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PROVENANCE OF WHITE MARBLES FROM THE NABATEAN SITES OF QASR AL BINT AND THE COLLONADED STREET BATHS AT PETRA, JORDAN

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ABSTRACT

Intercultural relations and trade are important components of understanding of historical interrelationships between regions and cultures. One of the most interesting objects of trade is stone, because of the expense and difficulty of its transport. Thus, the source of marble used in the Nabatean city of Petra was investigated using established petrological, geochemical and isotopic analyses. Specifically, marble from Qasr al Bint and the Colonnaded Street baths were sampled and investigated. The results of these analyses show that the marbles came from sources in Asia Minora and Greece. The most likely sources of the marble are the quarries of Thasos, Penteli, Prokennesos and Dokimeion. The choice of marble followed the desired utilitarian and aesthetic function of the stone. These results show that active trade in stone was part of the cultural interaction of the period.

KEYWORDS: Classical period, Marble provenance, Nabateans, Petra, trade relations.

1. INTRODUCTION

Marble is one of many categories of materials in which affluent societies traded during Classical times. Numerous methods have been used in the past to determine the primary provenance of marble in the Mediterranean basin. These attempts began with the study of the petrography of marbles at the major known sources, and went through several developments including trace element analysis, stable isotope analysis, electron spin resonance etc. The quarrying of marble and other coloured stones, especially from the Mediterranean area, has received much attention in the last two decades (e.g. Herz and Waelkens 1988; Waelkens et al. 1992; Maniatis 1995; Schvoerer 1999; Herrmann et al. 2002; Lazzarini 2002). It is generally recognized that no single method of analysis alone is sufficient for provenance studies of classical marbles, as overlaps are common when potential sources are compared. The various approaches applied, were all used to compare specific artifact characteristics with a database developed for the various known sources of marble at a particular period (Gorgoni et al., 2002; Liritzis, 1997; Liritzis & Galloway, 2000). Characteristics such as petrography and stable isotopic composition in marble reflect the metamorphic history of the limestone or dolostone which led to marble formation. Thus, since each marble underwent different metamorphic temperatures and pressures over varying times, it is expected that this variation will be reflected in the petrographic and isotopic characteristics of the resulting marble. In this paper, we will try and elucidate the source of various marbles found at the Nabatean city of Petra, present day Jordan (Figure 1). The Nabatean (ca. 200 BC to about 106 AD) state thrived adjacent to the Greek, and later Roman empires. This empire disappeared after it was annexed by the Romans in 106 AD. The Nabateans built up an elaborate trade and cultural network, which afforded them the means to build their impressive capital. For example, al Salameen (2008) argued for the presence of cultural relations between the Nabateans and the Lycians based on on epigraphic evidence and stylistic similarities in carved tombs between Petra and Lycia. Herein, we will examine an example of physical evidence of trade between the Nabateans and the people Asia Minor. The origin of the marble used and the cultural ramifications of this information will be discussed.

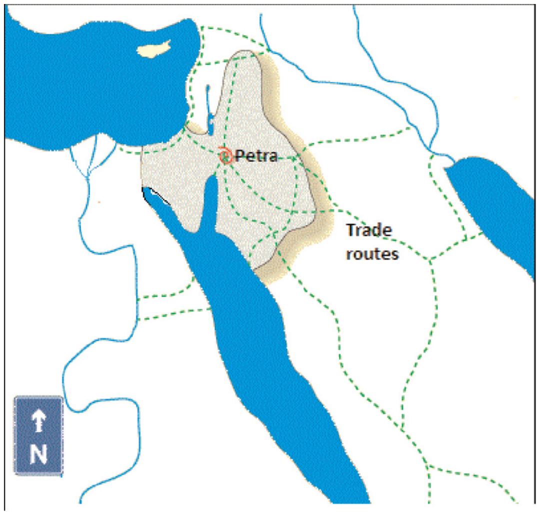

Figure 1. Map of the Nabatean Empire. Trade to the Mediterranean was probably through the port of Gaza on the route towards the west of Petra.

2. MATERIALS AND METHODS

Archaeological Context

Marble has been discovered at several sites of the ancient city of Petra, Jordan. Marble was extensively used in many architectural and decorative elements in the temple of Winged Lions, the Great Temple, the Colonnaded Street, the Qasr al-Bint and the Byzantine-era Petra church. For the purpose of this study, marble samples were selected from two locations: the Qasr al-Bint and the

Colonnaded Street. Twenty-three samples of various marble types were selected from the monument of Qasr al Bint where large amounts of marble fragments and broken pieces have been discovered in the temple. Marble has been found in the architectural and decorative use in the temple (revetment, cornices, pavement) indicating primary use of marble despite the lack of local marble resources in or around Petra.

Qasr al-Bint is one of the rare built structures in the city of Petra, Jordan, which is famous for its rock-cut facades. Archaeological evidence revealed by the archaeological excavations conducted in the monument has shown that Qasr al-Bint was built as a temple during the late Nabatean period, most probably during the reign of Obodas II (30 B.C.-9 B.C.) (Browning, 1974, Taylor, 2002).

Qasr al-Bint is composed of five areas: Portico in Antis, Cella, God-Block or Statue, East Adyton (restricted area for the temple priests), and West Adyton. The monument was built of hewn sandstone blocks that were joined by lime-based mortar. The temple stood on a high podium, the edge of which is set well out from the main walls, creating a spacious ledge several feet wide around the building. The exterior of the monument is square looking (32 x 32 m), giving a total ground area of 1024 m2. There is evidence that both the exterior and the interior of the monument were decorated at one time with painted plaster.

Excavations on the colonnaded street of the monumental city center of Petra uncovered many architectural remains. Walls of very well dressed stone ashlars, distinguished by diagonal masonry chisels marks (known as a typical Nabataean marks) were revealed. Amongst other remains a semi-barrel vault section with a complex net of ceramic pipes and water conduits was uncovered, suggesting that this structure was the hypocaust of a public bathhouse in the city center of Petra. The building had a white and gray marble floor with well paved and organized square slabs of 30cm in length.

3. SAMPLES

Twenty-three samples of the various marble types occurring at Qasr al Bint and sixteen samples of the marbles at the Colonnaded Street Baths were chosen for further analysis. Fresh samples were taken from the cores of the fragments after they were broken. These varied in outward color and texture, ranging from pure white to light gray to yellowish white, and from fine to coarse crystalline.

4. METHODS

Standard petrographic thin sections were made from the samples, allowing textural analysis under a polarizing microscope. These were used to determine the maximum grain size of the carbonates in the imported marble (Herz, 1980 and 1987). Also, the nature of the grain size distribution and grain boundaries were taken into consideration (Gorgoni et al., 2002). Table 1 lists the various outward characteristics of the samples used, as well as maximum grain size as determined under the polarizing microscope.

Portions of the samples were analyzed for carbon and oxygen stable isotopic signatures. The samples from Qasr al Bint were analyzed at the Water Authority of Jordan Laboratories in Amman. The samples were reacted with high purity H_3PO_4 at 25°C, and the resulting CO_2 gas was collected and analyzed with a Finnigan-Mat 251 ratio mass spectrometer. The analytical error is estimated to be ± 0.15‰. Samples from the Colonnaded Street Baths were analyzed at the University of Erlangen. The samples were reacted with 100% phosphoric acid at

75°C in an online carbonate preparation line (Carbo Kiel single sample bath) connected to a Finnigan Mat 252 mass spectrometer. Isotope data are expressed as per mil (‰) deviation from the Vienna Pee Dee Belemnite (V-PDB) standard. Reproducibility was checked by replicate analysis of laboratory standards and is better than 0.02‰ for $\delta^{13}C$ (1σ) and 0.03‰ for $\delta^{18}O$ (1σ).

The mineralogy of the Qasr al Bint carbonates was determined through chemical analysis using atomic absorption spectroscopy (AAS) (Perkin Elmer) after dissolution in hydrochloric acid. Calcium, magnesium, manganese and iron concentrations were determined. The mineralogy of the Collonaded Street Baths samples was determined by X-ray diffraction (Philips). A small amount of sample was mounted on a graphite plate. Operational parameters were as follows: Cu K radiation, graphite monochromator, 45 kV, 30 mA, automatic divergence slit, and receiving slit of 0.1.

5. RESULTS AND DISCUSSION

The macroscopic and microscopic descriptions of the samples analyzed are listed in Table 1. The results of the stable isotopic analyses are listed on table 2 and plotted on Figure 2.

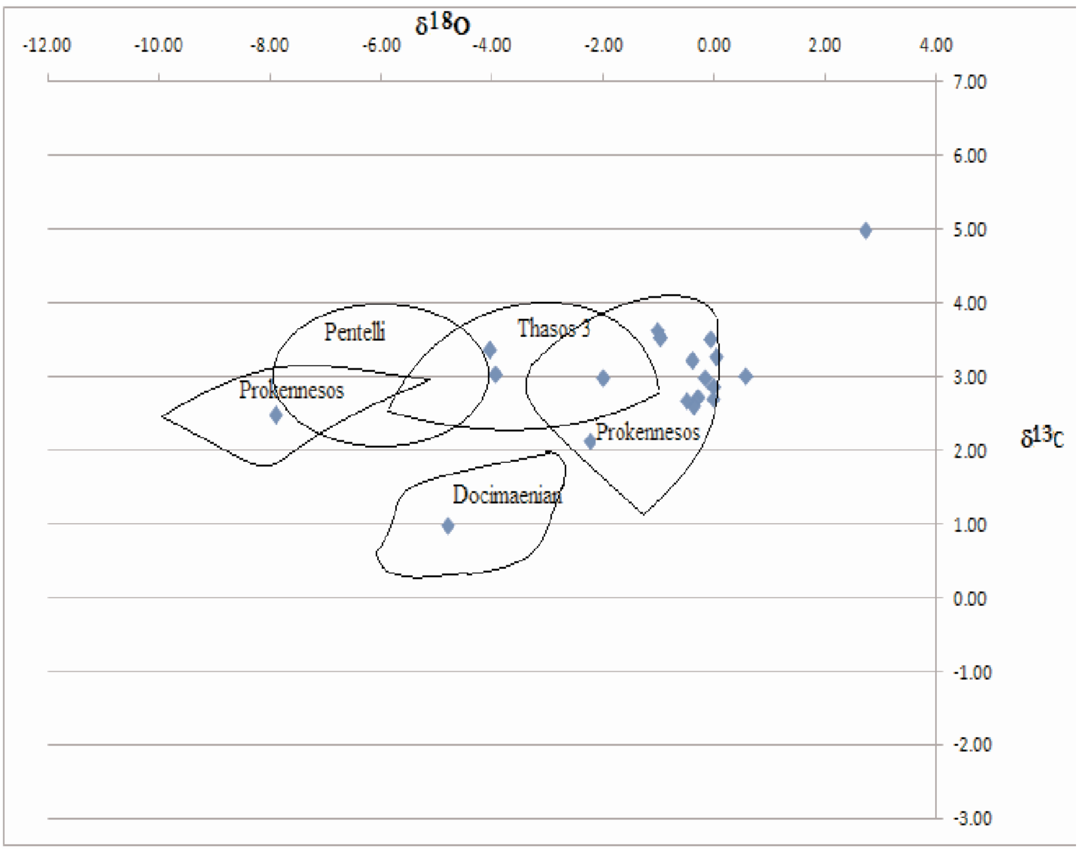

Figure 2. The isotopic compositions of the samples and the corresponding source fields from Lazzarini (2004).

Table 1. Textural characteristics of the marble samples.

Sample	Maximum Grain size (mm)	Other notes
QB0601	2.0	Snow white. Coarse crystalline marble
QB0602	2.0	Snow white. Coarse rhombic crystals.
QB0603	0.3	Grey white. Coarse rhombic crystals.
QB0604	NA	Yellow white. Fossilferous marble.
QB0605	NA	Yellow. Laminated travertine.
QB0606	0.1	White. Equidimentional calcitic marble with sandy texture. Friable
QB0701	1.6	Grey white. Coarse rhombic crystals
QB0702	1.8	Grey white. Coarse rhombic crystals
QB0703	2.0	Grey white. Coarse rhombic crystals
QB0704	1.0	Yellowish white. Fine to coarse rhombic crystals
QB0705	2.0	Grey white. Coarse rhombic crystals
QB0706	1.6	Grey white. Coarse rhombic crystals
QB0707	2.0	Grey white. Coarse rhombic crystals
QB0708		Grey white. Coarse rhombic crystals
QB0709	2.0	Grey white. Coarse rhombic crystals
QB0710	1.6	Grey white. Coarse rhombic crystals
QB0711	1.6	Grey white. Coarse rhombic crystals
QB0712	1.6	Grey white. Coarse rhombic crystals
QB0713	1.0	Grey white. Coarse rhombic crystals
QB0714	1.8	Grey white. Coarse rhombic crystals
QB0715	1.4	Grey white. Coarse rhombic crystals
QB0716	1.6	Grey white. Coarse rhombic crystals
QB0717	1.8	Grey white. Coarse rhombic crystals
CSB09PE1	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE2	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE3	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE4	<2	Grey white. Coarse rhombic crystals
CSB09PE5	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE6	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE7	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE8	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE9	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE10	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE11	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE12	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE13	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE14	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE15	>2	Snow white. Coarse crystalline marble, dolomite in XRD
CSB09PE16	>2	Snow white. Coarse crystalline marble, dolomite in XRD

Table 2. Chemical cation constituents of the carbonate (weight percent%)

Sample	Ca^{++}	Mg^{++}	Fe^{++}	Mn^{++}
QB1	19.0	20.3	0.03	0.03
QB2	16.2	16.2	0.05	0.00
QB3	32.9	0.7	0.03	0.00
QB4	34.4	0.8	0.01	0.03
QB5	38.4	0.7	0.32	0.00
QB6	38.3	0.5	0.00	0.00
QB0701	43.7	0.4	1.4	0.01
QB0702	43.9	0.4	1.6	0.01
QB0703	40.4	0.7	2.6	0.02
QB0704	49.9	1.1	2.2	0.02
QB0705	45.3	0.6	3.2	0.02
QB0706	43.2	0.4	2.2	0.02
QB0707	43.3	0.4	2.3	0.02
QB0708	59.8	0.5	2.5	0.02
QB0709	19.3	7.4	2.5	0.03
QB0710	35.8	0.4	2.3	0.02
QB0711	34.5	0.6	2.0	0.02
QB0713	43.4	0.5	2.8	0.03
QB0714	39.8	0.5	1.8	0.02
QB0715	49.8	0.5	2.0	0.02
QB0716	44.3	0.5	2.0	0.02

A number of marble types can be discerned from the data available. The chemical and mineralogical analyses show that three samples from Qasr al Bint (QB0601, QB0602 and QBO709) and almost all samples from the Colonnaded Street Baths (CSB09PE1-3 and CSB09PE5-16) contain dolomite. According to Lazzarini (2004), these samples match the petrographical characteristics of Cape Vathy, Saliara marble (also termed Thasos 3 by Moens et al., 1988), in that they have rather large Maximum Grain Sizes (MGS)(greater than 2mm), as well as curved to sutured crystal boundaries (Figures 3 and 4). The isotopic composition of these samples also falls within the field of the Thasos-Aliki source (Fig. 2) (Germann et al., 1980 and Herz, 1987). Lorenzo Lazzarini (personal communication) believes that this material is probably from the dolomitic marble quarries of Cape Vathy on Thasos.

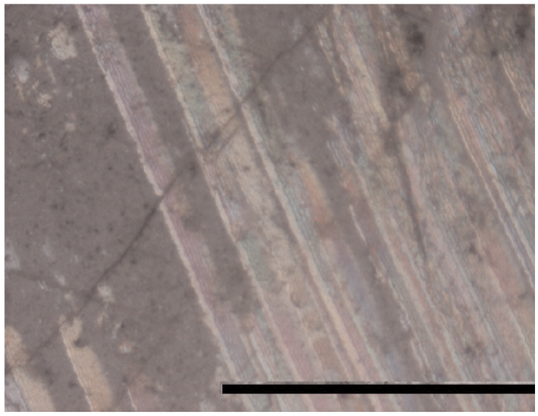

Figure 3. Photomicrograph of a large calcite crystal showing cleavage planes from sample QB0809, indicating an MGS exceeding 2 mm (Bar is 1 mm).

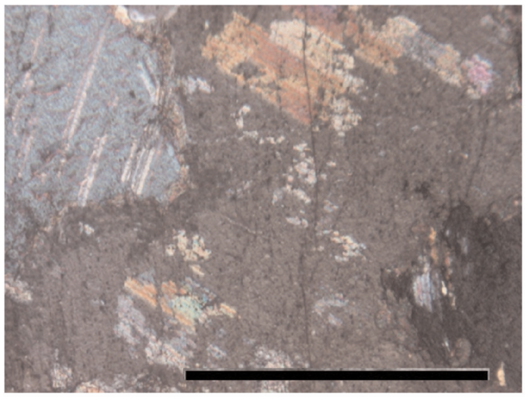

Figure 4. Sample QB0709. Photomicrograph showing curved to sutured crystal boundaries seen in the Thasos dolomitic marble. Bar is 1mm.

Sample QB0603 from Qasr el Bint, is white to gray in color, and consists of smaller grain sizes and boundaries that are largely defined by graphite, which probably gives the marble its gray color (Fig. 5). Its petrography is similar to that of Prokennesos (the island of Marmara) marble (mortar fabric), and its isotopic signature matches that of Prokennesos as well.

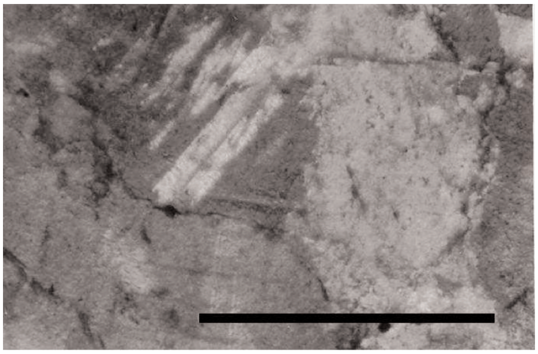

Figure 5. Photomicrograph of sample QB0603. Note the dark boundaries between the grains, suggesting graphite separation between them. Bar is 1mm.

So-called heteroblastic textures (with a varied grain sized distribution) are seen is samples QB0701, QB0704, QB0712, QB0713, QB0714, QB0715, and QB0717 from Qasr el Bint. All of these samples have maximum grain sizes that range from 1.4 to 1.8 mm. The grain boundaries for these samples are curved to sutured, and the mortar fabric suggests that these are from the Prokennesos source as well (Figures 6 and 7).

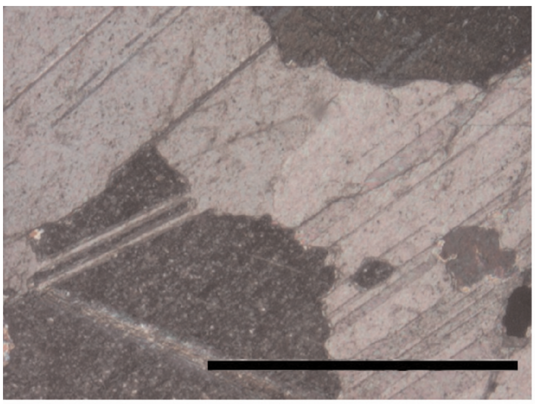

Figure 6. QB0701.Photomicrograph showing curved to sutured grain boundaries in the Prokennesos marble. Bar is 1mm.

Homoblastic textures are seen in samples QB0702, QB0703, QB0707, QB0710 and QB0711 form Qasr-al-Bint and sample CSB09PE4 from the Colonnaded Street Baths. These have mosaic textures and seem to have been extracted from the Penteli Quarries (Fig. 8). The isotopic signature

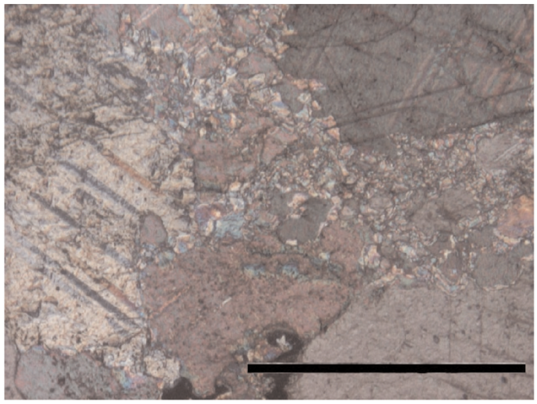

Figure 7. QB0717.Photomicrograph showing the mortar texture seen in the Prokennesos marble. Bar is 1mm.

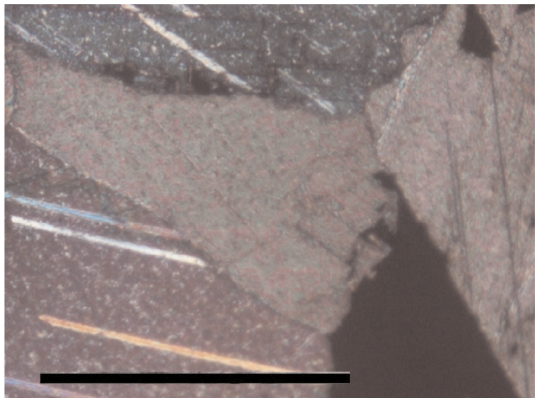

Figure 8. QB0707. Photomicrograph of the mosaic texture seen in the Penteli marble. Bar is 1mm.

of sample CSB09PE4 matches a Penteli source (Fig. 2).

Sample QB0606 from Qasr al Bint is a white friable marble with well defined grain boundaries and small crystal sizes (Figure 9).

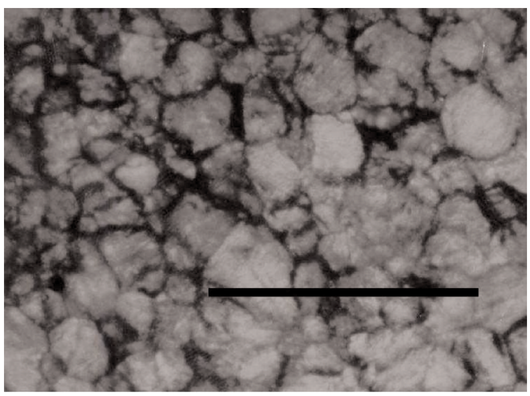

Figure 9. QB0606. Fine grained Dokimeian marble. Bar is 1mm.

Table 3. Oxygen and carbon isotopic characteristics of the marble samples studied.

Sample	$\delta^{13}C$ VPDB	$\delta^{18}O$ VPDB
QB0601	3.35	-4.05
QB0602	3.03	-3.93
QB0603	3.51	-0.05
QB0604	-3.55	-6.23
QB0605	-8.26	-10.35
QB0606	0.98	-4.79
CSB09PE1	2.72	-0.29
CSB09PE2	2.99	-0.15
CSB09PE3	2.67	-0.35
CSB09PE4	2.47	-7.90
CSB09PE5	3.01	0.58
CSB09PE6	3.21	-0.40
CSB09PE7	2.13	-2.23
CSB09PE8	2.98	-1.99
CSB09PE9	2.59	-0.36
CSB09PE10	3.63	-1.02
CSB09PE11	2.86	0.00
CSB09PE12	3.52	-0.96
CSB09PE13	2.69	-0.02
CSB09PE14	2.68	-0.50
CSB09PE15	4.98	2.72
CSB09PE16	3.26	0.04

The source seems to be from Docimaenian in Asia Minor. based on the texture and isotopic nature of the sample.

6. CONCLUSION

The isotopic analysis in addition to textural, geochemical and petrographic analyses helped to identify the geological sources of the marbles discovered at Qasr al-Bint and the Colonnaded Street. Determining the geological sources of marble can help to establish the variety in marble trade business during the Nabatean time and can be an indicator of the distances the marble would have traveled to reach its final destination in Petra. Analyses show that there are four different imported types of marble at the sites studied. The first is a coarse-grained dolomitic marble which is highly durable, and seems to have been imported from the Thasos 3 quarry site. The second is a coarse grained hard grayish calcitic marble imported from Prokennesos, the third is also a course grained hard calcitic marble that seems to have been imported from the Penteli quarries. A finer grained friable variety which looks like a calcarenite in thin section (Sample QB0606) seems to have come from Dokimeion.

Nabateans imported marble from far sources in Western Anatolia and Greece. Such activity would have required two types of transportation including a trip over water. Overland journey from the nearest port in Gaza to Petra is about 160km which was a real ordeal, taking in consideration the road system at the time. It is quite clear that marble was a culturally desirable material for the Nabateans as its use necessitated trade relations that covered great distances

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