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ORIGINAL PAPER

Marbles, granites and basalt used in the cruciform basilica of Abila (Decapolis, Jordan): archaeometric characterization and provenance

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Abstract The provenance of granite, basalt, and marble used in building the cruciform basilica of Abila of the Decapolis, northwestern Jordan, is investigated using chemical and petrographic techniques. The basilica is dated to the late fifth or early sixth century AD. The stones were characterized using macroscopic traits in combination with optical microscopy, X-ray diffraction, and stable oxygen and carbon isotope spectrometry. These data were compared to the published databases for marbles, granites, and basalts used in antiquity. The comparison showed that the basalts are most probably local. The islands of Marmara (Proconessos-1), Turkey, are the primary source of the white marbles, while Paros island (Paros-2), Greece, is a minor source. The source of the green *Cipollino* marbles is Styra in the island of Euboea (Greece). The pink and gray granites are likely microasiatic from the Çigri and Kozak Dâgs, respectively, northwest Turkey.

Keywords Abila · Jordan · Cruciform basilica · Building stones · Provenance

Introduction

The archaeological site of Abila (Qweilbeh) of the ancient Decapolis is situated in the far northwestern part of Jordan about 5 km south of the border with Syria (Fig. 1).

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Archaeological surveys and excavations during the past decades have shown that Abila was a thriving city during the Roman and Byzantine periods with a population of 8000–10,000 persons (Mare 1992a). Archaeological evidence clearly shows the prosperity of Abila (Mare 1992b). The cultural richness and diversity of the city can be seen in the archaeological remains of its villas, tombs, basilicas, theater, aqueducts, and baths. The use of its natural resources includes natural defenses, water supplies, and agricultural lands. The city had a multilevel social structure reflected in the construction and embellishment of its tombs. The economic and artistic richness of the city is seen in the wide variety of local and foreign luxury artisan products. In addition, the city has an extensive and well-established road system that connected Abila with the other cities in the region, indicative of significant trade and commerce.

Topographically, the site is formed of two tells (Tell Abil and Umm el-Amad) separated by a saddle depression. A cruciform basilica was recently excavated in the civic center of the site located on the lowest terrace of the saddle in area E (Mare 1996) and facing the Wadi Qweilbeh just to the west of a Roman bridge (Fig. 2).

The basilica has five aisles and three (north, south, and east) apses forming a cruciform design (Mare 1996; Fig. 3). The architectural plan of the church is uncommon among the Byzantine basilicas of Jordan but is reminiscent of the plan of the basilica of the Nativity in Bethlehem (Menninga 2004). The church has seven entrances; five of them are located in the west wall, and each leads to an aisle of the church, while the remaining two entries are located on the north and south sides. The north-south and east-west sides of the church (excluding the apses) are 26.6 and 25.4 m in length, respectively (Menninga 2004; Fig. 3).

This basilica has been dated to the late fifth or early sixth century AD, based on pottery remains and architectural

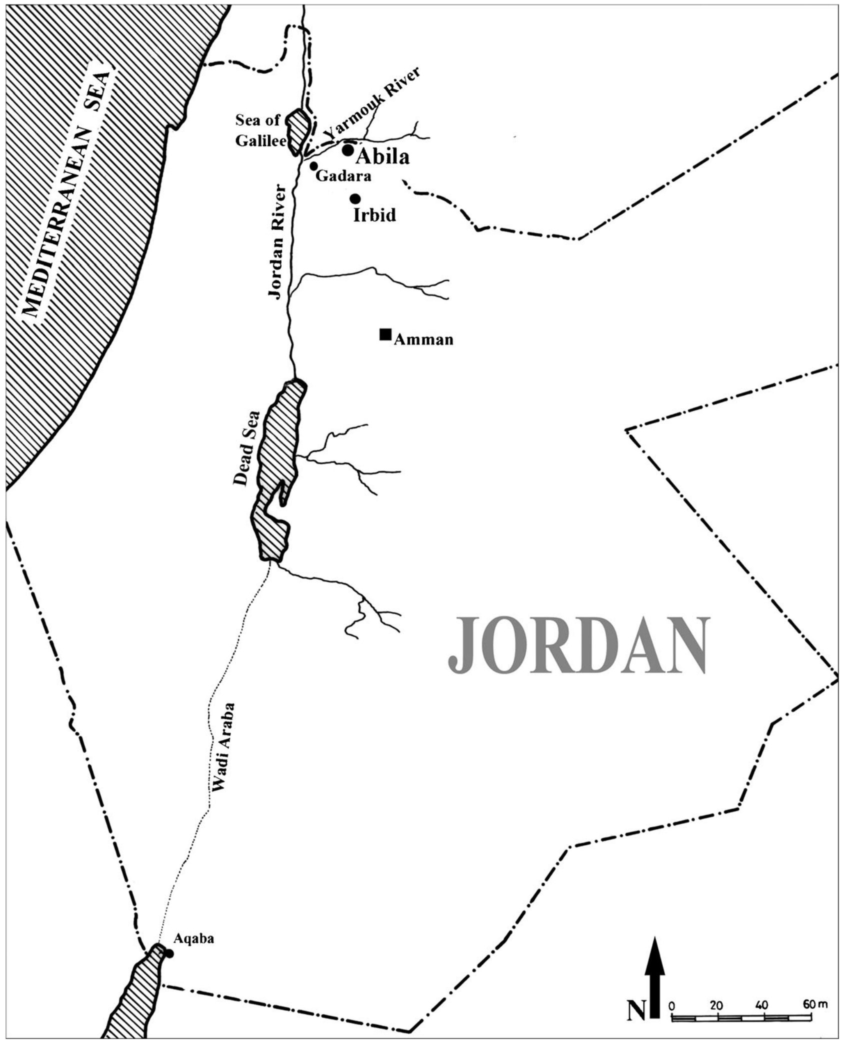

Fig. 1 Location map of Abila within the Decapolis

designs. The date is also indirectly confirmed by a mid-sixth century AD inscription uncovered in a water tunnel mentioning a bishop of Abila (Van Elderen 1989; Menninga 2004). However, a Roman inscription from the second century AD found on a granite column just west of the basilica suggests that the church was used as a municipal building or a Roman temple before its modification into a church (Chambers 2009; Menninga 2004).

Four east-west rows of columns (designated north, north-central, south-central, and south) were used to support the roof of the church. Although the columns were made of basalt, granite, and green *Cipollino* marble, most of the bases (found in situ), column drums, and capitals uncovered during excavations were of basalt (for more details, see Menninga 2004, p. 45–47). A column of white marble with wavy green stripes was found near the two in situ white marble column bases of the westernmost two columns of the north-central row, while other broken parts of similar columns were found just west of the church's west wall. Two Corinthian capitals of white marble were also found outside the north wall. In addition, two granite columns were found near the central altar screen foundation and broken parts of two other granite columns were uncovered just west of the south apse (Menninga 2004). The toppled column elements were used to re-erect the 26 columns of the basilica during the 1992 and 1999 excavation seasons (Fig. 4) (Mare 1994, p. 367; Mare 2000). In addition to these interior columns, a row of eight columns (one fallen) of granite and green marbles stands to the west of the basilica. These columns were most probably re-erected sometime after 2000.

Both the bronze pins embedded in the outside of the west wall and the numerous broken marble pieces found throughout the basilica indicate that there was originally marble facing on the walls (Mare 1999). It is also very likely that the floors of the church were covered with marble as seen in a 10-m^2 section of marble floor uncovered in the southwest part of the church (Menninga 2004).

It is very unlikely that the basalt building materials were imported from outside the region since it outcrops very close to Abila within the Harrat Ash Sham volcanic field of northeast Jordan and southern Syria (Guba and Mustafa 1988; Iliani

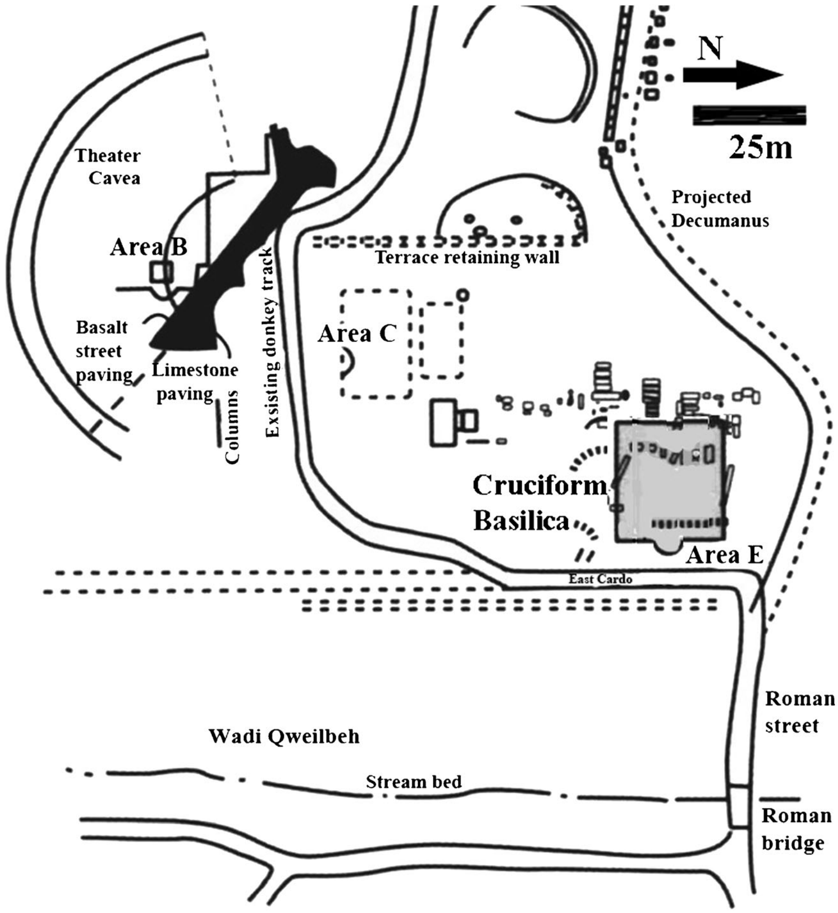

Fig. 2 Plan of ancient Abila showing the location of the Basilica in area E (after Mare 1997, 1999)

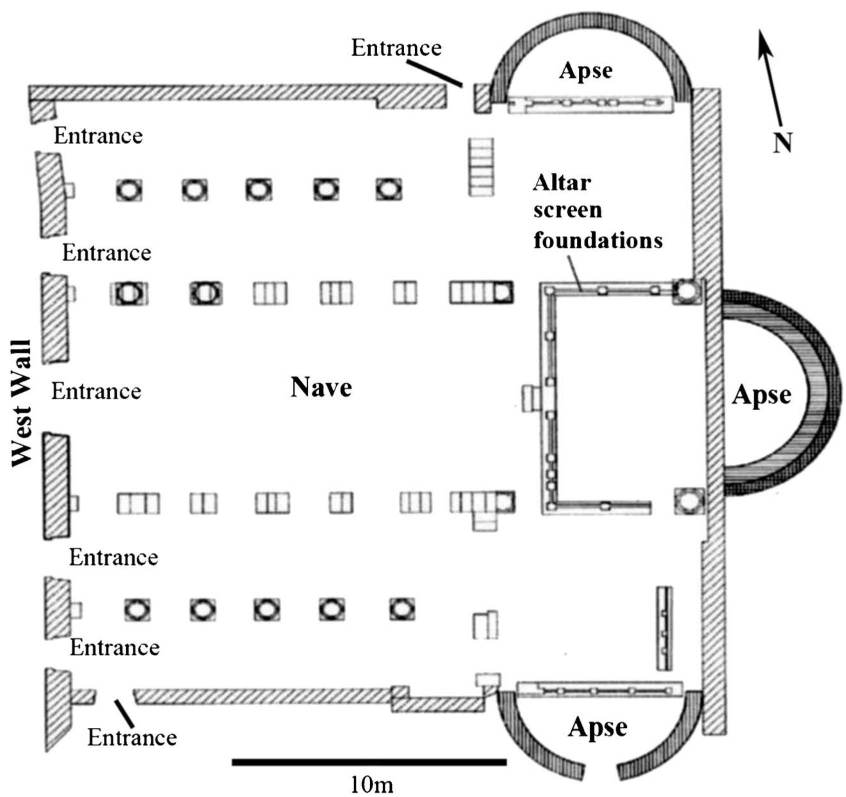

Fig. 3 Plan of the basilica showing rows of columns, apses, aisles, and entrances (after Menninga 2004)

Fig. 4 The columns of the cruciform basilica (facing northeast)

et al. 2001). Granite and the white and green marbles must have been imported because the region lacks local sources of these luxurious stones (Fischer 1991, 1998; Al-Bashaireh 2011). Some proposed sources for Abila building stones have been published. A granite column uncovered in the 1990 excavation season was attributed to an Aswan source, and Naxos was proposed as the source of the white marble fragments of the sanctuary partition (Deeds 1991, p. 18). Deeds' preliminary report, however, gave no method for sourcing these stones. It seems likely that they were simply correlated based on visual examination only, a process that has proved to be extremely unreliable. Granite samples from different quarries often have similar visual characteristics but are chemically different, while marbles from different parts of the same quarry may have different macroscopic characteristics (Lazzarini et al. 1980; Herz 1987).

The primary source of granites found in Roman period archaeological sites of the Levant was the Çigri Dag in Troad, northwest Turkey. Minor sources for granite were Aswan, southern Egypt, and Kozak Dağ in Mysia, western Turkey (Williams-Thorpe and Henty 2000; Lazzarini 2010; Russell 2013). White marble in the region had multiple sources (Herz 1992), while the most common source of green-banded marble was Carystia, Greece (also called *Cipollino Verde*) (Sutherland and Sutherland 2002; Lazzarini 2007; Al-Bashaireh 2011). This paper uses different archaeoemetric methods to determine the sources of igneous (basalt and granite) and metamorphic (marble) building stones used in the construction of the Ablia basilica.

Materials and methods

Macroscopic examination of numerous examples of granites, basalts, and green marbles showed that each of these three types of building stones were very similar in grain size, color, porosity, and patterns of banding; therefore, we assumed a single source for these stones and took only two samples of each type of stone for analysis. In contrast, ten different samples of white marble were collected from different architectural elements, because of the multiple possible sources of white marble in this region. Samples were obtained by detaching small flakes of material with a small sharp chisel and a hammer from either hidden or already broken surfaces of columns or other architectural elements (Table 1).

Mineralogical analyses and the presence of a possible dolomitic component in the marbles was evaluated using X-ray diffraction (XRD) (Shimadzu Lab X, 6000 X-Ray Difractometer: CuKα radiation, 1.5418 Å, 30 kV, 30 mA energy, and graphite monochromator). Petrographic study of thin sections used a polarized light microscope (Leitz 7062 model) in order to classify and determine the paragenesis of each stone. Diagnostic petrography of the marbles focused on fabric features, maximum grain size (MGS), calcite crystal boundary shapes, and the frequency and distribution of accessory minerals (Moens et al. 1992). Oxygen and carbon stable isotope ratios (expressed as $\delta^{18}O$ and $\delta^{13}C$ values) of the white marbles were measured using an automated carbonate preparation device (KIEL-III) coupled to a gas ratio mass spectrometer (Finnigan MAT 252). The precision of the isotopic ratio is ±0.1 ‰ for $\delta^{18}O$ and ±0.06 ‰ for $\delta^{13}C$ (1 sigma), and the measurements were calibrated based on repeated measurements of the NBS-19 and NBS-18 standards.

The results of these analyses were compared to databases of marbles used in antiquity (Gorgoni et al. 2002; Attanasio et al. 2006) and individual studies of granite and basalt building stones (see below).

Results and discussion

White marbles

The results of the minero-petrographic and isotopic analyses are summarized in Table 1. The XRD analysis shows that the white marble samples are mineralogically calcite, with the exception of sample 2, which contains both calcite and dolomite (Table 1). Quartz is present in minor quantities in all samples, while samples 2 and 3 also contain plagioclase. These observations eliminate Thassos-3 as a possible source for the white marbles because its mineralogical composition is predominately dolomitic (Bruno et al. 2002).

Oxygen and carbon stable isotope data are compared with quarry C-O isotope ratio fields from Gorgoni et al. (2002) and Attanasio et al. (2006) (Fig. 5). Samples 5, 6, 7, and 10 fall within the Proconessos-1, Paros-2, and Thassos-1(2) isotopic fields. Samples 1 and 4 fall within the Proconessos-1 and Thassos-3 isotopic fields. Sample 9 overlaps with the Proconessos-1, Paros-2, Naxos, and Aphrodisias isotopic

Table 1 Summary of the results of the petrographic and isotopic analyses of white marble samples

S. No.	Object	Fabric	Calcite crystal boundaries	Maximum grain size (mm)	Quartz	Muscovite-mica	Plagioclase	Apatite	Graphite	Opaque minerals	Dolomite (XRD)	$\delta^{13}C$ PDB±SD	$\delta^{18}O$ PDB±SD	Probable provenance
1	Frieze	HE, mortar, lineated	Straight-embayed	3.5	±±	±	–	–	++	±	–	3.15±0.063	−3.87±0.041	Pr-1
2	Pavement	HE, mortar, lineated	Embayed	2.08	±±	±/+	±±	–	++	±	++	0.74±0.031	−1.68±0.025	Pr-1
3	Chancel screen	HE, mortar, lineated	Curved-embayed	2.5	±±	±±	±	–	+	±	±±	1.58±0.021	−4.42±0.052	Pr-1
4	Pavement	HE, mortar	Curved	3.6	±±	±	–	–	+	±	–	4.02±0.023	−2.52±0.022	Pr-1
5	Column base	HO, mosaic	Straight-curved	2.7	±±	±	–	–	+	±	–	2.52±0.034	−1.82±0.53	Pa-2
6	Pavement	HE, mortar	Straight-embayed	2.9	±±	±	–	–	+	±	–	2.76±0.037	−1.61±0.072	Pr-1
7	Corinthian c	HE, mortar	Straight-embayed	2.5	±±	±	–	–	+	±	–	2.65±0.044	−1.89±0.039	Pr-1
8	Chancel screen	HE, mortar	Curved-embayed	2.3	±±	±±	–	–	+	±	±	1.59±0.006	−4.44±0.046	Pr-1
9	Column base	HE, mortar, strained	Embayed-sutured	3.5	±	–	–	–	+++	±	–	1.19±0.029	−2.91±0.014	Pr-1
10	Column base	HO, mosaic	Straight-curved	2.0	±	–	–	–	++	±	±	2.72±0.025	−1.45±0.040	Pa-2

HE heteroblastic, *HO* homeoblastic, *Pr-1* Proconessos-1, *Pa-2* Paros-2, +++ very abundant, ++ abundant, + present, ± traces, – absent

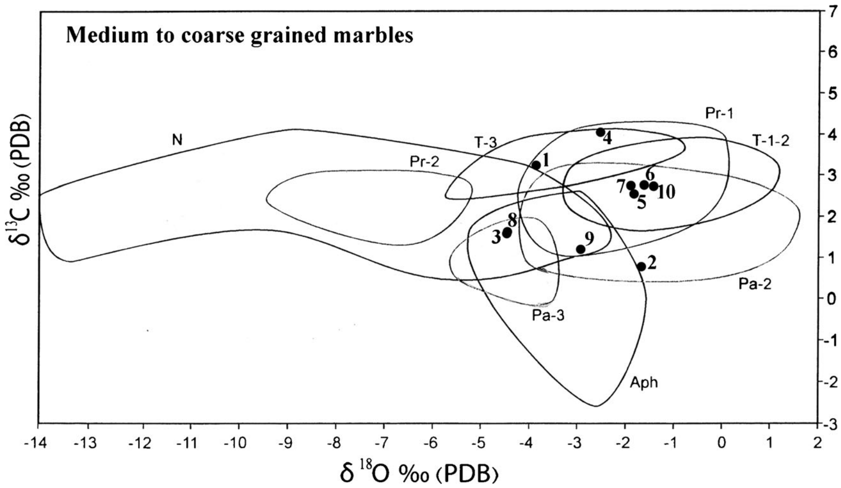

Fig. 5 White marble stable isotope data compared to fields of the major ancient quarries of medium to coarse-grained marbles: *N*=Naxos, *Aph*= Aphrodisias, *Pr*=Proconessos (1,2), *Pa*=Paros (2,3), *T*-(*1,2,3*)= Thassos-(1,2,3) (after Gorgoni et al. 2002)

fields. Sample 2 is located in the Paros-2 field but is also very close to the Aphrodisias and Proconessos-1 isotopic fields. Finally, samples 3 and 8 overlap with isotopic data from Paros-3, Naxos, and Aphrodisias and fall close to the Proconessos-1 isotopic field.

Petrographic examination shows that samples 1 to 4 and 6 to 9 are coarse grained (MGS ranges between 2.0 to 3.5 mm, Table 1), heteroblastic, and show a typical mortar fabric with mostly embayed to sutured boundaries. These characteristics are similar to the Proconessos-1 marble. In addition, sample 9 shows deformed polysynthetic twins, while samples 2, 3, and 8 have muscovite and show two different grain size distributions of the calcite crystals in the mortar fabric. In some areas, the larger crystals are small in size (about 1 mm) and sporadically dispersed in a very fine matrix, while in other areas, larger crystals (2–3 mm) are distributed in a fine matrix and alternate with areas of smaller crystals. De Nuccio et al. (2002: 298 and Fig. 5) observed similar features in the Proconessos-1 marbles from the Bellona Temple in Rome. In contrast, samples 5 and 10 (MGS ~2 mm) are homeoblastic and granoblastic in texture and the crystals have straight to curved boundaries. These petrographic features correspond well with the Paros-2 marble from the open-pit quarries of Lakkoi.

Both petrographic features and stable isotope data point to Proconessos-1 (Figs. 6a–c) and Paros-2 provenances (Fig. 6d) for the white marble samples. Although the isotope data for samples 2, 3, and 8 do not lie within the field assigned to Proconessos-1 marble in Gorgoni et al. 2002, they are very close to match this dataset and suggest that the data are consistent with Proconessos-1. We, therefore, conclude that there are two likely sources of white marble used in the construction of the Basilica. The majority of the samples originated from the Island of Marmara, Turkey, Proconessos-1. A smaller proportion came from Paros-2, Greece. These were probably marble spoils collected from earlier Roman structures at the site and reused in the Basilica.

Green marble

Macroscopically, the green marble samples are typical *marmor carystium* (*Cipollino Verde* in the old traditional Italian terminology). These samples correlate with the variety having plane-parallel schistosity created by green layers of phyllosilicates (Lazzarini 2007, p. 183–203). Petrographic examination of the samples showed typical lepidoblastic fabrics (Fig. 6e) with alternating calcitic and phyllosilicatic bands. The paragenesis is composed of the following major minerals: calcite >>quartz>plagioclase>muscovite/phengite>chlorite. The accessory minerals are epidote, apatite, sphene, graphite, and iron oxides. The primary petrographic characters of the minerals are as follows:

- Calcite occurs often in large crystals, with occasionally deformed polysynthetic twinning.
- Quartz occurs as single or polycrystalline grains with undulatory extinction. It is often associated with plagioclase.
- Plagioclase is albitic in composition and often twinned.
- Biotite and muscovite occur in needles and lamellae, with muscovite more abundant and often associated with phengite and chlorite.
- Chlorite is present either in needles or flakes. It occurs in both a colorless and a green pleochroic variety, both of which have low birefringence.

Based on comparison with the existing data on *cipollini verde* marble (Lazzarini 2007), both the macroscopic characteristics and the paragenesis of the samples confirm its identification as “*Cipollino Verde Euboico*” from Styra-Karystos on the island of Euboea, Greece. Styra-Karystos was a Roman imperial property which had more than 140 quarries (some very extensive). The region produced the most widespread type of *Cipollino* from the second century BC into the Middle Byzantine period. This important stone was distributed all

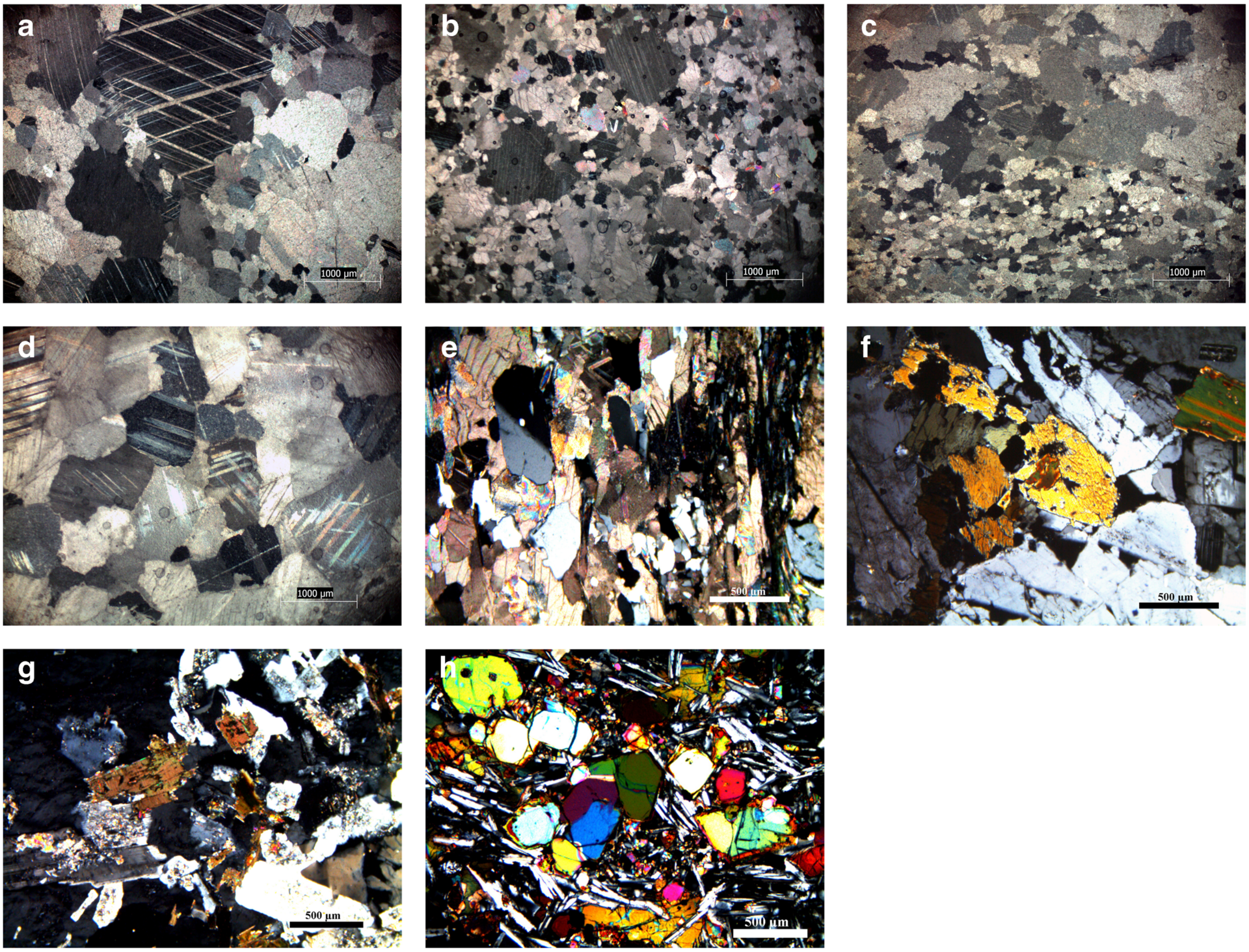

Fig. 6 Petrographic fabrics observed in Ablia building stone. **a** Sample 1—the typical mortar fabric of Proconessos-1 white marble. **b** Sample 2—less common fabric of Proconessos-1 marble, large crystals are 1-mm diameter dispersed in a fine 0.1-mm matrix. **c** Sample 3—another less common fabric of Proconessos-1 marble with fine and coarse-grained alternating bands. **d** Sample 5—granoblastic texture and straight to curved boundaries of Paros-2 marble. **e** Lepidoblastic fabric of the green (*Cipollino*) marble samples with alternating calcitic and phyllosilicatic bands. **f** Holocrystalline granular fabric of the Traodic (pink) granite samples. **g** Holocrystalline fabric of the Mysian (gray) granite samples, nearly equigranular and isotropic. **h** Doleritic fabric of the basalt samples, characterized by interstitial-intergranular and subophitic texture formed by very abundant phenocrysts of olivine in a plagioclase-rich groundmass

over the Mediterranean world and used for both columns and for *opera sectilia*, facing slabs installed on floors and walls.

In addition, the isotopic ratios of the two samples ($\delta^{13}C$ and $\delta^{18}O$) ($\delta^{13}C$=2.4 and 2.4 ‰ VPDB; $\delta^{18}O$=−3.1 and −2.2 ‰ VPDB) are consistent with source quarries of the western districts of Styra, Island of Euboea, Greece (Lazzarini 2007).

The pink granite

The samples clearly have macroscopic features typical of *Marmor Troadense* (*Granito Violetto*) (Fig. 7a), identifiable to the variety with coarse (2–3 cm across) pink K-feldspars. This was a well-known and important stone much used in antiquity for columns and pillars (Lazzarini 1987, 2004; Williams-Thorpe 2008).

The granite fabric is holocrystalline granular (Fig. 6f), slightly anisotropic due to weak iso-orientation of the K-feldspars and hornblende. The paragenesis is as follows: K-feldspar=plagioclase>>hornblende>biotite>quartz, with apatite, titanite, and iron oxides as accessory minerals.

The petrographic characters of the main minerals are as follows:

- K-feldspar shows only minor alteration. The grains have very limited areas of kaolinisation and often have mirmekitic edges.
- Plagioclase is unaltered, always twinned, and of oligoclasic composition.
- Hornblende crystals are unaltered and include abundant opaque minerals, mostly iron oxides. The grain size is

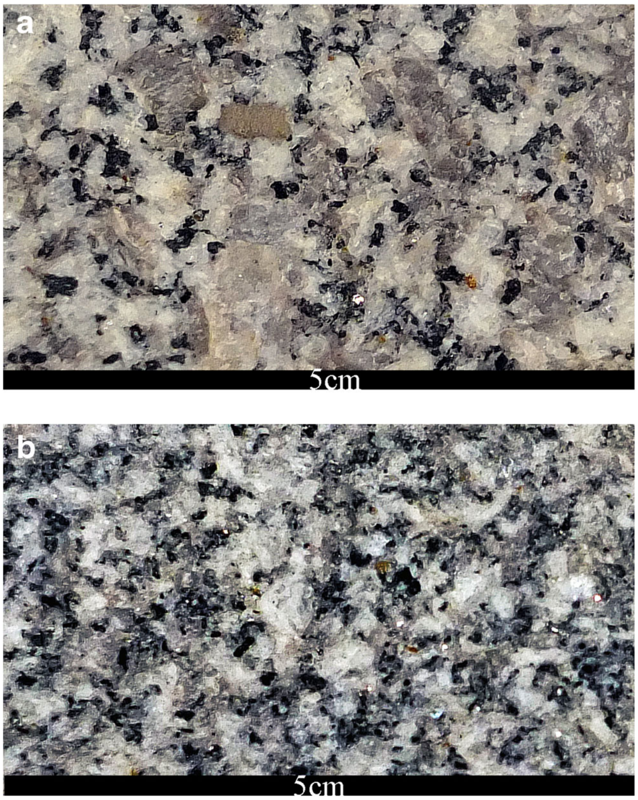

Fig. 7 Macroscopic characteristics of the granite columns: **a** *Marmor Troadense*, **b** *Marmor Mysium*

smaller than in samples taken from the main ancient quarries of Yedi Taşlar (see discussion below).
- Biotite is also unaltered, with abundant small inclusions of apatite.
- Quartz is anhedral and intragranular.

This granitoid stone may be classified as a typical quartz-monzonite (Lazzarini 1987; Birkle and Satir 1995).

The *Marmor Troadense* granite was the most important granite of Classical Antiquity as demonstrated by its very wide distribution (Lazzarini 2010) and use for columns and pillars. It was quarried from the lower slopes of the Çigri Dâg in the province of Ezine (Turkey). The main quarries are at Yedì Taslar (a Turkish name that may be translated as "the seven stones" after seven very large columns abandoned in the quarry). Quarried stone was shipped from the ancient harbor of Alexandria Troas (now Dalyan) to all the provinces of the Roman and Byzantine empires (Ponti 1995). Its use started locally in the Greek Archaic period, and Romans began to export it in the Hadrianic period.

The gray granite

Macroscopic features of these samples are very similar to those of the granite/granodiorite named *Marmor Mysium* by Lazzarini (1992, 1998) (Fig. 7b). The name derives from its quarry location in ancient Mysia (west Turkey), in accordance with the Roman practice of denominating stones with geographical names. The granites are gray in color, fine-to-medium grain size with characteristic, although rare, idioblastic black hornblende crystals (Lazzarini 1998; De Vecchi et al. 2000). Examination of thin sections showed that the fabric is holocrystalline, nearly equigranular, and isotropic (Fig. 6g) with a composition of a biotite-amphibole granodiorite: plagioclase>K-feldspar>quartz >>biotite>hornblende. Accessory minerals are iron oxides, apatite, zircon, allanite, and titanite. The petrographic characters of the major minerals are as follows:

- Plagioclase is euhedral, often twinned, always strongly saussuritized with formation of abundant sericite/muscovite.
- K-feldspar forms subhedral to anhedral somewhat kaolinized crystals, sometimes developing mirmekitic edges.
- Quartz grains are anhedral.
- Biotite is brown in color and frequently associated with hornblende.
- Hornblende occurs as rare euhedral prismatic pleochroic crystals with a deep green color.

Although the Mysian granodiorite, also used for pillars and columns, was contemporaneous with the Troadic granite, it occurs much less frequently and with a more limited distribution (Lazzarini 2004; Williams-Thorpe 2008).

The basalt

Macroscopically, this stone is black and rather porous. Microscopically, it shows a typical doleritic fabric characterized by interstitial-intergranular and subophitic texture (MacKenzie et al. 1982) formed by very abundant phenocrysts of olivine and much rarer calcic plagioclase in a porous groundmass (porosity visually estimated=30 %) (Fig. 6g).

- Olivine occurs in isodiametric, globular shapes; it is rarely idiomorphic. There are often brown alteration rims formed by serpentine and iron oxides.
- Plagioclase is unaltered and occurs as single and twinned crystals of bytownite composition.

The groundmass is formed by plagioclase microliths, always twinned albite-carlsbad, forming a tight net with olivine (in small crystals), and abundant opaque minerals (magnetite and ilmenite). Small areas of spathic calcite are also present as an alteration product.

Olivine basalts of this type outcrop in broad areas of northern Jordan and southern Syria (Shatsky et al. 1966; El-Akhal 2004).

Conclusions

These archaeometric analyses of the marbles and other stones used for building and decorating the Abila's Basilica indicate that both local basalts and imported marbles and granites were used. Imported stone came from the Aegean islands and western Asia Minor. The basalt was most likely sourced from nearby basalt flows outcropping in the northwestern part of Jordan or southwestern Syria. These basalt outcrops provided the stonemasons of the northwestern Jordanian cities of the Decapolis (such as Abila and Gadara) with very durable building stone. The architectural elements made of marble (friezes, chancel screens, capitals, floor slabs, and some column bases) primarily came from the island of Marmara, with some bases from open-pit quarries at Lakkoi on the island of Paros. The hetereogeneity and macroscopic variability of the marbles suggest some were *spolia* from older Roman monuments. The granite columns were originally quarried in Troas and Mysia, two ancient regions of present day northwestern Turkey and should also be viewed as *spolia* from earlier Roman monuments. These observations are in accord with other studies showing that Troad granite columns were often used with Proconessos Corinthian capitals, which indicates the use of standardized dimensions across a wide area (Rodá et al. 2012). Our provenance data for granites and marbles indicate that Proconessos in the Marmara Sea, Troas and Mysia (Turkey), and the Styra-Karystos on the island of Euboea, Greece, were important centers for the Roman stone trade.

This study sheds light on another aspect of Abila's prosperity. The presence of imported granite and marble architectural items in the city confirms the high socioeconomic status and extended trade networks employed by the city during the Roman and Byzantine periods. Our results show multiple sources of the imported stone used in the basilica, which could reflect the important role it played in this region. The city's proximity to the Mediterranean Sea and the high-quality regional road system allowed and probably encouraged the import of these stones from across the Mediterranean (Ward-Perkins 1992). These conclusions are in agreement with the results of Al-Bashaireh (2003, 2011) which showed that Proconessos white and *Cipollino Verde* marbles were the major sources of the marble used in the building of Gadara structures, a few kilometers west of Abila (Fig. 1).

This study adds important new information about the presence of imported marbles in the Decapolis region, an important region little studied in relation to the trade networks of antiquity. Although there is a good deal known about the trade in architectural marbles and their distribution throughout the ancient Middle East (Lazzarini 2009), and there are records of white marble and several polychrome stones in ancient Syrian and Palestinian cities (Dodge 1988; Wielgosz et al. 2002; Wielgosz and Degryse 2009; Fischer 1998), almost nothing is known about the building stone trade in Jordan. Even if the imported marbles and stones studied here were re-used materials, their presence implies an imperial trade route from important Greek and Microasiatic quarries to far eastern provinces of the empire, and a continued appreciation of prestigious lithotypes in the Decapolis from the Roman into the Byzantine periods. Because granites from Mysia and Troas were exported beginning in the Hadrianic age (Lazzarini 1987, 1998), it is likely that the original context of the columns in the Abila basilica was a Roman public building dating from the second century AD. It is also important to note the presence of *marmor troadense* in this distant location. It was by far the most widespread granite used by the Romans and this stone's distribution now spans an area from Spain (the columns at *Tarraco*, now Tarragona), to Jordan. Similarly, this paper extends the presence of the Mysian granite to a region hitherto not identified.

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