara in the previous periods) and the related higher risk of wreckage, likely explain the slightly later chronology of the shipwreck evidence.[61]

The compositions of the wrecks with white marble cargoes suggest that at least two different trade systems, that is, direct and indirect trade, were in operation at the same time in the Roman period (Table 1). Cargoes consisting of material from a single quarry suggest that the traffic was part of direct trade or voyages, in which the cargo was loaded at one port for transport to another, pre-determined port. The material was transported to meet a specific demand of the final consumer or an intermediary workshop.[62] Cargoes consisting of material from multiple quarries indicate an alternative system of indirect trade. Loading in this case would be either at various points along the voyage, that is, the respective quarries or their related ports, or at one or more entrepots or (re)distribution centers. The idea of such facilities for marble assumes the existence of stockpiles at centralized locations, where marble objects quarried for an undefined destination were stored.[63] The marble yards at Portus and the Emporium at Rome are generally advanced as evidence for such

[59] Proconnesian marble has been identified as the primary architectural white marble in the Severan period for the construction of the Arch of Septimius Severus and the Baths of Caracalla, and for the restoration of the Porticus of Octavia and the Temple of Bellona. See Lazzarini et al. 1988; Lazzarini et al. 1997; Bruno et al. 2002; De Nuccio et al. 2002; Attanasio and Bruno 2008; Bruno et al. 2009; Bruno et al. 2015b.

[60] These sites include Barium, Brindisium, Regium Lepidi, Sarsina, Sentinum, Tauriana, and Uria. See Zezza et al. 1992; Capedri and Venturelli 2004; Calia et al. 2005; Del Pietro 2012; Antonelli et al. 2016; De Luca et al. 2020; Taelman and Antonelli 2022.

[61] Russell 2013a, 348; Russell 2013b, 123.

[62] Russell 2013b, 133–34.

[63] This has been the prevailing view for the Roman period since the beginning of marble studies by Ward-Perkins (e.g., Ward-Perkins 1992). For a more recent discussion of the process of marble

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

stocks intentionally amassed for (re)distribution purposes. More recent studies, however, critique the existence of such intentional marble stockpiles, even for the large marble yards of Portus and Rome.[64]

Conclusions

The study of white marble distribution presented in this article is the first to approach the Roman white marble trade from a quantitative and diachronic perspective, based on a large dataset of reliable provenance data. The observed trends and patterns point towards increased trade and distribution of white marble in the period from the late 1st c. BCE to the end of the 2nd c. CE. The situation from the 3rd c. CE onwards is less straightforward and displays object-, material-, and region-specific trajectories. The decline in distribution starting in the 3rd c. CE seems to have been less abrupt and more gradual than traditionally suggested, and it can be discerned mainly for sculptural marble and much less so for architectural uses. The reduced distribution (or quasi-disappearance) of certain marbles in the Later Roman Empire, in particular Carrara, is at least partly countered by the continued widespread use of Eastern marbles, such as the material from Prokonnesos. Within this general view, the data shows a common market for Italy and the Eastern Mediterranean, while the situation in the Western Mediterranean (in particular, the Iberian Peninsula) is much more complex, with the joint usage of imported and regional marbles at many sites.

With this study, I argue for a more nuanced view of the complex situation of the Roman economy, particularly for the Later Roman periods, that is, from the 3rd c. CE onwards, for which quantified trends and patterns need to be interpreted within a frame of wider societal and cultural transformations. This is particularly true for the notable differences between architectural and sculptural marble distribution, which can be explained to a certain degree as resulting from changes in cultural practices related to the erection of statues and urbanization, and less in terms of a declining economic reality. However, it needs to be noted that the long-distance trade in white marble was not at the same level from the 3rd c. CE onwards as during the 2nd c. CE. Likewise, the decreasing figures for architectural marble distribution in the West and in Italy, albeit at a lower level than for sculptural marble, need to be seen in light of a growing ruralization and reduced interest among the Roman elite in using urban centers as a setting for capital investment, as well as a growing importance of reuse/recycling of marble elements.

---

supply, in particular of the principles of production-to-stock as opposed to production-to-order, see Russell 2013b.

[64] Fant 1992; Fant 2001 and Russell 2013b, 232–39 convincingly argue that the marble yards of Portus and Rome can be considered unintentional stockpiles and do not provide evidence for the widespread use of the production-to-stock trade model for marble. Their main arguments are (1) the limited amount of material in these piles compared to the estimated annual amount of marble needed in Rome, Italy, and the rest of the Roman world; (2) the absence of standardization in size and form of the architectural elements, without which an effective production-to-stock system could not have functioned; and (3) the quality of the material, in particular the frequent presence of flaws and repairs in many blocks and columns. They identify the marble yards at Portus and Rome as accumulations of unintentional stocks resulting from salvage for reuse after demolition or abandonment of building projects. Similar smaller unintentional piles must have existed at quarries and elsewhere in the form of reusable second-hand objects.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

Acknowledgments: Research for this article was possible thanks to support by the Research Foundation–Flanders (FWO) through a postdoctoral fellowship awarded to the author (grant number 12N8219N) and carried out at Ghent University (Belgium). Part of the research was conducted during a one-month research stay at the Academia Belgica (Rome) in 2021, funded by the Stipendia Academiae Belgicae grant program. The anonymous reviewers are thanked for their constructive and helpful comments, which helped to improve the quality of this article.

Supplementary Materials: The Supplementary Materials contain the underlying data for Figs. 5, 6, and 7 in Excel spreadsheet form. To view the Supplementary Materials for this article, please visit https://doi.org/10.1017/S1047759422000447.

References

Abrams, E. M. 1989. "Architecture and energy: An evolutionary perspective." *Archaeological Method and Theory* 1: 47–87.

Al-Bashaireh, K. 2021. "Ancient white marble trade and its provenance determination." *JAS: Reports* 35: 102777.

Al-Bashaireh, K., and A. Q. Al-Housan. 2015. "Provenance investigation of white marbles of chancel screens from Rihab Byzantine churches, northeast Jordan." *Journal of Cultural Heritage* 16: 591–96.

Al-Bashaireh, K., and A. Q. Al-Housan. 2019. "Provenance of marble elements from the Middle Church at Hayyan Al-Mushrif, northeast Jordan: A multidisciplinary approach." *Archaeological and Anthropological Sciences* 11, no. 5: 2237–47.

Al-Bashaireh, K., and D. L. Dettman. 2015. "Geochemical analyses and provenance determination of white marble samples from churches in North Jordan." *BASOR* 374: 49–59.

Antonelli, F., A. Bloise, F. Bruno, R. De Luca, I. Allegretta, S. Medaglia, A. Taliano Grasso, R. Terzano, and D. Miriello. 2020. "Archaeometric approach to identifying the provenance of white marbles from the shipwreck of Cala Cicala (Crotone, Calabria, Italy)." *JAS: Reports* 30: 102204.

Antonelli, F., P. Lapuente, D. Dessandier, and S. Kamel. 2015. "Petrographic characterization and provenance determination of the crystalline marbles used in the Roman city of Banasa (Morocco): New data on the import of Iberian marble in Roman North Africa." *Archaeometry* 57: 405–25.

Antonelli, F., and L. Lazzarini. 2015. "An updated petrographic and isotopic reference database for white marbles used in antiquity." *Rendiconti Lincei. Scienze fisiche e naturali* 26: 399–413.

Antonelli, F., P. Santi, A. Renzulli, and S. Santoro Bianchi. 2016. "The architectural reuse of Roman marble and stone *spolia* in the early medieval Monte Sorbo church (Sarsina, central Italy)." *Archaeometry* 58: 353–70.

Attanasio, D., M. Brilli, and N. Ogle. 2006. *The Isotopic Signature of Classical Marbles*. StArch 145. Rome: L'Erma di Bretschneider.

Attanasio, D. and M. Bruno. 2008. "Il reimpiego nel portico di Ottavia: i marmi del propileo monumentale." In *Il reimpiego in architettura. Recupero, trasformazione, uso*, ed. J.-F. Bernard, P. Bernardi, and D. Esposito, 51–66. CÉFR 418. Rome: École française de Rome.

Attanasio, D., M. Bruno, and W. Prochaska. 2016. "The marbles of the Roman villa of Chiragan at Martres-Tolosane (Gallia Narbonensis)." *AA* 2016, no. 1: 169–200.

Attanasio, D., M. Bruno, W. Prochaska, and A. B. Yavuz. 2015. "A multi-method database of the black and white marbles of Göktepe (Aphrodisias), including isotopic, EPR, trace and petrographic data." *Archaeometry* 57: 217–45.

Attanasio, D., M. Bruno, W. Prochaska, and A. B. Yavuz. 2018. "The marble of Roman imperial portraits." In *ASMOSIA XI. Interdisciplinary Studies on Ancient Stone. Proceedings of the XI ASMOSIA Conference, Split, 18–22 May 2015*, ed. K. Marasović and D. Matetić Poljak, 185–94. Split: Arts Academy in Split - University of Split.

Attanasio, D., M. Bruno, W. Prochaska, and A. B. Yavuz. 2021. *Göktepe Marbles. White, Black and Two-Tone*. Bibliotheca Archaeologica. Rome and Bristol: L'Erma di Bretschneider.

Aylward, W., D. Carlson, D. Laroche, J.-C. Moretti, and S. Pike. 2012. "The Temple of Apollo at Claros and the Kizilburun shipwreck: Preliminary analysis of isotopic data." In *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX Association for the Study of Marbles and Other Stones in*

Antiquity (ASMOSIA) Conference (Tarragona 2009), ed. A. Gutiérrez Garcia-Moreno, P. Lapuente, and I. Rodà de Llanza, 540–48. Documenta 23. Tarragona: Institut Català d'Arqueologia Clàssica.

Barker, S. J. 2010. "Roman builders - pillagers or salvagers? The economics of deconstruction and reuse." In *Arqueología de la construcción II: Los procesos constructivos en el mundo romano: Italia y provincias occidentales*, ed. S. Camporeale, H. Dessales, and A. Pizzo, 127–42. Anejos de Archivo Español de Arqueología 57. Madrid and Merida: Consejo Superior de Investigaciones Científicas.

Barker, S. J. 2012. "Roman marble salvaging." In *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference (Tarragona 2009)*, ed. A. Gutiérrez Garcia-Moreno, P. Lapuente, and I. Rodà de Llanza, 22–30. Documenta 23. Tarragona: Institut Català d'Arqueologia Clàssica.

Barker, S. J. 2020. "Reuse of statuary and the recycling habit of Late Antiquity: An economic perspective." In *Recycling and Reuse in the Roman Economy*, ed. C. N. Duckworth and A. I. Wilson, 105–90. Oxford: Oxford University Press.

Barker, S. J., and J. C. Fant. 2018. "Recent work on the stone décor at the Villa Arianna and the Villa San Marco (Castellammare Di Stabia) and their context within the Vesuvian area." In *ASMOSIA XI. Interdisciplinary Studies on Ancient Stone. Proceedings of the XI ASMOSIA Conference, Split, 18–22 May 2015*, ed. K. Marasović and D. Matetić Poljak, 65–78. Split: Arts Academy in Split - University of Split.

Barker, S. J., and D. Taelman. 2021. "Painted imitation marble in the context of the marble economy in the Roman period: Examples from Pompeii." In *Imitaciones de piedras preciosas y ornamentales en época romana: Simbolismo, color y lujo*, ed. M. Cisneros, 233–69. Anejos de Archivo Español de Arqueología 93. Madrid: Consejo Superior de Investigaciones Científicas (CSIC).

Becerra-Fernández, D., E. Ontiveros Ortega, and J. Beltrán-Fortes. 2021. "*Marmora* of the *Traianeum* of *Italica* (Santiponce, Seville, Spain): New data provided by archaeometric analysis." *Geoarchaeology* 36: 683–711.

Beltrame, C., and F. Antonelli. 2022. "Archaeological and archaeometric investigation of the Roman marble cargos of Porto Cervo (Arzachena, Sassari, Italy) and Secche Della Meloria (Livorno, Italy)." *Archaeometry* 64: 578–96.

Beltrame, C., L. Lazzarini, and F. Antonelli. 2020. "A Roman shipwreck with a cargo of Apuan marble (Marmor Lunense) at Punta Del Francese (Stintino-Sassari, Sardinia)." *Archaeometry* 62: 1081–94.

Beltrame, C., L. Lazzarini, and S. Parizzi. 2016. "The Roman ship 'Punta Scifo D' and its marble cargo (Crotone, Italy)." *OJA* 35: 295–326.

Beltrame, C., T. Percic, and L. Lazzarini. 2019. "The archaeometric identification of the marbles of the Roman shipwrecks of Capo Granitola (TP), Isola Delle Correnti and Marzamemi I (SR)." *JAS: Reports* 23: 953–67.

Bini, M., C. Baroni, and A. Ribolini. 2013. "Geoarchaeology as a tool for reconstructing the evolution of the Apuo-Versilian Plain (NW Italy)." *Geografia Fisica e Dinamica Quaternaria* 36: 215–24.

Bini, M., H. Brückner, A. Chelli, M. Pappalardo, S. Da Prato, and L. Gervasini. 2012. "Palaeo-geographies of the Magra Valley coastal plain to constrain the location of the Roman harbour of *Luna* (NW Italy)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 337–38: 37–51.

Bini, M., A. Chelli, A. M. Durante, L. Gervasini, and M. Pappalardo. 2009. "Geoarchaeological sea-level proxies from a silted up harbour: A case study of the Roman colony of Luni (northern Tyrrhenian Sea, Italy)." *Quaternary International* 206: 147–57.

Bowman, A. K., and A. I. Wilson. 2009a. "Quantifying the Roman economy: Integration, growth, decline?" In *Quantifying the Roman Economy. Methods and Problems*, ed. A. K. Bowman and A. I. Wilson, 3–84. Oxford Studies on the Roman Economy. Oxford: Oxford University Press.

Bowman, A. K., and A. I. Wilson, eds. 2009b. *Quantifying the Roman Economy. Methods and Problems*. Oxford Studies on the Roman Economy. Oxford: Oxford University Press.

Bruno, M., D. Attanasio, W. Prochaska, and A. B. Yavuz. 2015a. "An update on the use and distribution of white and black Göktepe marbles from the first century AD to Late Antiquity." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 461–68. Rome: L'Erma di Bretschneider.

Bruno, M., S. Cancelliere, C. Gorgoni, L. Lazzarini, P. Pallante, and P. Pensabene. 2002. "Provenance and distribution of white marbles in temples and public buildings of Imperial Rome." In *ASMOSIA 5. Interdisciplinary Studies on Ancient Stone. Proceedings of the Fifth International Conference of the Association for the Study of Marble and Other Stones in Antiquity, Museum of Fine Arts, Boston, 1998*, ed. J. J. Herrmann Jr., N. Herz, and R. Newman, 289–300. London: Archetype Publications Ltd.

Bruno, M., C. Gorgoni, and P. Pallante. 2009. "On the provenance of white marbles used in the baths of Caracalla in Rome." In *ASMOSIA VII. Actes du VIIe Colloque International de l'ASMOSIA, Thasos, 15-20 Septembre 2003*, ed. Y. Maniatis, 385–98. BCH Suppl. 51. Athens: École française d'Athènes.

Bruno, M., C. Gorgoni, and P. Pallante. 2015b. "Provenance and distribution of white marbles in the arches of Titus and Septimius Severus in Rome." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 43–54. Rome: L'Erma di Bretschneider.

Busch, S. O. 1991. "Luni in the middle ages: The agony and the disappearance of a city." *Journal of Medieval History* 17: 283–96.

Calia, A., M. T. Giannotta, L. Lazzarini, and G. Quarta. 2009. "The Torre Sgarrata wreck: Characterization and provenance of white marble artefacts in the cargo." In *ASMOSIA VII. Actes du VIIe Colloque International de l'ASMOSIA, Thasos, 15-20 Septembre 2003*, ed. Y. Maniatis, 333–42. BCH Suppl. 51. Athens: École française d'Athènes.

Calia, A., M. T. Giannotta, G. Quarta, and E. Pellegrino. 2005. "I matronei della cattedrale di Bari: studio integrato sull'identificazione, la provenienza e il reimpiego dei marmi." *Marmora: International Journal for Archaeology, History and Archaeometry of Marbles and Stones* 1: 187–208.

Capedri, S., and G. Venturelli. 2004. "Accessory minerals as tracers in the provenancing of archaeological marbles, used in combination with isotopic and petrographic data." *Archaeometry* 46: 517–36.

Carlson, D. N. 2009. "A marble cargo of monumental proportions: The Late Hellenistic shipwreck at Kızılburun, Turkey." In *Leukos Lithos. Marbres et autres roches de la méditerranée antique: études interdisciplinaires / Interdisciplinary Studies on Mediterranean Ancient Marble and Stone. Actes du VIIIe Colloque International de l'Association for the Study of Marble and Other Stones Used in Antiquity (ASMOSIA), Aix-en-Provence, 12-18 Juin 2006*, ed. P. Jockey, 475–93. Paris: Maisonneuve & Larose and Maison méditerranéenne des sciences de l'homme.

Crema, E. R. 2012. "Modelling temporal uncertainty in archaeological analysis." *Journal of Archaeological Method and Theory* 19: 440–61.

Crema, E. R. 2015. "Time and probabilistic reasoning in settlement analysis." In *Mathematics and Archaeology*, ed. J. A. Barceló and I. Bogdanovic, 314–34. Boca Raton, London, and New York: CRC Press.

De Luca, R., D. Barca, A. Bloise, R. Dominici, M. Lezzerini, M. M. Sica, and D. Miriello. 2020. "Provenance of white marbles from the Roman city of Tauriana (Palmi, Reggio Calabria, Italy)." *Minerals* 10: 297.

De Nuccio, M., M. Bruno, C. Gorgoni, and P. Pallante. 2002. "The use of Proconnesian marble in the architectural decoration of the Bellona Temple in Rome." In *ASMOSIA VI. Interdisciplinary Studies on Ancient Stone. Proceedings of the Sixth International Conference of the Association for the Study of Marble and Other Stones in Antiquity. Venice, June 15-18 2000*, ed. L. Lazzarini, 293–302. Padua: Bottega d'Erasmo Aldo Ausilio Editore in Padova.

De Callataÿ, F., ed. 2014. *Quantifying the Greco-Roman Economy and Beyond*. Bari: Edipuglia.

Del Pietro, L. 2012. "Investigations on the white marbles of architectural elements in Salento (Southern Italy)." In *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference (Tarragona 2009)*, ed. A. Gutiérrez Garcia-Moreno, P. Lapuente, and I. Rodà de Llanza, 355–63. Documenta 23. Tarragona: Institut Català d'Arqueologia Clàssica.

DeLaine, J. 1997. *The Baths of Caracalla. A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome*. JRA Supplementary Series 25. Portsmouth, RI: Journal of Roman Archaeology.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press

Dutta, R., D. K. Levine, N. W. Papageorge, and L. Wu. 2018. "Entertaining Malthus: Bread, circuses, and economic growth." *Economic Inquiry* 56: 358–80.
Erdkamp, P. 2012. "Urbanism." In *The Cambridge Companion to the Roman Economy*, ed. W. Scheidel, 241–65. Cambridge: Cambridge University Press.
Erdkamp, P. 2016. "Economic growth in the Roman Mediterranean world: An early good-bye to Malthus?" *Explorations in Economic History* 60: 1–20.
Erdkamp, P. 2020. "Population, technology, and economic growth in the Roman world." In *Capital, Investment, and Innovation in the Roman World*, ed. P. Erdkamp, K. Verboven, and A. J. Zuiderhoek, 39–66. Oxford: Oxford University Press.
Fant, J. C. 1988. "The Roman emperors in the marble business: Capitalists, middlemen or philanthropists?" In *Classical Marble: Geochemistry, Technology, Trade*, ed. N. Herz and M. Waelkens, 147–58. NATO ASI Series E, Applied Sciences 153. Dordrecht: Kluwer Academic Publishers.
Fant, J. C. 1992. "The Roman imperial marble yard at Portus." In *Ancient Stones: Quarrying, Trade and Provenance*, ed. M. Waelkens, N. Herz, and L. Moens, 115–20. Leuven: Leuven University Press.
Fant, J. C. 1993. "Ideology, gift, and trade: A distribution model for the Roman imperial marbles." In *The Inscribed Economy. Production and Distribution in the Roman Empire in the Light of Instrumentum Domesticum*, ed. W. V. Harris, 145–70. JRA Supplementary Series 6. Ann Arbor: Journal of Roman Archaeology.
Fant, J. C. 2001. "Rome's marble yards." *JRA* 14: 167–98.
Fant, J. C., B. Russell, and S. J. Barker. 2013. "Marble use and reuse at Pompeii and Herculaneum: The evidence from the bars." *PBSR* 81: 181–209.
Fazzini, P., and M. Maffei. 2000. "The disappearance of the city of Luni." *Journal of Cultural Heritage* 1: 247–60.
Fentress, E., S. Fontana, R. B. Hitchner, and P. Perkins. 2004. "Accounting for ARS: Fineware and sites in Sicily and Africa." In *Side-by-Side Survey: Comparative Regional Studies in the Mediterranean World*, ed. S. E. Alcock and J. F. Cherry, 147–62. Oxford: Oxford University Press.
Fentress, E., and P. Perkins. 1988. "Counting African Red Slip Ware." In *L'Africa romana: atti del V convegno di studio, Sassari, 11-13 dicembre 1987*, ed. A. Mastino, 205–14. Sassari: Dipartimento di storia, Università degli studi di Sassari.
Fischer, M. L. 1998. *Marble Studies. Roman Palestine and the Marble Trade*. Xenia 40. Konstanz: Universitätsverlag Konstanz.
Gabellone, F., M. T. Giannotta, and A. Alessio. 2009. "The Torre Sgarrata wreck (South Italy): Marble artefacts in the cargo." In *ASMOSIA VII. Actes du VIIe Colloque International de l'ASMOSIA, Thasos, 15-20 Septembre 2003*, ed. Y. Maniatis, 319–31. BCH Suppl. 51. Athens: École française d'Athènes.
Germann, K., G. Gruben, H. Knoll, V. Valis, and F. J. Winkler. 1988. "Provenance characteristics of Cycladic (Paros and Naxos) marbles. A multivariate geological approach." In *Classical Marble: Geochemistry, Technology, Trade*, ed. N. Herz and M. Waelkens, 251–62. NATO ASI Series E, Applied Sciences 153. Dordrecht: Kluwer Academic Publishers.
Giannotta, M. T., G. Quarta, A. Alessio, and A. Pennetta. 2015. "Provenance of the Roman marble sarcophagi of the San Pietro in Bevagna wreck." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 143–53. Rome: L'Erma di Bretschneider.
Gutiérrez Garcia-Moreno, A., and I. Rodà de Llanza. 2012. "El mármol de Luni-Carrara en la fachada mediterránea de Hispania." In *Rome, Portus and the Mediterranean*, ed. S. Keay, 293–312. Archaeological Monographs of the British School at Rome 21. London: The British School at Rome.
Jongman, W. 2007a. "Gibbon was right: The decline and fall of the Roman economy." In *Crises and the Roman Empire. Proceedings of the Seventh Workshop of the International Network Impact of Empire (Nijmegen, June 20-24, 2006)*, ed. O. Hekster, G. de Kleijn, and D. Slootjes, 183–99. Impact of Empire 7. Leiden and Boston: Brill.
Jongman, W. 2007b. "The Early Roman Empire: Consumption." In *The Cambridge Economic History of the Greco-Roman World*, ed. W. Scheidel, I. Morris, and R. P. Saller, 592–618. Cambridge: Cambridge University Press.

Kulpa, Z. 1997a. "Diagrammatic representation for a space of intervals." *Machine Graphics & Vision* 6: 5–24.

Kulpa, Z. 1997b. "Diagrammatic representation of interval space in proving theorems about interval relations." *Reliable Computing* 3: 209–17.

Kulpa, Z. 2006. "A diagrammatic approach to investigate interval relations." *Journal of Visual Languages & Computing* 17: 466–502.

Lapuente, P. 1995. "Mineralogical, petrographical and geochemical characterization of white marbles from Hispania." In *The Study of Marble and Other Stones Used in Antiquity. ASMOSIA III Athens: Transactions of the 3rd International Symposium of the Association for the Study of Marble and Other Stones Used in Antiquity*, ed. Y. Maniatis, N. Herz, and Y. Basiakos, 151–60. London: Archetype Publications.

Lapuente, P., and P. Blanc. 2002. "Marbles from Hispania: Scientific approach based on cathodoluminescence." In *ASMOSIA 5. Interdisciplinary Studies on Ancient Stone. Proceedings of the Fifth International Conference of the Association for the Study of Marble and Other Stones in Antiquity, Museum of Fine Arts, Boston, 1998*, ed. J. J. Herrmann Jr., N. Herz, and R. Newman, 143–51. London: Archetype Publications Ltd.

Lapuente, P., T. Nogales Basarrate, and A. Carvalho. 2021. "Mineralogical insights to identify Göktepe marble in the sculptural program of Quinta Das Longas Villa (Lusitania)." *Minerals* 11: 1194.

Lapuente, P., T. Nogales Basarrate, H. Royo Plumed, and M. Brilli. 2014. "White marble sculptures from the National Museum of Roman Art (Mérida, Spain): Sources of local and imported marbles." *European Journal of Mineralogy* 26: 333–54.

Lapuente, P., H. Royo Plumed, and M. Brilli. 2016. "Mármoles escultóricos romanos del patrimonio de Aragón. Nuevas aportaciones arqueométricas." In *Actas / I Congreso CAPA Arqueología Patrimonio Aragonés, 24 y 25 de noviembre de 2015*, ed. J. I. Lorenzo Lizalde and J. M. Rodanés Vicente, 539–48. Zaragoza: Colegio Oficial de Doctores y Licenciados en Filosofía y Letras y en Ciencias de Aragón.

Lapuente, P., and B. Turi. 1995. "Marbles from Portugal: Petrographic and isotopic characterization." *Science and Technology for Cultural Heritage* 4: 33–42.

Lapuente, P., B. Turi, and P. Blanc. 2000. "Marbles from Roman Hispania: Stable isotope and cathodoluminescence characterization." *Applied Geochemistry* 15: 1469–93.

Lapuente, P., B. Turi, L. Lazzarini, and T. Nogales Basarrate. 1999. "Provenance investigation of white marble sculptures from Augusta Emerita, Hispania." In *Archéomatériaux. Marbres et autres roches. Actes de la IVème Conférence Internationale de l'Association pour l'étude des marbres et autres roches utilisés dans le passé, 9-13 Octobre 1995*, ed. M. Schvoerer, 111–16. Bordeaux-Talence: CRPAA-PUB.

Lazzarini, L. 2004. "Archaeometric aspects of white and coloured marbles used in antiquity: The state of the art." *Periodico di Mineralogia* 73: 113–25.

Lazzarini, L., C. Gorgoni, P. Pallante, and B. Turi. 1997. "Identification of white marbles in Rome. 2: the Portico of Octavia." *Science and Technology for Cultural Heritage* 6: 185–98.

Lazzarini, L., M. Mariottini, M. Pecoraro, and P. Pensabene. 1988. "Determination of the provenance of marbles used in some ancient monuments in Rome." In *Classical Marble: Geochemistry, Technology, Trade*, ed. N. Herz and M. Waelkens, 399–409. NATO ASI Series E, Applied Sciences 153. Dordrecht: Kluwer Academic Publishers.

Lazzarini, L., G. Ponti, M. Preite Martinez, P. Rockwell, and B. Turi. 2002. "Historical, technical, petrographic, and isotopic features of Aphrodisian marble." In *ASMOSIA 5. Interdisciplinary Studies on Ancient Stone. Proceedings of the Fifth International Conference of the Association for the Study of Marble and Other Stones in Antiquity, Museum of Fine Arts, Boston, 1998*, ed. J. J. Herrmann Jr., N. Herz, and R. Newman, 163–68. London: Archetype Publications Ltd.

Lo Cascio, E. 2009. "Urbanization as a proxy of demographic and economic growth." In *Quantifying the Roman Economy. Methods and Problems*, ed. A. K. Bowman, and A. I. Wilson, 87–106. Oxford Studies on the Roman Economy. Oxford: Oxford University Press.

Machado, C. 2021. "Statue habit and statue culture in Late Antique Rome." *JRA* 34, no. 2: 632–66.

Maniatis, Y., and K. Polikreti. 2000. "The characterization and discrimination of Parian marble in the Aegean region." In *Paria Lithos: Parian Quarries, Marble and Workshops of Sculpture*, ed. D. U. Schilardi, 575–84. Athens: The Paros and Cyclades Institute of Archaeology.

Morley, N. 2011. "Cities and economic development in the Roman Empire." In *Settlement, Urbanization, and Population*, ed. A. K. Bowman and A. I. Wilson, 143–60. Oxford: Oxford University Press.

Nogales Basarrate, T., A. Carvalho, and M. J. Almeida. 2004. "El programa decorativo de la Quinta das Longas (Elvas, Portugal): un modelo excepcional de las *uillae* de la *Lusitania*." In *Actas de la IV Reunión sobre Escultura Romana en Hispania*, ed. T. Nogales Basarrate and L. J. R. Gonçalves, 103–56. Madrid: Ministerio de Cultura.

Nogales Basarrate, T., P. Lapuente, H. Royo Plumed, and M. Preite Martinez. 2015. "Stone materials in Lusitania reflecting the process of Romanization." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 253–61. Rome: L'Erma di Bretschneider.

Ontiveros Ortega, E., J. Beltrán-Fortes, R. Taylor, O. Rodríguez Gutiérrez, and P. López Aldana. 2012. "Petrography and elemental geochemistry of the Roman quarries of Los Castillejos and Los Covachos (Almadén de La Plata, Seville, Spain). Outcrops and semi-elaborated products." In *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference (Tarragona 2009)*, ed. A. Gutiérrez Garcia-Moreno, P. Lapuente, and I. Rodà de Llanza, 407–18. Documenta 23. Tarragona: Institut Català d'Arqueologia Clàssica.

Orton, C. 1980. *Mathematics in Archaeology*. Cambridge: Cambridge University Press.

Palmisano, A., A. Bevan, and S. Shennan. 2017. "Comparing archaeological proxies for long-term population patterns: An example from central Italy." *JAS* 87: 59–72.

Pensabene, P. 2004. "La diffusione del marmo lunense nelle province occidentali." In *La decoración arquitectónica en las ciudades romanas de Occidente*, ed. S. F. Ramallo, 421–43. Murcia: Universidad de Murcia.

Prochaska, W. 2015. "Fine-grained dolomitic marble of high sculptural quality used in antiquity." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 661–70. Rome: L'Erma di Bretschneider.

Roberts Jr., J. M., B. J. Mills, J. J. Clark, W. Randall Haas, D. L. Huntley, and M. A. Trowbridge. 2012. "A method for chronological apportioning of ceramic assemblages." *JAS* 39: 1513–20.

Rodà de Llanza, I. 2020. "Los primeros usos del mármol en la escultura de Hispania." In *Escultura romana en Hispania IX. Actas de la Reunión Internacional celebrada en Yecla del 27 al 29 de marzo de 2019*, ed. J. M. Noguera Celdrán and L. Ruiz Molina, 101–19. Yakka, Revista de estudios yeclanos, Año XXVI, Número 22, 2017–2019. Yecla and Murcia: Editum.

Royo Plumed, H., P. Lapuente, J. A. Cuchí, M. Brilli, and M.-C. Savin. 2018. "Updated characterisation of white Saint-Béat marble. Discrimination parameters from classical marbles." In *ASMOSIA XI. Interdisciplinary Studies on Ancient Stone. Proceedings of the XI ASMOSIA Conference, Split, 18–22 May 2015*, ed. K. Marasović and D. Matetić Poljak, 379–89. Split: Arts Academy in Split - University of Split.

Royo Plumed, H., P. Lapuente, E. Ros, M. Preite Martinez, and J. A. Cuchí. 2015. "Discriminating criteria of Pyrenean Arties marble (Aran Valley, Catalonia) from Saint-Béat marbles: Evidence of Roman use." In *Interdisciplinary Studies on Ancient Stone - ASMOSIA X. Proceedings of the Tenth International Conference of ASMOSIA. Association for the Study of Marble & Other Stones in Antiquity. Rome, 21-26 May 2012*, ed. P. Pensabene and E. Gasparini, 671–80. Rome: L'Erma di Bretschneider.

Russell, B. 2012. "Shipwrecks and stone cargoes: Some observations." In *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference (Tarragona 2009)*, ed. A. Gutiérrez Garcia-Moreno, P. Lapuente, and I. Rodà de Llanza, 533–39. Documenta 23. Tarragona: Institut Català d'Arqueologia Clàssica.

Russell, B. 2013a. "Roman and Late Antique shipwrecks with stone cargoes: A new inventory." *JRA* 26: 331–61.

Russell, B. 2013b. *The Economics of the Roman Stone Trade*. Oxford Studies on the Roman Economy. Oxford: Oxford University Press.

Scheidel, W. 2009. "In search of Roman economic growth." *JRA* 22: 46–70.

Taelman, D. 2022. "Upgrading town appearances: Relating white marble exploitation and town development in Roman Lusitania." In *The Archaeology of Roman Portugal in Its Western Mediterranean Context*, ed. T. D. Stek and A. Carneiro, 93–115. Oxford: Oxbow Books.

Taelman, D., and F. Antonelli. 2022. "Provenance of the white and polychrome marbles used for the architecture and sculpture of Roman Sentinum (Sassoferrato, Marche, Italy)." *Archaeometry* 64: 1–24.

Taelman, D., M. Elburg, I. Smet, P. De Paepe, L. Lopes, F. Vanhaecke, and F. Vermeulen. 2013. "Roman marble from Lusitania: Petrographic and geochemical characterisation." *JAS* 40: 2227–36.

Taelman, D., D. Van Limbergen, and F. Antonelli. 2021. "Architectural and sculptural decoration of Roman central Adriatic Italy: An archaeological and archaeometric approach to region-wide marble trade." *Archeologia e Calcolatori* 32: 249–60.

Taylor, R. 2003. *Roman Builders. A Study in Architectural Process*. Cambridge: Cambridge University Press.

Trigger, B. G. 1990. "Monumental architecture: A thermodynamic explanation of symbolic behaviour." *WorldArch* 22: 119–32.

Verboven, K. 2018. "Ancient cliometrics and archaeological proxy-data: Between the devil and the deep blue sea." In *Cuantificar las economías Antiguas: Problemas y métodos / Quantifying Ancient Economies: Problems and Methodologies*, eds. J. Remesal Rodríguez, V. Revilla Calvo, and M. Bermúdez Lorenzo, 345–71. Barcelona: Universitat de Barcelona.

Walker, S. 1988. "From west to east: Evidence for a shift in the balance of trade in white marbles." In *Classical Marble: Geochemistry, Technology, Trade*, ed. N. Herz and M. Waelkens, 187–95. NATO ASI Series E, Applied Sciences 153. Dordrecht: Kluwer Academic Publishers.

Ward-Perkins, J. B. 1992. "The Roman system in operation." In *Marble in Antiquity. Collected Papers of J. B. Ward-Perkins*, ed. H. Dodge and B. Ward-Perkins, 23–30. Archaeological Monographs of the British School at Rome 6. London: British School at Rome.

Willet, R. 2014. "Experiments with diachronic data distribution methods applied to Eastern Sigillata A in the eastern Mediterranean." *HEROM* 3: 39–69.

Wilson, A. I. 2009. "Indicators for Roman economic growth: A response to Walter Scheidel." *JRA* 22: 71–82.

Wilson, A. I. 2011a. "City sizes and urbanization in the Roman Empire." In *Settlement, Urbanization, and Population*, ed. A. K. Bowman and A. I. Wilson, 160–95. Oxford: Oxford University Press.

Wilson, A. I. 2011b. "Developments in Mediterranean shipping and maritime trade from the Hellenistic Period to AD 1000." In *Maritime Archaeology and Ancient Trade in the Mediterranean*, ed. D. Robinson and A. I. Wilson, 33–59. Oxford Centre for Maritime Archaeology Monographs 6. Oxford: School of Archaeology, University of Oxford.

Wilson, A. I. 2014. "Quantifying Roman economic performance by means of proxies: Pitfalls and potential." In *Quantifying the Greco-Roman Economy and Beyond*, ed. F. de Callataÿ, 147–67. Bari: Edipuglia.

Wu, L. 2012. "Does Malthus really explain the constancy of living standards?" *SSRN Electronic Journal*. http://dx.doi.org/10.2139/ssrn.2187113.

Zezza, F., F. Macri, D. Decrouez, V. Barbin, K. Ramseyer, J. Garcia-Rowe, and C. Saiz-Jimenez. 1992. "Origin, weathering and biological colonization of the marble terminal column on the Via Appia." In *Proceedings of the 2nd International Symposium on Monument Conservation in the Mediterranean Basin*, 99–112. Brindisi.

Zuiderhoek, A. J. 2009. *The Politics of Munificence in the Roman Empire. Citizens, Elites and Benefactors in Asia Minor. Greek Culture in the Roman World*. Cambridge: Cambridge University Press.

https://doi.org/10.1017/S1047759422000447 Published online by Cambridge University Press