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ORIGINAL PAPER

Provenance of marble elements from the Middle Church at Hayyan Al-Mushrif, Northeast Jordan: a multidisciplinary approach

Khaled Al-Bashaireh[1] · Abdul Qader Al-Housan[2]

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Abstract

A multidisciplinary approach examined the provenance of ecclesiastical marble elements uncovered in situ at the Middle Church of Hayyan Al-Mushrif archeological site, northeast Jordan. Initially, the church was partly a subterranean hall, lacking sanctuary. Later, during the Byzantine period, it was remodeled and a rectangular sanctuary bordered with a marble chancel screen was added. The study of the marble was based on physical, mineralogical-petrographic, and geochemical analyses using optical microscopy, X-ray diffractometry, and mass spectrometry. Analytical results were compared with the main reference databases of known Mediterranean marble quarries exploited in antiquity. Proconnesus-1 marble from Saraylar (Maramara Island, Turkey) is the most likely primary source of the marbles, while Proconnesus-2 marble from Çamlik (Marmara Island, Turkey) is a minor source. These results support previous research which indicated that imperial Proconnesus (Marmara) Island was the dominant marble source during the Byzantine period. It is likely that the low cost and availability of ecclesiastical products of standard sizes, large labor force, and advanced transportation methods were the principal reasons for the success of Marmara Island in supplying ecclesiastical marble for the construction of new churches arising from the spread of Christianity during the Byzantine period.

Keywords Hayyan Al-Mushrif · Jordan · Provenance · Marble · Proconnesus · Multidisciplinary approach · Byzantine period

Introduction

Marble provenance studies have become an important topic in art history, conservation, and archeological science. Ancient marble is widely dispersed, and some marble quarries have similar physical and chemical properties; therefore, the past few decades saw many researchers utilizing different analytical methods and establishing new databases in an attempt to uniquely determine marble provenance (Antonelli et al. 2015; Antonelli and Lazzarini 2015; Asgari and Matthews 1995; Attanasio et al. 2015; Barbin et al. 1992; Brilli et al. 2015; Capedri and Venturelli 2004; Gorgoni et al. 2002; Herz 1988; Lazzarini et al. 2002; Lazzarini and Antonelli 2003; Lazzarini 2004; Manfra et al. 1975; Matthews 1997; Origlia et al. 2012; Pike 2009). However, it is generally agreed that combining multiple analytical methods could lead to definitive conclusions on marble provenances (Maniatis et al. 2010; Moens et al. 1988; Al-Bashaireh 2011; Tykot et al. 2002). Scholars often combine grain size and oxygen and carbon isotope geochemistry with petrography (Al-Bashaireh 2018), or electron paramagnetic resonance (Attanasio et al. 2013; Al-Bashaireh and Al-Housan 2014; Maniatis et al. 2010), or X-ray diffraction (Al-Bashaireh and Bedal 2017), or trace elements (Matthews 1997), or cathodoluminescence (Barbin et al. 1992). In some cases, most of these analytical methods were utilized to solve problematic case studies of marble provenance (Al-Bashaireh and Dettman 2015; Brilli et al. 2015).

The major source of architectural marble uncovered at some archeological sites in Jordan is the Marmara Island (Turkey), while Paros, Naxos, Thasos (Greece), Carrara (Italy), and Docimium (Turkey) marbles are minor sources (Al-Bashaireh 2003; Al-Bashaireh and Lazzarini 2016). The Marmara Island was the source of ecclesiastical marble used in the production of the chancel screens of Rihab (Al-Bashaireh and Al-Housan 2014) and Abila (Al-Bashaireh and Dettman 2015) Byzantine churches. Recently, Al-

✉ Khaled Al-Bashaireh
khaledsm@email.arizona.edu

1 Department of Archaeology, Yarmouk University, Irbid 211-63, Jordan

2 Al-Mafraq, Jordan

Bashaireh and Bedal (2017) have examined architectural white marbles used in the Petra Garden and Pool Complex (Petra, south Jordan) and concluded that fine-grained Penteli (Greece) and medium coarse-grained Paros-2 (Greece) marbles were the major marble sources during the Nabatean and Roman periods.

This paper examines the provenance of the marbles used for chancel screen elements and communion plates uncovered from the Middle Church at Hayyan Al-Mushrif archeological site, northeast Jordan (Fig. 1), using a multidisciplinary analytical approach. The results will provide new data about the Jordan marble trade, its economic aspects, and exchange

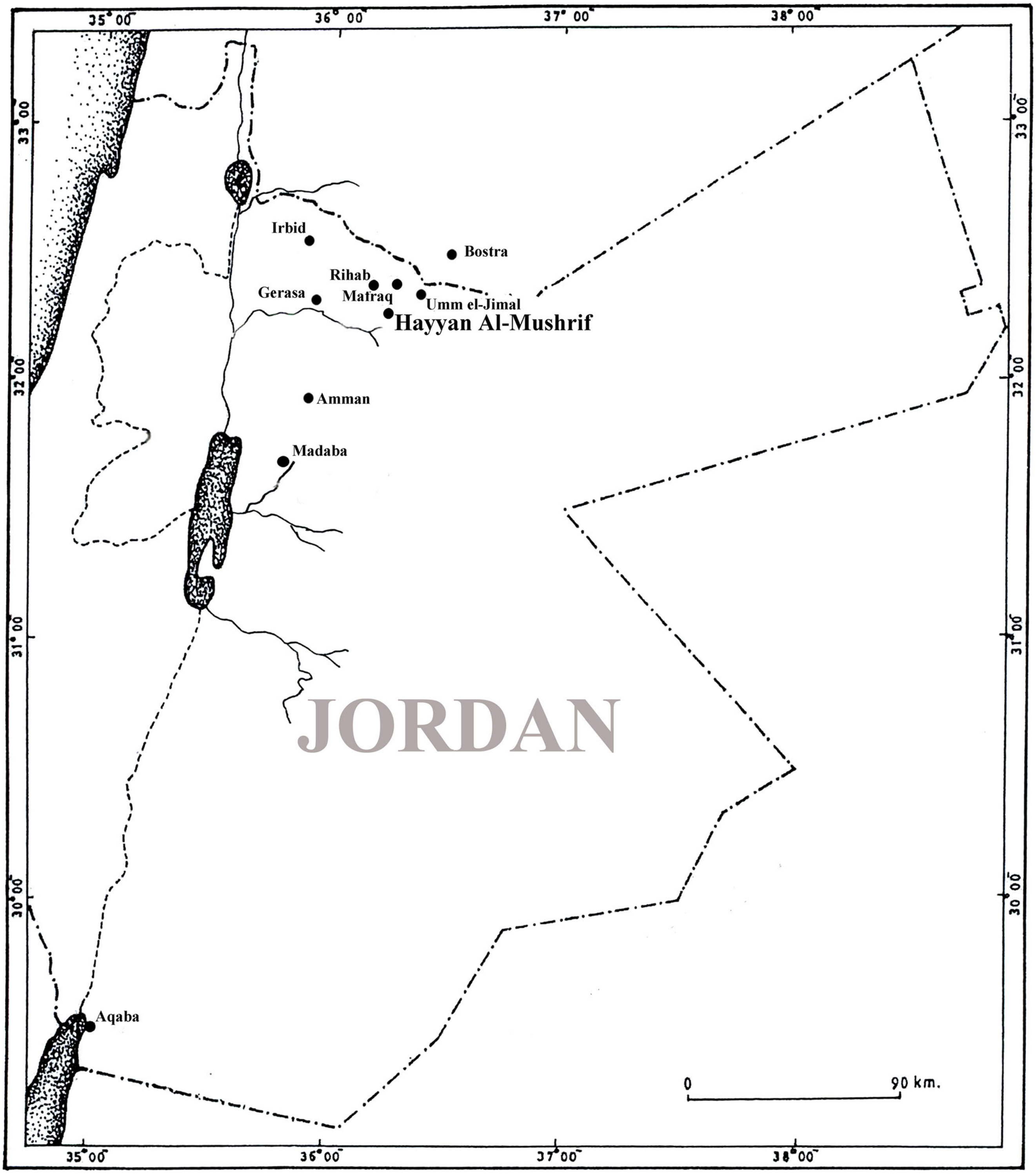

Fig. 1 Location of Hayyan Al-Mushrif and other adjacent sites

systems and shed light on the chronology and reasons for the intensive exploitation of particular marble sources during the Byzantine period.

Hayyan Al-Mushrif archeological site

The Hayyan Al-Mushrif archeological site is located about 8 km southwest of Al-Mafraq City, north Jordan. It is close to the Al-Fudein (Mafraq) and Rihab archeological sites and somewhat farther from Gerasa, Umm el-Jimal, and Bostra (Fig. 1). The site is surrounded by a modern village that has flourished in recent decades; because of this, the extent of the ancient site is not well known (Al-Muheisen 1998). The presence of a large pool and cisterns indicates that the site depended on rainfall for water. The occurrence of chert layers within local limestone beds (Bender 1974) enabled the site's inhabitants to use the chert for lithic artifacts and the limestone for building stone and carving sarcophagi.

The site was first mentioned by Mittmann (1970) during his surveys between 1963 and 1966. Piccirillo (1981) identified three of its six churches only. Later, between 1995 and 1997, the site was excavated by Yarmouk University in cooperation with the Department of Antiquities of Jordan (Al-Muheisen 1998). From 1999 to 2011, excavations were taken up by the Department of Antiquities of Jordan. Based on the recovered archeological materials during the surveys and excavations, the site was dated from the Paleolithic up to the Mamluk periods (Al-Housan 2002; Al-Muheisen 1998). During the Roman and Byzantine periods, the site belonged to the *Provincia Arabia*, which had Bostra as its capital (Horsfield 1937). The presence of six churches, domestic buildings, and civil structures is evidence for the site's prosperity during the Byzantine period. In contrast, the small Mamluk mosque indicates a limited usage of the site during the Mamluk period (Al-Muheisen 1998).

The Middle Church

The marbles in this study were uncovered from the Middle or Syriac church located within the church complex at the center of Hayyan Al-Mushrif. The complex comprises three adjacent churches: the middle, Obeidah, and the south church. The Middle Church is a rectangular hall (19 × 8.5 m) built on eight lateral arches without an apse (Fig. 2) and has two small rooms at its east end. It was partly built below the ground level with two narrow entrances (0.9 m) and stairs descending to the north and south walls. The church was probably renovated by the addition of a rectangular sanctuary comprising an altar and a chancel screen. The probable date for the church's renovation is the middle of the sixth century AD, manifested in the general trend of the addition of chancel screens in the region (Habas 2000). The altar is made up of two marble plates, one is rectangular and the other circular, raised on marble columns. A marble reliquary with a cross carved in high relief was uncovered under the altar. The reliquary has a sarcophagus shape and contains hand and finger bones. The church's chancel screen is made of marble, and most of it was uncovered in situ and later was stored at the Department of Antiquities of Al-Mafraq, at Al-Mafraq.

Fig. 2 The Middle Church of Hayyan al-Muashrif (facing east)

The art of the chancel screen

Chancel screens are an essential part of the Byzantine church and have symbolic meaning. The chancel screen of the Middle Church, which separated the altar from the rest of the church, consists of carved and decorated panels (slabs) (Fig. 3: samples 4, 5, 14, 15, 16) firmly placed in grooves cut into the sides of square marble posts (Fig. 3: samples 1 and 6). The altar's panel is plain, but its inner area is recessed (Fig. 3: sample 2). One of the chancel screen panels is ornamented with a Cross Pattée (Patty or Formy) which has four arms that narrow at the center and widen at the ends (Fig. 3: sample 15). Another panel is decorated in high relief with a laurel wreath and bordered by two concentric frames (Fig. 3: sample 14). The wreath is circular, encloses a Cross Pattée, and is made of ten bundles of leaves. The bundles are made up of three leaves each, which end in an *ovolo* motif at the top and in an inverted *fleurs-de-lys* motif at the bottom. It is worth noting that the cross lacks *fleurs-de-lys* or a *chrisma* monogram, and the wreath lacks ribbons.

The church's posts vary in shape and dimensions (Fig. 3). Some of the low posts are square, decorated by two concentric frames, and have hemispherical or onion-shaped heads (Fig. 3: 1, 6, 20). Other low posts are balusters (short and belly shaped) (Fig. 3: samples 10, 11, 19). In addition, one small thin post or colonnette ends in a Corinthian capital (Fig. 3: sample 18). The high posts are cylindrical and plain (Fig. 3: 7, 8, 9, 12, 13, 17). For more detail on the art of chancel screens, see Habas (2009).

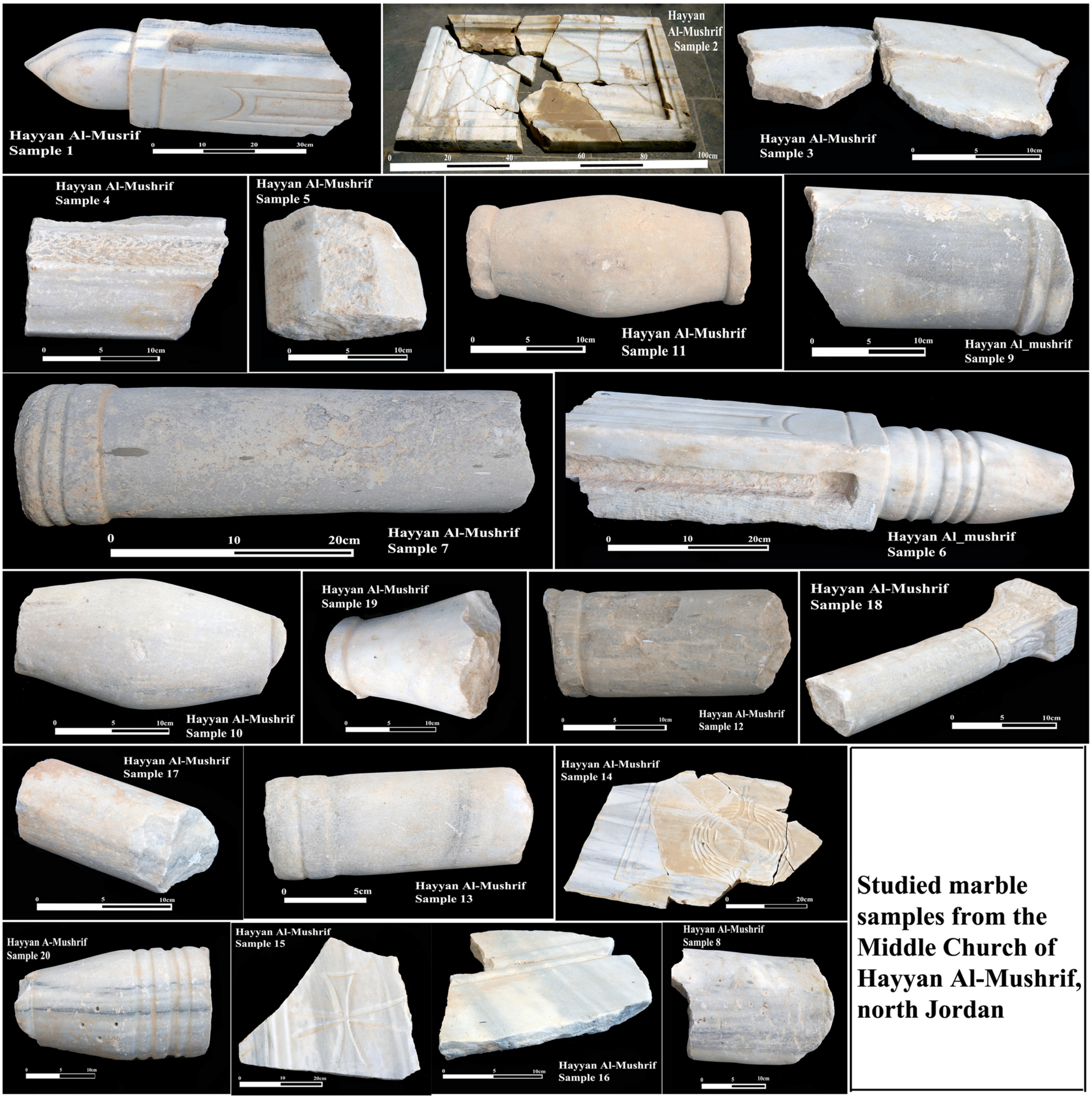

Fig. 3 The 20 Ecclesiastical marble samples from the Middle Church of Hayyan Al-Mushrif

Materials and methods

Twenty samples from 20 white marbles, described in Table 1 and illustrated in Fig. 3, were collected. One was taken from a broken rounded communion plate (panel) (Fig. 3: sample 3), another one from a broken rectangular altar plate (Fig. 3: the right slab of sample 2), and 18 others from different parts of the church's chancel screen including rails, panels, and columns of different shapes and dimensions. The outer material of the marble elements was removed, and small chips of material were detached with a sharp chisel and a hammer from broken portions or from hidden areas. The sampling strategy focused on obtaining representative samples while maintaining the esthetic appearance of the sampled architectural elements. The samples were characterized by different analytical techniques including X-ray diffractometry (XRD), optical microscopy, and stable isotope mass spectrometry. The analyses were carried out on bulk samples representing the components of the marbles. A few milligrams of each chip were ground and used for X-ray diffraction and stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope analyses, while the rest of the chip was used for thin section preparation.

Table 1 Sample description, color, the analytical results, and the probable provenance (Pr Proconnesus, M.G.S maximum grain size; +++very abundant, ++abundant, +present, +/−traces, −not detected)

Serial no.	Object	Macroscopic features	M.G.S. (mm)	Microscopic features	Trace and minor minerals (petrography and XRD)						$\delta^{13}C$, PDB ± SD	$\delta^{18}O$, PDB ± SD	Probable provenance
					Quartz	K-mica	Plagioclase	Carbon/graphite	Opaque mineral	Dolomite (XRD)			
1	Broken post, rectangular base, carved with M shape on one face, deep carving on the adjacent face for fixing the panels.	Light gray, dark gray bands, coarse-grained.	2.6	Mosaic, Mortar, He, curved-embayed boundaries.	+/−	+/−	−	+++	+/−	−	3.59 ± 0.022	− 0.31 ± 0.021	Pr-1
2	Broken plain, recessed altar panel (plate).	Light gray, gray bands, coarse-grained.	2.6	Lineated, Mortar, He, straight-curved boundaries.	+/−	+	−	+++	+/−	+/−	2.78 ± 0.017	− 11.23 ± 0.025	Pr-2
3	Broken rounded communion tray.	Light gray, dark gray bands, coarse-grained.	2.8	Mosaic, Mortar, He, curved-embayed--sutured boundaries.	+	+/−	−	+++	+/−	+/−	2.34 ± 0.003	− 1.75 ± 0.042	Pr-1
4	Broken rail of trapezoid cross section.	Gray, dark gray bands, coarse-grained.	2.4	Mosaic, Mortar, He, curved-embayed--sutured boundaries.	+/−	+	−	++	+/−	+/−	2.84 ± 0.024	− 0.37 ± 0.036	Pr-1
5	Broken rail of trapezoid cross section.	Gray, dark gray bands, coarse-grained.	3.2	Mosaic, Mortar, He, curved-embayed boundaries.	+/−	+/−	−	++	+/−	+/−	3.73 ± 0.033	− 1.99 ± 0.032	Pr-1
6	Broken post, rectangular base, carved with M shape, top tapered with parallel grooves.	Light gray, dark gray bands, coarse-grained.	2.6	Lineated, Mortar, He, straight-curved boundaries.	+/−	+/−	−	++	+/−	+/−	2.83 ± 0.019	− 2.35 ± 0.021	Pr-1
7	Broken semi-round column, base has parallel grooves.	Dark gray, coarse-grained.	2.5	Mosaic, Mortar, He, curved-embayed boundaries.	+/−	+/−	−	+++	+/−	+/−	3.47 ± 0.013	− 1.27 ± 0.055	Pr-1
8	Broken rounded column.	Light gray to gray, dark gray bands, coarse-grained.	2.4	Mosaic, Mortar, He, straight-embayed boundaries.	+/−	+	−	+++	+/−	−	3.17 ± 0.049	− 0.91 ± 0.002	Pr-1
9	Broken rounded column, base has parallel grooves.	Gray, dark gray bands, coarse-grained	2.1	Mosaic, Mortar, He, curved-embayed boundaries.	+	++	−	+++	+/−	+/−	2.75 ± 0.052	− 5.33 ± 0.038	Pr-2
10	Broken belly column.	Gray, dark gray bands, coarse grained.	3.6	Mosaic, Mortar, He, curved-embayed boundaries	+/−	−	−	++	+/−	+/−	3.00 ± 0.028	− 1.42 ± 0.025	Pr-1
11	Broken Belly column.	Gray, dark gray bands, coarse grained.	3.2	Mosaic, Mortar, He, Straight-embayed Boundaries	+/−	+	−	+++	+/−	+/−	2.75 ± 0.022	− 1.27 ± 0.062	Pr-1
12	Broken rounded column, base has parallel grooves.	Dark gray, gray bands, coarse-grained.	3.7	Mosaic, Mortar, He, curved-embayed boundaries	+/−	+/−	−	++	+/−	+++	3.02 ± 0.015	− 3.09 ± 0.086	Pr-1
13	Rounded column, base has parallel grooves.	Light gray, dark gray bands, coarse-grained.	2.7	Mosaic, Mortar, He, curved-embayed boundaries	+	+	−	+++	+/−	+/−	3.35 ± 0.019	− 0.79 ± 0.029	Pr-1
14	Broken chancel screen panel decorated with a cross at the		3.2		+/−	+/−	−	+++	+/−	−	3.15 ± 0.013	− 1.32 ± 0.026	Pr-1

Table 1 (continued)

Serial no.	Object	Macroscopic features	M.G.S. (mm)	Microscopic features	Trace and minor minerals (petrography and XRD)						$\delta^{13}C$, PDB ± SD	$\delta^{18}O$, PDB ± SD	Probable provenance
					Quartz	K-mica	Plagioclase	Carbon/graphite	Opaque mineral	Dolomite (XRD)			
	middle and encircled by acanthus wreath.	Light gray, dark bands, coarse grained.		Mosaic, Mortar, He, curved-embayed boundaries									
15	Broken chancel screen panel decorated with a Cross at the middle.	Light-dark gray, dark bands, coarse-grained.	2.9	Mosaic, Mortar, He, curved-embayed boundaries	+/−	+/−	–	+++	+	+/−	2.57 ± 0.018	− 1.27 ± 0.052	Pr-1
16	Broken chancel screen panel.	Light gray, dark bands, coarse-grained.	2.7	Mosaic, Mortar, He, curved-embayed--sutured boundaries	+	+	–	+++	+	–	3.29 ± 0.028	− 1.60 ± 0.027	Pr-1
17	A baluster short column for the communion table.	Light-dark gray, dark bands, coarse-grained.	2.5	Mosaic, Mortar, He, curved-embayed--sutured boundaries	+/−	+	–	+++	+	+/−	3.07 ± 0.026	− 1.73 ± 0.016	Pr-1
18	Chancel screen colonette, the base is decorated with lotus flowers.	Gray, dark gray bands, coarse-grained.	2.7	Mosaic, Mortar, He, curved-embayed boundaries	+	+/−	–	++	+	+/−	1.07 ± 0.060	− 4.72 ± 0.043	Pr-1
19	Broken belly column.	Light gray, dark gray bands, coarse grained.	2.4	Mosaic, Mortar, He, curved-embayed boundaries	+/−	+/−	–	++	+/−	+/−	2.97 ± 0.051	− 1.51 ± 0.023	Pr-1
20	Tapered head of a post, with parallel grooves.	Dark gray, dark bands, coarse-grained.	2.7	Mosaic, Mortar, He, curved-embayed boundaries	+	+/−	–	+++	+	+++	2.89 ± 0.031	− 1.43 ± 0.055	Pr-1

Thin sections were prepared following the standard procedures described by Camuti and McGuire (1999) and examined by a Leitz 7062 polarizing microscope to identify a number of petrographic parameters of important diagnostic significance for marble analyses: maximum grain size (MGS) and grain boundary shapes (GBS) of calcite or dolomite grains and marble texture and fabric (Lazzarini et al. 1980; Moens et al. 1988; Gaggadis-Robin et al. 2009).

Mineralogical identification was carried out on powdered samples using a Shimadzu Lab X, 6000 X-ray diffractometer. Further, powder diffraction patterns were obtained under the following conditions: CuKα radiation ($\lambda = 1.5418$ Å) with 30 kV, 30-mA energy, and graphite monochromatic. Thin sections were prepared and examined, and XRD analysis was carried out in the laboratories of the Faculty of Archeology and Anthropology, Yarmouk University, Irbid, Jordan.

Measurements of the oxygen and carbon stable isotope ratios of the samples were performed by means of the automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). The measurements were calibrated based on repeated measurements of the NBS-19 and NBS-18 standards, and the precision of the isotopic ratio is ± 0.1‰ for δ^{18}O and ± 0.08‰ for δ^{13}C (1 sigma). Isotope analyses were carried out at the Environmental Isotope Laboratory, the Department of Geosciences at the University of Arizona, Tucson, Arizona, USA. The results were compared to the main reference databases of Mediterranean marbles exploited in antiquity mentioned above. The stable isotope values were plotted against Antonelli and Lazzarini's (2015, Fig. 7a) updated global isotopic reference diagram.

Results and discussion

Macroscopic observations and the analytical data including isotopic signatures, maximum grain size, and mineralogical composition are summarized in Table 1 and Figs. 4 and 5. The color of the investigated marble elements varies from light gray to gray with clear semi-parallel to parallel dark gray patches or veins (Fig. 3). Because of their large grains, individual grains within some samples are visible to the naked eye. The samples also emitted a sulfur odor when ground. XRD analyses showed that calcite is the principal mineral of the samples, dolomite is a minor component for few samples, and quartz is a trace mineral in several samples. In particular, dolomite was not detected in samples 1, 8, 14, and 16, and dolomite content was highly variable in the rest of the samples. For example, XRD diffractograms of samples 12 and 20 showed the highest dolomite abundance (about 35% of their total mineral content); meanwhile, other samples had much lower amounts or only traces. A petrographic analysis showed traces of quartz, K-mica, and opaque minerals in several samples (Fig. 5 and Table 1).

Petrographically, all the samples have heteroblastic textures, mortar fabrics, curved to embayed crystal boundaries, and deformed polysynthetic twinning lines (Fig. 5). MGS measurements showed that all the samples are coarse-grained (2.1–3.2 mm). In Fig. 4, the δ^{18}O and δ^{13}C values of 17 samples clustered to the right of the plot within the isotopic regions of multiple quarries. The values of samples 9 and 18 sat to the left of the cluster, while the values of sample 2 sat to the left of the plot within the Naxos isotopic region but relatively close to the border of Proconnesus-2 isotopic region.

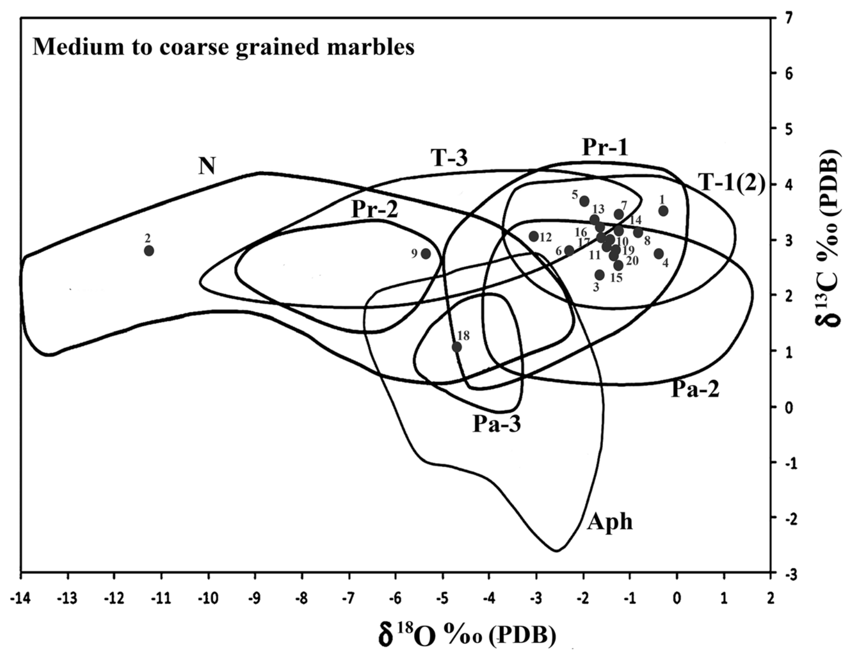

Fig. 4 The isotopic signatures of the marbles from Hayyan Al-Mushrif Middle Church plotted in the δ^{18}O-δ^{13}C diagram of Antonelli and Lazzarini (2015) for the main Mediterranean medium coarse-grained marbles used in antiquity. *N* Naxos, *Pr* Proconnesus (*Pr-1* Proconnesus from Saraylar, *Pr-2* Proconnesus from Camlik), *Pa* Paros (*Pa-2* Chorodaki valley, *Pa-3* Agios Minas valley), *T* Thasos (*T-1* district of Phanari, *T-2* district of Aliki (Thasos-(1) 2: this domain comprises the vast quarrying district of Alikı' (Thasos-2) and the small extraction site of Phanari (Thasos-1)), *T-3* district of Vathy-Saliara)

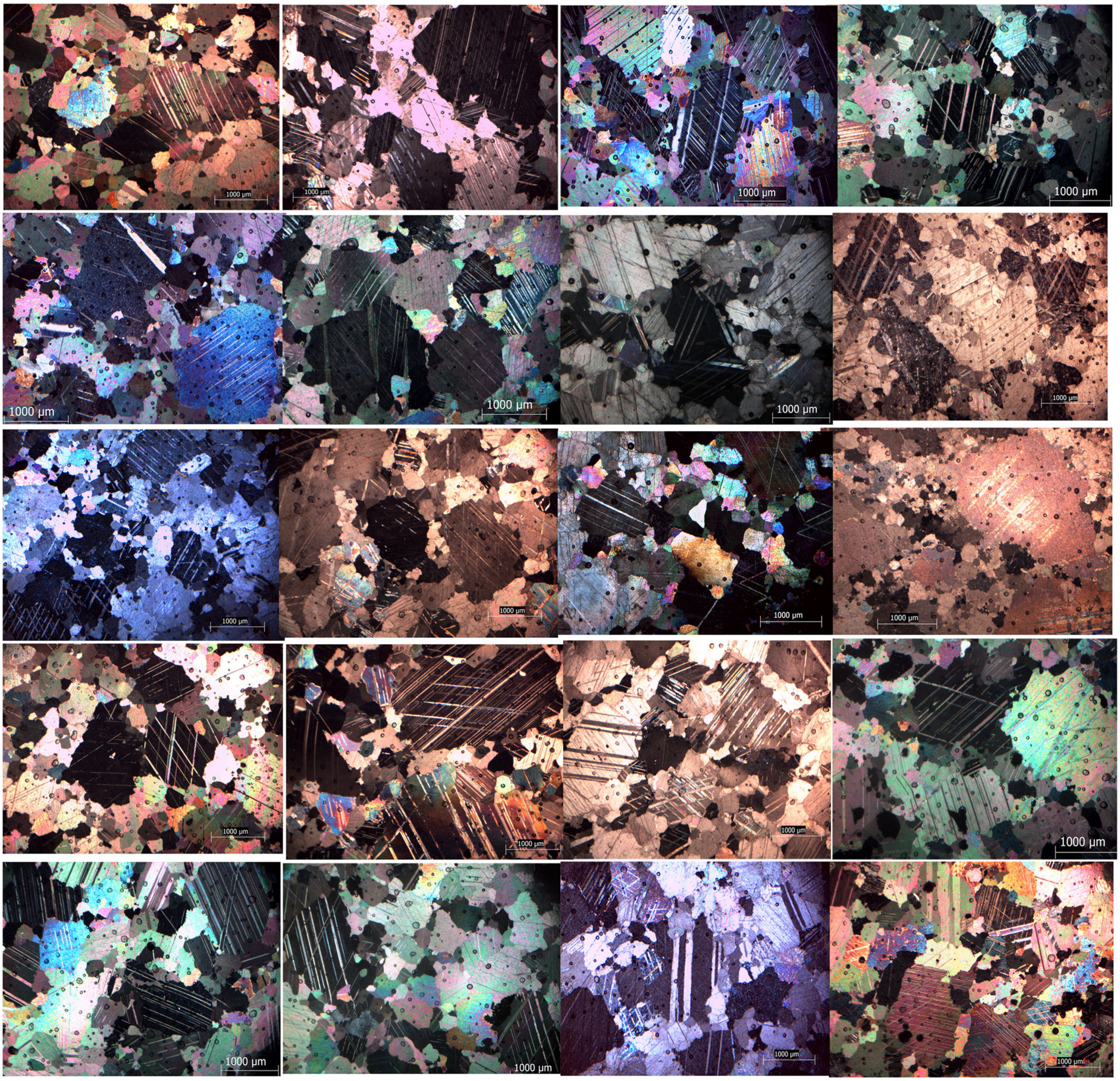

Fig. 5 Microphotographs of thin sections show the main textural features of the investigated marbles. The samples have heteroblastic textures, mortar fabrics, sutured to embayed crystal boundaries and deformed polysynthetic twinning lines. The samples 1–20 are arranged in an ascending order from left to right, top to bottom

The cluster of the 17 samples (1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20) and sample 18 most probably belong to Proconnesus-1 marble. It is probable that this set of contiguous samples originated from the same outcrop. It is worth noting that the isotopic value of sample 18 is located at the edge of the Proconnesus-1 marble field in this database, but it lies outside this isotopic region in older isotope databases; for example, see Gorgoni et al. (2002), Capedri and Venturelli (2004), and Lazzarini (2004).

Sample 9 could be assigned to Proconnesus-2 marble from Çamlik (Marmara Island). It has similar petrographic features to the Proconnesus-1 marble but its $\delta^{18}O$ value is more negative, placing it in the Proconnesus-2 isotopic region. Despite its location in the Naxos isotopic region to the left of Proconnesus-2, the anomalous sample 2 has microscopic features (Fig. 5c) that are very similar to those of the Proconnesus-1 marble. These microscopic features are very different from those of the Naxos marble, typified by very coarse calcite crystals commonly stretched, conjoined with strong polysynthetic twinning (Lazzarini et al. 1980; Germann et al. 1988). These features exclude Naxos and point to Çamlik (Marmara Island) as the most probable source for sample 2. Similar anomalously negative $\delta^{18}O$ values were reported by Asgari and Matthews (1995) and Attanasio et al. (2008). The variation in the negative $\delta^{18}O$ values can be attributed to different interactions between the carbonate rock and circulating fluids in different locations of the quarry (Attanasio et al. 2008).

Most of the samples contain dolomite which is absent in Paros marbles and common in Proconnesus marbles; therefore, Paros is an unlikely source (Capedri et al. 2004).

The results of this study are in agreement with Al-Bashaireh and Al-Housan (2014), who concluded that most of the studied chancel screen marbles from Rihab churches were Proconnesus-1 marble. Similarly, the chancel screen elements from Humayma, south Jordan, analyzed by Al-Bashaireh (Schick et al. 2014) and the chancel screen plate and posts studied by Al-Naddaf et al. (2010) were Proconnesus-1 marble.

The presence of only two samples of the Proconnesus-2 marble among the Hayyan Al-Mushrif marbles confirms the limited diffusion of the Proconnesus-2 marble in Jordan, and the Levant in general, during the Byzantine period. Other studies have observed similar cases of limited use of the Proconnesus-2 marble in Jordanian archeological sites. Al-Bashaireh (2003) found two Proconnesus-2 samples, while Al-Bashaireh and Al-Housan (2014) found only one Proconnesus-2 sample among the chancel screen marbles they studied. It is noteworthy that Gorgoni et al. (2002) confirmed Asgari and Matthews's (1995) observation that Proconnesus marbles have highly negative $\delta^{18}O$ values and classified them as Proconnesus-2.

The marble elements are of standard dimensions and do not show signs of secondary dressing or reuse; therefore, they were most likely imported. In addition, several observations consolidate the theory of the import of chancel screen marble elements including a stylistic analysis of chancel screens in Jordan and Palestine, field surveys on Proconnesus Island, discoveries of similar marble elements in shipwrecks, and the restriction of their production to religious authority; for more details, see Habas (2009), Al-Bashaireh and Al-Housan (2014), and references therein.

Conclusions

A multidisciplinary analytical examination of an ecclesiastical marble collection of chancel screen elements revealed that Proconnesus (Marmara, Turkey) is the source of the collection. These results support previous marble provenance studies that showed that the Proconnesus-1 (Saraylar) marble was the most common marble used for church furnishing and the primary choice for the stonemasons during the Byzantine period. In contrast, the use of the Proconnesus-2 (Çamlik) marble was much more limited. This work provides more evidence that the Proconnesus-1 marble was used mainly for decorative carved stones, and became the most widely used architectural white marble during Byzantine times.

It is likely that the spread of Christianity and the construction of new churches significantly increased demand for and trade in ecclesiastical marble. Proconnesus marbles (an imperial property since the first century AD) supported the trade of large quantities and cargoes and met this challenge for several reasons: low cost and the availability of unfinished and semi-finished ecclesiastical products of standard sizes, a large labor force, and advanced transportation methods (Attanasio et al. 2008; Al-Bashaireh and Dettman 2015).

The renovation of the sacred area of the Middle Church during the Byzantine period using imported luxurious marbles clearly points to the prosperity of the region in general and Hayyan Al-Mushrif in particular. It is likely that Hayyan Al-Mushrif location, in close proximity to the trade routes between Gerasa, Umm el-Jimal, Al-Fudein, and Bostra, facilitated the import of these stones.

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