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Technology and Composition of the Mortar and Origin of the Stone and the Smalta Tesserae of the Early Christian Mosaics from Parthicopolis. The Beginning of Database on the Ancient Mosaics from Middle Strymon

Harcın Teknolojisi ve Bileşimi ile Taşın Kökeni ve Parthicopolis'teki Erken Hıristiyan Mozaiklerinin Smalta Tesserası. Orta Strymon'daki Antik Mozaiklere İlişkin Veri Tabanının Başlangıcı

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Abstract

The article presents the results of a study on the mortar and tesserae made of marble, sandstone, brick, and smalta in the mosaic pavement of the exonarthex of Basilica No. 2 in Parthicopolis. This basilica served as an important episcopal center in the province of Macedonia I. The methods employed include macro- and micro-analysis, as well as SEM-EDS and XRD analysis of the mineral phases.

It has been established that the mosaic was laid on a mortar layer without a statumen and rudus. The study of the mortar revealed the presence of a fine fraction among the tesserae, as well as lumps of lime in the mortar composition, which were reinforced with a fine brick powder. The brick and stone tesserae, including marble and sandstone, originated locally, while the smalta used for the glass tesserae was imported, possibly undergoing secondary processing on-site.

The analysis of the smalta composition identified several technological processes, including secondary heating, a significant presence of small air bubbles, and unwanted crystalline impurities. These phenomena likely occurred during the melting, molding, annealing, or secondary processing of sodium-lime-silicate glass. This suggests the possibility of imported manufactured production being remade in situ, demonstrating the utilization of local materials and techniques.

The study revealed that the mosaicists possessed a profound understanding of the craft, including a deep knowledge of the underlying processes and a diverse range of technical skills. With this expertise, they were able to successfully achieve the desired result by utilizing local materials.

Keywords: *Mosaics, mortar, tesserae, local production and import, provenance.*

Öz

Bu makale, Makedonya I eyaletinde önemli bir piskoposluk merkezi olan Parthicopolis'teki 2 numaralı bazilikanın ekzonarteksinin mozaik döşemesinin mermer, kumtaşı, tuğla ve smaltadan yapılmış harç ve tesseralarının incelenmesinden elde edilen sonuçları sunmaktadır. Uygulanan yöntemler makro ve mikro analizdir, ayrıca mineral fazların SEM-EDS ve XRD analizi yöntemleri de kullanılmıştır.

Mozaiğin, statümen ve rudus içermeyen harç tabakası üzerine döşendiği tespit edilmiştir. Harcın incelenmesi, tesseralar arasında ince bir fraksiyonu, harcın bileşimindeki kireç topaklarını ve ince bir tuğla tozu ile güçlendirildiğini ortaya koymaktadır. Mermer ve kumtaşından tuğla ve taş tesseralar yerel kökenlidir ve cam tesseralar için smalta, muhtemelen sahada ikincil işlemden geçirilerek ithal edilmiştir.

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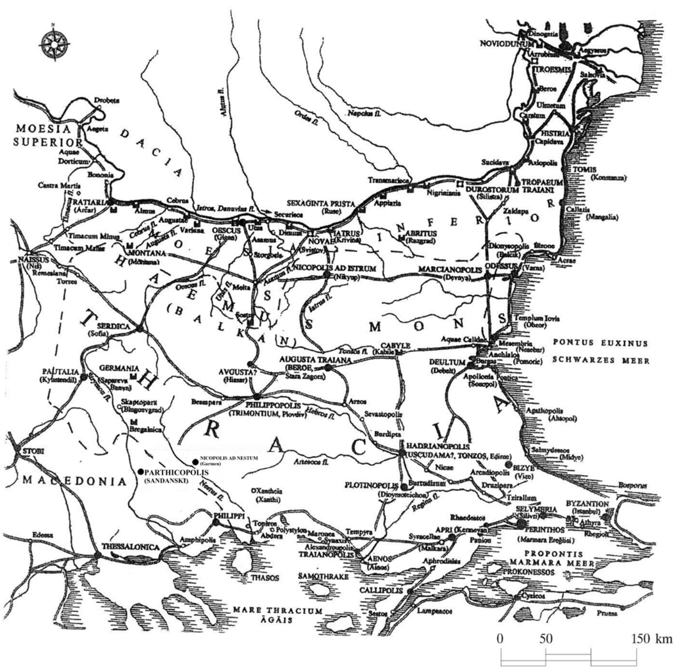
Smaltanın bileşiminde şu teknolojik süreçler tespit edilmiştir: ikincil ısıtma, büyük miktarda küçük balon, eritme, kalıplama, tavlama veya sodyum-kireç-silikat camın ikincil işlenmesi sırasında istenmeyen kristalin safsızlıklar. Bu durum, yerinde yeniden üretilen mamul üretimin ithal edilme olasılığını ortaya koymaktadır.

Çalışma, mozaikçiler hakkında, süreçlerin özü, yerel malzemeler kullanarak istenen sonucu elde etmeyi başardıkları zengin teknik beceri cephaneliği hakkında çok derin bir bilgi birikimi oluşturmuştur.

Anahtar Kelimeler: *Mozaikler, harç, tesseralar, yerel üretim ve ithalat, köken.*

Introduction

The renowned Episcopal center Parthicopolis, which is now known as the town of Sandanski, was a Roman and Early Byzantine city located in the northeastern region of the Roman province Macedonia I (Fig. 1). Among the structures discovered along the main city street, six Early Christian basilicas have been excavated. One of these basilicas, possibly referred to as basilica-memoria, is designated as No. 7 (Petrova 2016: 202). Additionally, three basilicas were identified as episcopal structures, namely No. 1, No. 2, and No. 3, while the fourth basilica served as the Cathedral (Fig. 2). Parthicopolis features two types of mosaics: pavement mosaics and wall mosaics, showcasing a variety of mosaic techniques. Wall mosaics were laid in the baptistery of Basilica No. 4 (Pillinger et al. 2016: taf. 287 abb. 708). Three of the basilicas (No. 2, No. 3, and No. 4) are adorned with pavement mosaics, as well as the Episcopal residence located between Basilica No. 1 and No. 2 (Popova 2007: 408-421; Pillinger et al. 2016: 371-375 taf. 307 abb. 751-752 (V.P.)), and the space in front of the *praefurnium* of Basilica No. 4. The most commonly employed technique is *opus tesselatum* for the pavement mosaics. However, in small areas with figural representations, *opus vermiculatum*, predominantly using smalta, is utilized. In the baptistery‘s piscina, a polychrome *opus sectile* is employed, while a finely detailed palette is found in the apse of Basilica No. 4 (Pillinger et al. 2016: 351 taf. 285 abb. 699, 700, 701 (B.A.)). A rare technique, not commonly found in Bulgaria, is present in the reception room of the Episcopal residence between Basilica No. 1 and No. 2 in Parthicopolis/Sandanski. This technique combines the three mentioned techniques along with a fourth, reminiscent of *opus sectile* but with irregularly



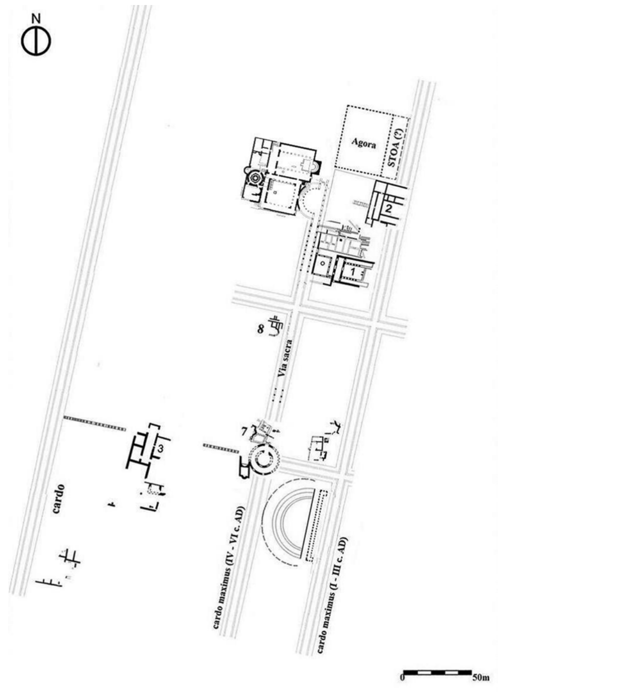


Figure 1
Map of the Roman provinces Lower Moesia, Thrace and part of Macedonia (after R. Ivanov, supplemented by S. Petrova)

Figure 2
The early Byzantine main street – *Via sacra*, the basilicas, the theater, the North round(?) piazza, the South Rotunda (Fountain/ Nimphaeum), the baths and the quarter of glass and pottery workshops – general plan of the discovered archeological structures (after S. Petrova).

shaped stone pieces (Pillinger et al. 2016: taf. 307 abb. 751). It is likely that this technique was influenced by the mosaic workshops in Macedonia and Thessalia and spread to the region of Parthicopolis.

Basilica No. 2 is preserved only in its western part (Fig. 3) because its eastern section, including the chancel and the apse, is situated just under the main street of the contemporary town (Ivanov et al. 1969: 109-205). This basilica was erected at the end of the second quarter to the middle of the 5th century. It is three-aisled, following the Hellenistic architectural style. Similar to all the basilicas of Parthicopolis, it likely had only one half-round apse on the east. Two mosaic panels are preserved in the naos: both feature geometric compositions and small plant elements (Fig. 4). In the eastern panel, there are representations of octagons with fishes and birds (Fig. 5).

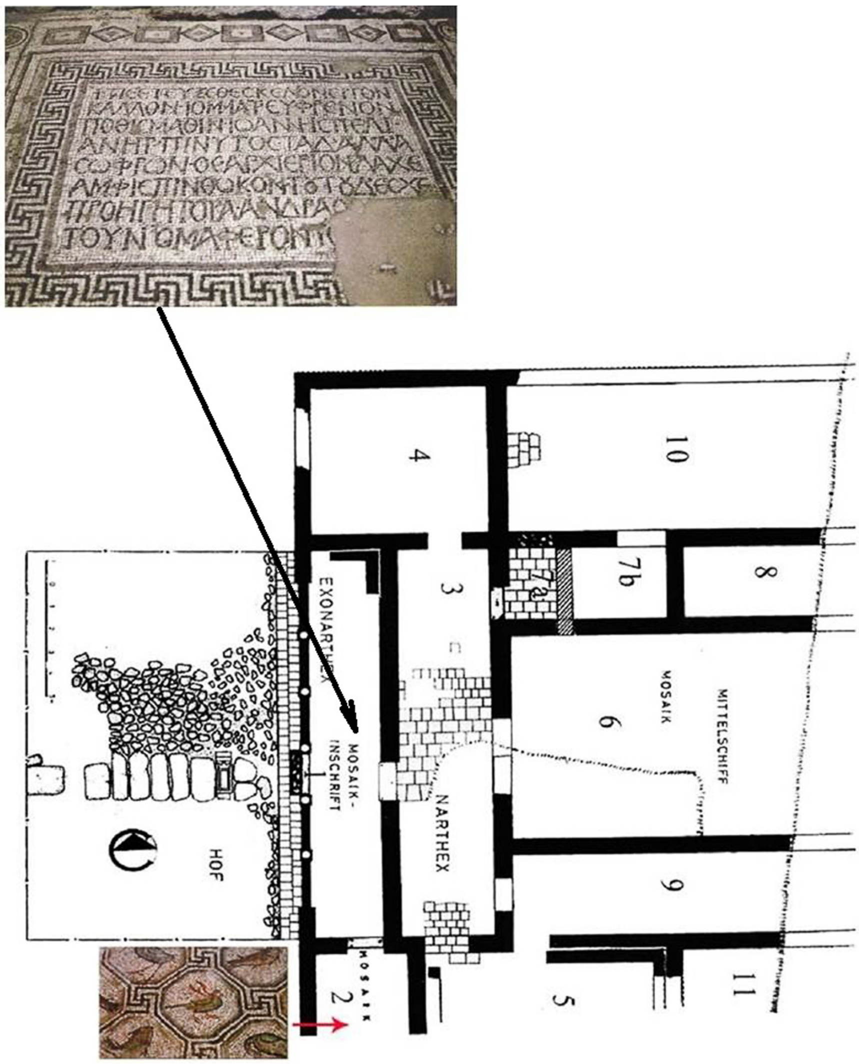


Figure 3
Plan of basilica No 2 (after R. Pillinger 2006: abb. 6) with mosaic inscription.

Figure 4
The mosaic in the middle nave of the basilica 2, western panel (photo by S. Petrova).

Figure 5
The mosaic in the middle nave of the basilica 2, eastern panel (photo by S. Petrova)

The floor of the exonarthex is adorned with several mosaic panels featuring geometric compositions, along with a central panel displaying a mosaic building inscription of Bishop Ioannes (Figs. 6-6a). Together, these panels create a large mosaic carpet-like design. The inscription reveals that Bishop Ioannes inherited the hierarchical position from the previous unnamed bishop and also embellished this magnificent structure. Furthermore, the floor of room 2, located to the south of the exonarthex and identified as a transitional space between the basilica and the nearby discovered baptisterium adjacent to the Episcopal residence, is adorned with exquisite depictions of birds and fishes arranged within octagons (Figs. 7-7a) (Petrova - Petkov 2015: 414-424).

Figure 6
Part of the mosaic floor in exonarthex (photo by V. Vasilev, Archaeological Museum Sandanski).

Figure 6a
Mosaic inscription in the exonarthex (photo by V. Vasilev, Archaeological Museum Sandanski).

Figure 7
The mosaic floor in room 2 (photo by S. Petrova).

Figure 7a
Detail, northeast corner (photo by V. Vasilev, AM Sandanski).

The floors of the exonarthex and the naos are covered with mosaics, which were laid on a thin mortar layer directly over the debris of the previous Roman building. Technologically, various layers can be identified, including the *statumen, rudus, nucleus, bedding layer*, and *tessellatum*. However, the *statumen* and *rudus* layers are missing. It is likely that these layers were omitted considering the presence of the massive representative building from the Roman period that previously occupied the site. The destructions in this area have been utilized in place of the *statumen* and *rudus* layers.

Methodology

The research primarily concentrates on examining the composition and technology of the mortar, as well as determining the origin of the tesserae used in the mosaic panel from the exonarthex of the basilica. This investigation serves as a foundation for a comprehensive study of the mortar and mosaic tesserae employed in the mosaics discovered in Parthicopolis. The project's objective is to establish a database encompassing information on the mortar composition, as well as the types of stone utilized and their respective origins[1].

All microscope observations were conducted using the polarization microscope Amplival Pol D with the ProgRes CT3 camera from Jenoptic, Germany. XRD analysis of the mineral phases was performed using the TUR M 62 diffractometer from Germany. The diffractometer features a standard two-circle goniometer in Bragg-Brentano geometry, along with a secondary graphite monochromator. CuKα radiation (λ=0.15418 nm) was employed for the analysis. The measurement conditions included a tube voltage of 32 kV, a tube current of 15 mA, a step scan mode with a step size of 0.02° 2Θ, and a counting time of 2 seconds per step. Scanning electron microscope (SEM) analyses were carried out using the JEOL JSM 35 CF upgrade DISS 5 microscope equipped with a Rhoentgen microanalyzer from SAMx. The energy-dispersive X-ray spectroscopy (EDS) method was employed for the SEM analysis.

Figure 8
Mosaic piece with mortar and black and white tesserae, exonarthex of basilica No 2 (photo by S. Petrova).

Discussion and Results

The study of the mortar and tesserae from the exonarthex of Basilica No. 2 in Parthicopolis/Sandanski was conducted by a team of geologists and chemists led by Mrs. Denka Yanakieva from the Earth and Man National Museum in Sofia.

The mosaic carpet in the exonarthex comprises multiple panels featuring geometric compositions. These compositions are constructed using stone tesserae in white, brown-grey, and black colors, along with smalta tesserae in various shades of green. Additionally, brick tesserae are also incorporated into the mosaic design (Figs. 6-8, 8a-c). The mortar used in this area is mixed with brick particles.

The macroscopic characterization of the mortar[2] in the sample M-1(S B-2 en)[3] eveals its presence in several positions within the mosaic. The mortar is found in the gaps among the tesserae, serving as a supporting layer for the tesserae, and forming the base of the tesserae. It is evident that the mortar used in these different positions is the same, but the upper layer of the mortar is noticeably finer in texture (Fig. 8a-c).

Figure 8a-c
Macroscopic photographs of sample M-1 (S B-2 en): a) surface and transverse profile of the mosaic-mortar layer; b) cross profile of the mosaic-mortar layer; c) longitudinal section of the mortar layer (photo by D. Yanakieva).

The sample M-1 (S B-2 en) is a composite building material composed of mortar with a carbonate matrix. It contains an added material, primarily consisting of sand and crushed bricks. Additionally, an artificial pozzolanic component is present in the form of a finely ground fraction of the same bricks. This pozzolanic component acts as an inert material within the mixture.

1 We have already started with the study of the mosaic tesserae from the exonarthex of Basilica 2. See: Petrova 2022: 397-412.

2 The represented for study sample is a mosaic fragment from the exonarthex of basilica 2, i. e. the original aggregate of white s.T-5 (S B-2 en) and black s.T-6 (S B-2 en) tesserae and mortar, in which the tesserae have been laid.

3 M = Mortar sample, T= Tessera sample. (S B-2 en), where S = Sandanski, B-2 = Basilica No 2, en = exonarthex.

During the preparation of the sample for analysis, when dividing the mosaic fragment along the layer of mortar, a separation occurs at a depth of approximately 0.6 to 0.7 cm below the level of the tesserae. The mortar itself appears pale pink in color, exhibiting a uniform and dense texture. Upon closer examination with a magnifying binocular glass, the mortar material is observed to be fine-grained, homogeneous, and exhibits fine cohesion. It contains small-sized heterogeneous clastic pieces, both well-rounded and less well-rounded. The distribution of brick particles within the mortar is uneven throughout the volume, with most particles being less than 1 mm in size. There are also occasional larger brick pieces ranging from 2 to 5 mm, irregularly dispersed within the volume. Notably, numerous accumulations (lumps) of lime matrix can be observed, varying in size from 0.5 to 10 mm (Figs. 9, 10, 11). The material, or the mortar, consists of lime solder as the matrix along with added materials such as sand and brick fragments, with approximate proportions of 30-40% lime solder to 60-70% added materials.

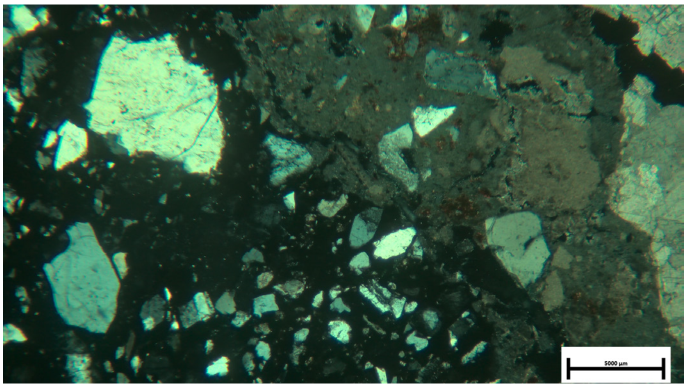


Figure 9
Photomicrographs of sample T-1(S B-2 en)-(dune grind 1 - mortar between the tesserae - the joints); the joint is between tessera sandstone - on the left and tessera marble - on the right - in the red-brown matrix rare grains of sand - crossed polars (photo by D. Yanakieva).

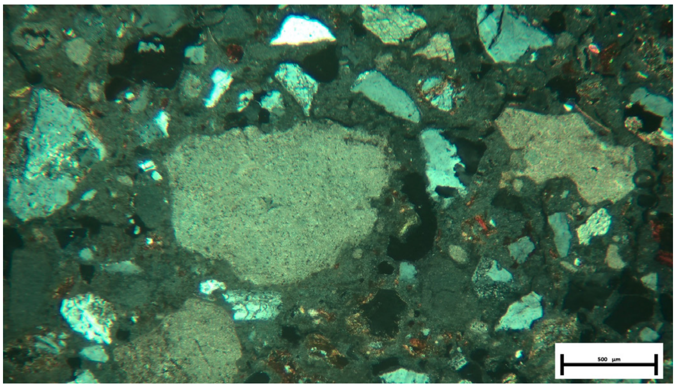


Figure 10
Photomicrographs of sample M-1(S B-2 en)- (dune grind 2- mortar under the tesserae, upper level); cryptocrystalline matrix, sand grains, large lime lumps, pore-cross polars (photo by D. Yanakieva).

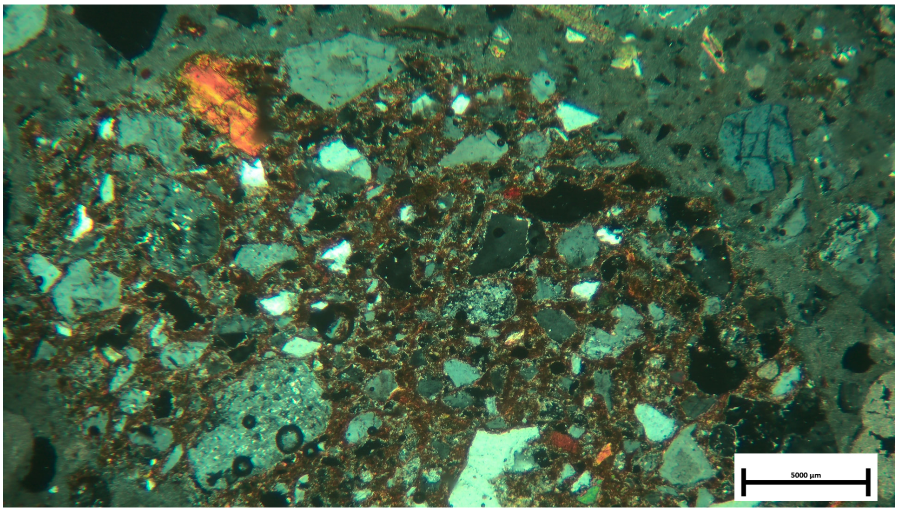


Figure 11
Photomicrographs of sample M-1(S B-2 en) - (dune grind 3 - mortar lower level); large brick fragment - crossed polars (photo by D. Yanakieva).

The lime solder: From the microscopic observation[4] it is seen that the lime solder is with irregular graininess. Its characteristic peculiarity is the presence of oval carbonate grains, resembling small-grained lime; however its structure is homogeneous and evenly grained for the latter. It can be presumed that these are aggregates connected with the lime, for instance the so-called lumps of lime, which represent incompletely calcined lime. The color of the solder is attributed to the presence of iron oxides and hydroxides.

Sand: Its sizes are from middle to small-grained. The separate grains can reach up to 3mm – fine-grained gravel. The form is mainly irregular, rounded and rarely

4 Three dune slides were made for microscopic study of the individual levels.

angular. The composition of the crystals is quartz, albite, orthoclase (feldspars), biotite and muscovite (mica). Single amphibole and epidote.

Bricks: The fragments observed are primarily fine and crypto-grained, with individual grains measuring up to 5 mm in size. These grains consist of a sand fraction that appears finer and more angular compared to the sand present in the mortar. Additionally, there is a clay solder component characterized by its red color, attributed to the presence of iron oxide-hydroxides.

Pores: Its distribution in the microscopic matrix is quite uneven. Its form and dimensions are varying (maximum dimension 3-4 mm). It can be also observed and found irregular set-like micro-cracks.

The X-ray diffraction analysis (XRD-analysis – qualitative phase analysis) reveals the presence of calcite, quartz, orthoclase, albite (feldspars), biotite (mica) and hematite (Fig. 12). Clay minerals are not registered[5]. It has been read amorphous phase expressed as a slight halo approximately to the 20-30° 2Θ. This allows the assumption that the reason of the appearance of halo is the sequence of the vitrification of the clayish minerals during the brick firing. The X-ray Fluorescence analysis (XRF), the silicate analysis reveals the presence of different quantity of oxides, with prevailing content of SiO_2 (Table 1).

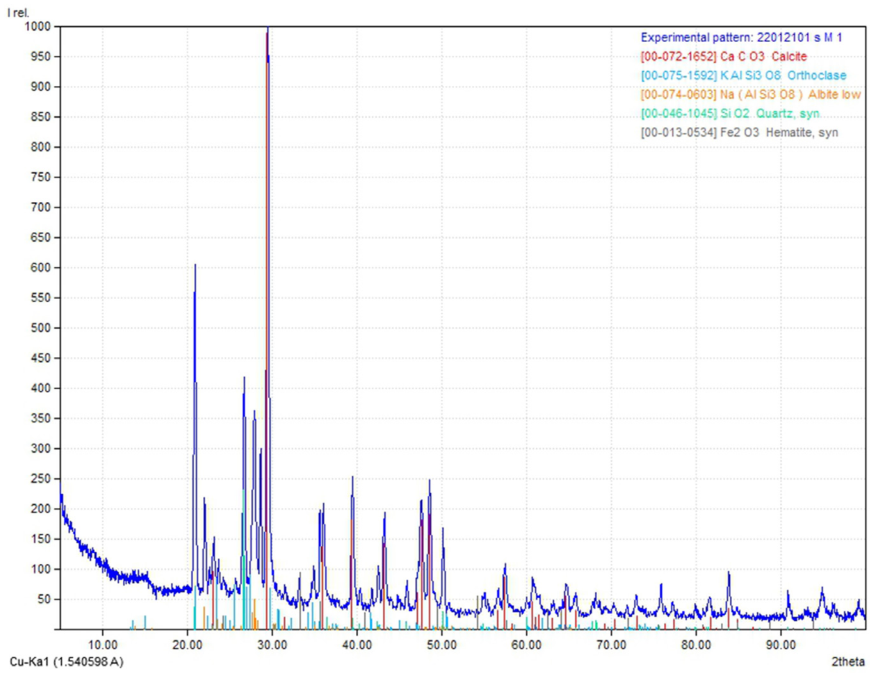


Figure 12
XRD pattern of s. M-1(S B-2 en) with phase analysis.

Table 1
Quantity – chemical XRF analysis.

Oxides	T1
Na_2O	2.31
MgO	2.22
Al_2O_3	10.49
SiO_2	43.53
P_2O_5	0.54
K_2O	2.14
CaO	33.17
TiO_2	0.53
MnO	0.06
Fe_2O_3	4.62

5 It can be supposed two reasons for that. The first one: the sand component is well washed. The second one: the 'bricks' have been fired at the temperature >8000C.

The general carbonation and the insoluble residuum after the study are in rate 47.25% : 52.75%, i.e. carbonate part : insoluble residuum = 1:1.12[6]. The grain-size composition was determined using screen analysis and laser diffraction techniques, and the results are presented in Tables 2, 3, and 4.

Table 2
Distribution by the classes of the screen analysis in %

Class (mm)	Yield	
	Weight (g)	Distribution (%)
>3.15	0.14	0.58
2.00-1.00	0.49	2.03
1.00-0.500	2.61	10.80
0.500-0.125	15.93	65.91
0.125-0.075	2.69	11.13
<0.075	2.31	9.56
Σ	24.17	100.00

Table 3
Results of the analysis of class <0.075mm for determination of the dimensions of the bits by laser diffraction. Distribution of the bits, expressed in cumulative %.

Dimensions of the bits (μm)	Content (%)	Dimensions of the bits, (μm)	Content (%)
< 0.1	0.0	< 9.0	20.5
< 0.5	1.0	< 9.5	22.4
< 1.0	2.6	< 10.0	24.9
< 1.5	3.8	< 11.0	30.7
< 2.0	5.9	< 12.0	38.2
< 2.5	8.3	< 13.0	46.1
< 3.0	10.7	< 14.0	54.3
< 3.5	12.6	< 15.0	62.0
< 4.0	14.0	< 16.0	69.3
< 4.5	15.0	< 17.0	75.4
< 5.0	15.6	< 18.0	81.2
< 5.5	15.9	< 19.0	85.3
< 6.0	16.1	< 20.0	89.3
< 6.5	16.2	< 25.0	97.5
< 7.0	16.5	< 30.0	99.2
< 7.5	16.9	< 35.0	99.6
< 8.0	17.8	< 40.0	99.9
< 8.5	18.7	< 45.0	100.0

Table 4
Distribution of the bits – predominantly.

Content, total %	Up to 10 %	Up to 50 %	Up to 90 %
Dimension of the bits, μm	2.8	13.5	20.2

The information got from the applied analytic procedures, at this stage of the studied material, allows formulating the following conclusions on the mortar padding from the exonarthex of basilica 2.

The mortar fragment is laid with white and black tesserae, sunken in the mortar matrix. The tesserae are rudely prepared, with irregular form, however pretending to be close to a regular geometric form, and different in its size. In the

6 The test was carried out on a shed 10.438 g. The sample is digested in 10% HCl. The insoluble residuum – 5.506 g. The calculation is done according the formula: HO=a/в.100%, where 'a' is the insoluble residuum in grams, 'b' is starting mass in grams (CP = carbonate part; IR = insoluble residuum). CP = 100-IR in %. IR=5.506/10.438.100% = 52.749%

CP= 100-52.749 = 47.251%

cross-piece profiles are seen the fillings of the gaps with visibly the same mortar as it is in all the layer. The tesserae have been laid not contact. The gaps among them are wide.

Special attention has been given to the study of the mortar in different positions, including the mortar found among the tesserae and the mortar serving as a base. The findings of the study indicate that the mortar is consistent and uniform throughout, with only a slightly higher concentration of lime solder observed in the gaps. Interestingly, in the area where a separation is observed between the padding layer and the base layer, the composition of the mortar remains the same[7].

The sample M-1(S B-2 en) represents a compositional building material, mortar, with a carbonate matrix, added material, consisting mainly of sand, crushed bricks and artificial pozzolanic component (fine ground fraction of the same bricks which are taking part as inert added material).

The calcite solder is mainly crypto-crystal, with separate clear crystal parts. But even with them, the maximum dimensions of the calcite grains are of the order of 4 – 6 μm. The solder is colored in pink as a result of a fine ground brick material up to amorphous state in significant quantity.

The artificial '*pozzolanic*' component which in the studied material is as a fraction with dimensions <75 μm in quality 9.56% from the insoluble residuum. The grain-metric laser diffraction gives an account of 100 volume % for the dimensions from 0.1 up to 45 μm.

Inert added materials:

- *Sand-like component.* Dominating is the sand, middle-grained up to small-grained (fraction 0.500 mm – 0.125 mm – 65.91%) with mineral composition of quartz, plagioclase, potassium feldspar and mica (muscovite, biotite).

- *The brick fragments* are small (more often 0.25 mm, in single cases max up to 3 mm); its form is mainly rounded. They are made of sand fraction with the same composition as of the sand, however usually with finer crystal clasts and clay solder with red color.

The correlations of the carbonate solder and supplementary materials obtained from different analyses exhibit varying ratios: 30-40%:60-70% in the petrographic analysis, 45%:55% in the XRD analysis, and 1:1.12 in the analysis of OK:HO. These variations can be attributed to the non-homogeneity of the material and the presence of large lumps of lime. Given the absence of carbonate crystal-clasts and considering the overall composition, the petrographic analysis correlation of approximately 1:2 is the most reasonable. In this correlation, the artificial pozzolanic component accounts for approximately 0.5 of the insoluble residuum. These dependencies align with the characteristics of such materials described in Vitruvius' treaty (Vitr. II. 4, 3; 5, 1), with a slight excess of the carbonate component.

The analysis of the carbonate component provides evidence to suggest that a highly pure raw material was used during the firing process to prepare the lime. The resulting CaO was then treated with a limited amount of water, as indicated by the presence of numerous detached lumps of lime. The studies

7 It is possible that the reason is technological because of the difference time of laying the different layers.

indicate that the role of the pozzolanic component was fulfilled by a finely powdered fraction of the same bricks used as inert added material. This fraction is highly dispersed and has undergone partial amorphization. Despite conducting combined microscope, XRD, and SEM-EDS studies, no products of hydraulic reactions such as calcium silicate hydrates and calcium aluminate hydrates were discovered. It can be inferred that the hydraulic properties are attributed to the presence of the brick fragments themselves.

Figure 13
Tesserae from glazed glass (smalta), marble, brick and sandstone.

The notable characteristic of the studied material is the absence of reactive zones around the fragments of the added material, such as sand and bricks. This suggests that the larger-sized fractions of sand and bricks were utilized solely as inert materials, serving as fillers and for enhancing certain properties. The specially prepared artificial pozzolanic component, composed of brick dust, is responsible for facilitating the hydraulic reactions in the material.

The results of the study of the origin of the three types of tesserae from the exonarthex mosaic of stone, glass and brick (Fig. 13) based on macro- and microscope characteristics, X-ray analysis, elemental analysis and fluorescent analysis are as follows: The studied samples of white-stone tesserae reveal the presence of two different kinds of structure of marble. The macroscopic characteristics of s. T-4 (S B-2 en) shows a clear-grained white rock with massive texture of the stone and grano-blastic structure (Fig. 14). The minerals forming the rock are dolomite and calcite with mixture of muscovite (mica). The provenance of the material is determined and snow-like-white, with mixture of mica impurities, small-grained to middle-grained, dolomite-calcite marble, extracted in the deposit Ermilovets of the 'Quarries of Trajan' at the today's village of Ilindentsi[8].

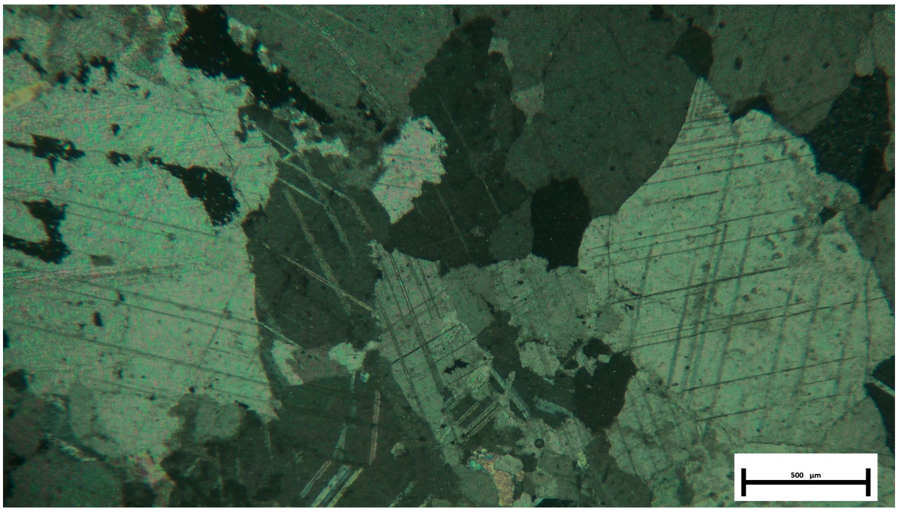
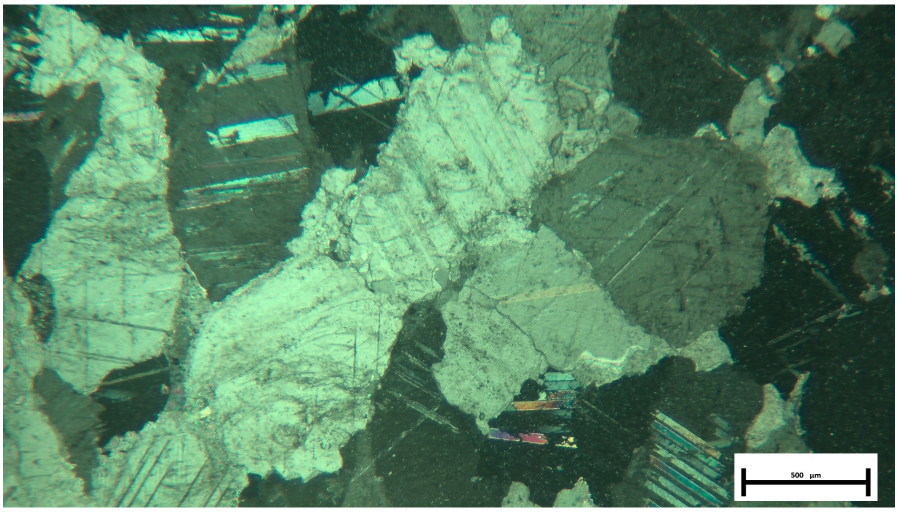


Figure 14
Photomicrographs of sample T-4(S B-2 en). Different sizes of the crystaloclasts – cross polars (photo by D. Yanakieva).

The second stone sample – T-5(S B-2 en) of white tesserae shows that dolomite and quartzite are the main rock-forming minerals (Fig. 15). The microscopic characteristics of the white-stone tesserae reveal that the rock used to make them is composed of dolomite-quartzite. The dimensions of the dolomite-quartzite grains range from 0.1 to 0.5 mm. This composition and grain size distribution give the rock a hetero-blastic structure. The analysis shows the material as snow-like-white, middle-grained, dolomite-quartzite marble. The marble of these tesserae corresponds to the one established in the deposit Guingera-Galchovo

8 Detailed data from the study of tesserae – marbles, sandstone, brick and glasses, see Petrova 2022: 397-412.

Figure 15
Photomicrographs of sample T-5(S B-2 en). Different sizes of the crystaloclasts – cross polars (photo by D. Yanakieva).

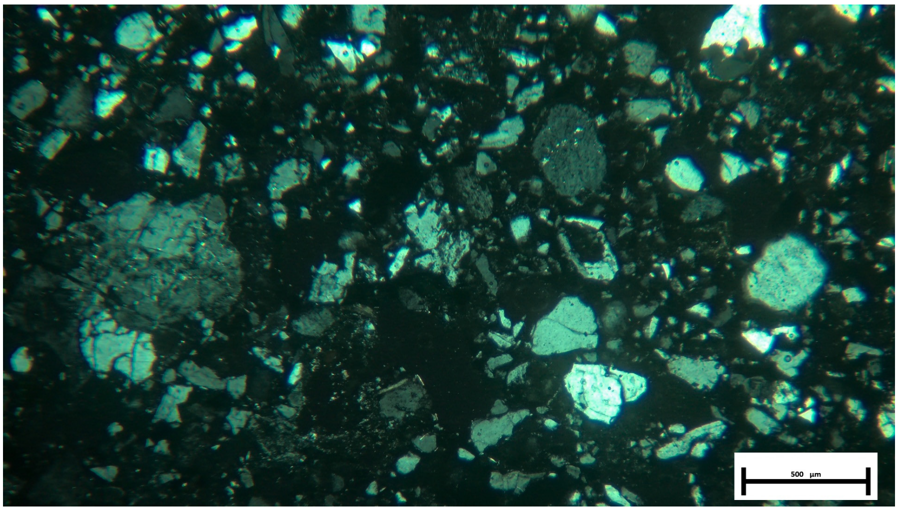


gnezdo of the 'Marble quarries of Trajan', near the village of Ilindenci. The analysis of the marble tesserae reveals the presence of calcite and dolomite marbles.

The marbles from the different sections of the Ilindentsi deposit have undergone thorough geological studies, which have included investigations of their decorativeness using macroscopic and microscopic analyses, X-ray diffraction for mineral composition, and chemical analysis of the main elements such as calcium (Ca) and magnesium (Mg). These studies have revealed the presence of various types of marbles in the Ilindentsi deposit, including calcite, dolomite-calcite, calcite-dolomite, dolomite, quartz-dolomite-calcite, quartz-calcite-dolomite, silicate-dolomite-calcite, and silicate-calcite-dolomite marbles. Among these types, dolomite marbles are the predominant variety in the deposit (Petrov 1982: 139-147; Petrov 1994: 23).

The microscope analysis of the tesserae, designated as s. T-6 (S B-2 en), reveals its black (brown-grey-red) color. Macroscopically, it is identified as sandstone (Fig. 16). The main components of the sand fraction include plagioclase, potassium feldspar, quartz, and mica. The joint, which exhibits a black-brown-red color, is likely due to the presence of iron and manganese oxide-hydroxides. X-ray analysis further confirms the presence of albite and orthoclase (feldspars), quartz, biotite (micas), and goethite / limonite. The stone can be classified as black-brown sandstone with an iron solder component.

Figure 16
Photomicrograph of sample T-6(S B-2 en); variegated, mostly fine-grained, rounded clastic component, dominant (90-95%), black-brown solder (5-10%), perfectly round and irregular pores - cross polars (photo by D. Yanakieva).



The brick tesserae, the second type studied from the exonarthex of the basilica, exhibit a dense brick-red color macroscopically. Microscopically, the sample is composed of a sand fraction and a clay joint with a red color, attributed to the presence of iron oxide-hydroxides. The tesserae have a sandy texture throughout the volume.

The macroscopic characteristic of sample T-1(S B-2 en) reveals a light green tessera with a glass to pearl glitter and a sub-conchoidal fracture that results in an uneven surface. The cube exhibits varying degrees of transparency, ranging from non-transparent to half-transparent in thin sections. The coloring on the horizontal surface of the cube is predominantly uneven, ranging from pale green to a white basic mass with scattered dark-green points and small spots. Numerous glass bubbles can be observed throughout the volume of the tessera (Fig.17). Under the microscope, certain crystal phases become apparent.

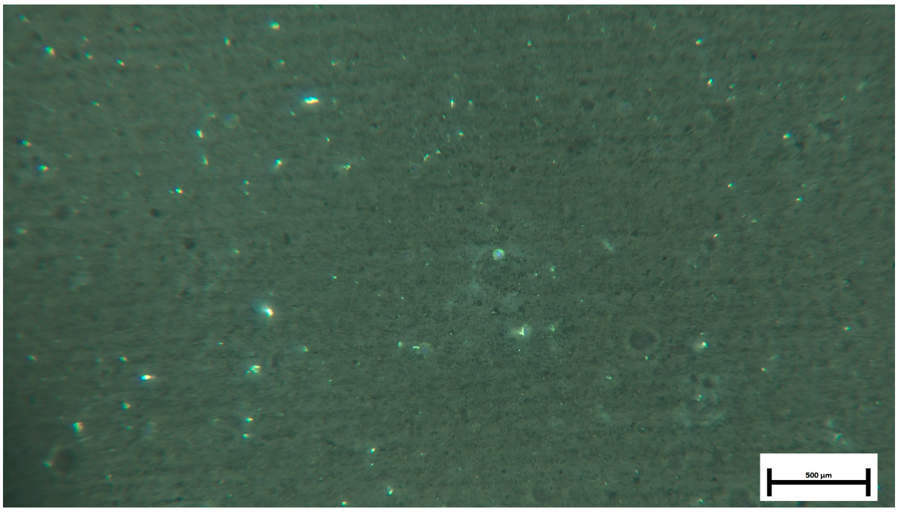


Figure 17
Photomicrograph of sample T-1(S B-2 en); amorphous phase with many bubbles and fine crystalline phases - crossed polars (photo by D. Yanakieva).

The microscope analysis of the sample shows the presence of an amorphous phase with abundant bubbles. The X-ray diffraction (XRD) diffractogram confirms the strongly expressed amorphous halo, but also indicates the presence of crystal phases. Further phase quality analyses identified the presence of devitrite, tridymite, and wollastonite (Fig. 18) within the sample.

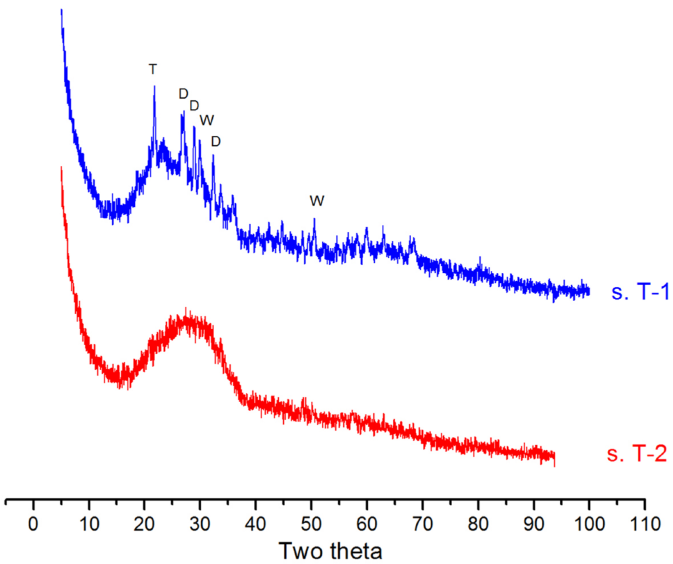


Figure 18
Aggregate graphics from XRD- tesserae analysis s. T-1(S B-2 en) и s.T-2(S B-2 en). Phase designations: D - devitrite, T - tridymite, W - wollastonite.

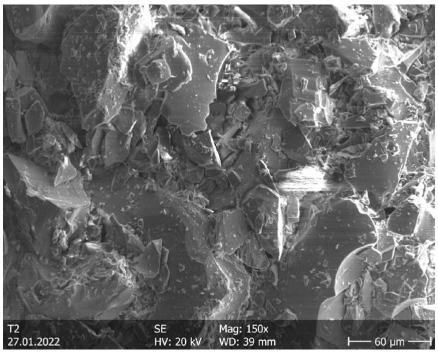
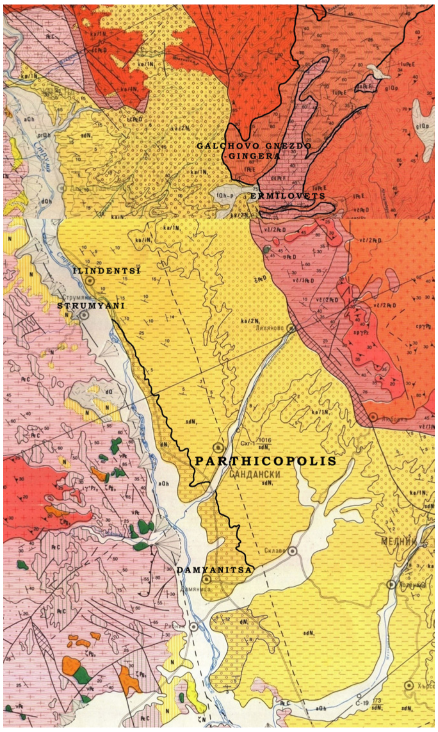


Figure 19
SEM/BSE photograph of grinded sample T-2(S B-2 en).

The second group of glass tesserae is characterized by a yellowish-green color, displaying a glassy appearance with a resinous shine and a smooth, curved surface. The tesserae are non-transparent and exhibit a homogeneous coloration throughout. Microscopic analysis of the sample confirms the presence of an amorphous phase, accompanied by the occurrence of bubbles (Fig. 19). The diffraction pattern obtained from X-ray analysis clearly exhibits a strong halo, which is a characteristic feature of the amorphous phase (Fig. 18).

The physical properties, behavior during analysis, and XRD data provide conclusive evidence that the tesserae are made of glass. The chemical composition and elemental correlations indicate that tesserae s.T-1(S B-2 en) and s.T-2(S B-2 en) can be attributed to Roman glasses, which were produced using natural sodium sources such as natron or trona (Na3H(CO3)2.2H2O) (Jackson 2005: 764-766; Rehren - Cholakova 2010: 81-96; Devulder - Degryse 2014: 89-91). The presence of chemical differences, particularly related to iron, can indicate variations in the raw materials used for producing the glass tesserae or intentional additions to achieve specific colors. Manganese is likely added for coloring purposes, while lead may contribute to both the color and non-transparency of the glass. The structure of the glass material differs between the two types of tesserae. While both types are amorphous, the first sample also contains crystal phases such as devitrite, tridymite, and wollastonite. These differences in composition and structure contribute to the unique properties and appearance of each type of glass tessera. These crystals are undesired impurities during the process of melting, forming, heating, and secondary work of Roman (window) glass (Georgieva et al. 2003: 143-146; Zlateva - Kuleff 2015: 53-68). Here, however, the non-transparency and presence of crystal phases are intentionally achieved through specific thermal conditions. When producing glass, a deliberate choice is made to apply different technologies for s.T-1(S B-2 en) and s.T-2(S B-2 en), likely involving variations in the cooling process.

Figure 20
Geological map: Dobrostan marble suite; Delchev suite – sandstone (by S. Petrova).



The research established that the stone tesserae from the mosaic panels in the exonarthex have a local provenance – from local marble and sandstone. Both samples s.T-4(S B-2 en) and s.T-5(S B-2 en) represent the dolomite-calcite marbles with a strong predominance of the dolomite[9]. The half- quantitative XRD analysis reveals 97.6% dolomite and 2.4% for s.T-4(S B-2 en) and 73.3% dolomite and 26.7% for s.T-5(S B-2 en). However, the EDS elemental analysis shows equal content as a fraction of 19.57% Mg и 47.88% Ca for s.T-4(S B-2 en) and 19.79% Mg и 47.55% Ca за s.T-5(S B-2 en). The differences in the marbles from the tesserae of the two samples are primarily in the dimensionality of the crystalloclasts and in the presence of accessory minerals: presence of muscovite mica from middle- to large-grained in s.T-4(S B-2 en), and of middle-grained dolomite-calcite marble, without accessories, for s.T-5(S B-2 en). The quarries from which the marble is extracted are at the distance of approximately 12 Roman miles far from Parthicopolis, in the foothills of the mountain Pirin (Fig. 20). The black sandstone T6(S B-2 en) is extracted from a deposit also near Parthicopolis, on the left bank of the Struma River (south of Strumyani up to south of Damyanitsa). Generally, the length of the deposit is about 11 Roman miles.

9 B. Petrov distinguishes eight different types of marble only in the quarry of Ilindentsi. See Petrov 1994: 22.

Conclusion

During the Early Christian period, Parthicopolis was home to a significant number of craftsmen, including those involved in the production of opaque glass. Archaeological excavations have revealed the presence of a furnace used for melting and molding glass in the city. In addition to the local glass production, Parthicopolis also received glass “cakes” and pre-made glass pieces with trade items from other regions. These items were likely brought by sea and were produced by skilled artisans in the Eastern provinces. Furthermore, Parthicopolis had connections with Thessalonica, a renowned artistic and commercial center in northern Greece and Macedonia, where glassware and other art forms were produced and traded. These exchanges of glass materials and products contributed to the artistic and economic vibrancy of Parthicopolis during that period (Popova 2017: 267-284 pls. III 1-4, IV 1-4, V 1-10). Mosaic tesserae could be made in situ or sold at a commercial site. In either case, at least two final stages of glass tesserae preparation can be identified in Parthicopolis: cutting the tesserae from the manufactured ‘cakes’ and polishing the necessary surfaces.

This research proves for the first time the origin of the source rock material for the mortar and for the tesserae in the mosaic carpet of the exonarthex of Basilica 2. The analysis of the mortar fragment and mosaic tesserae reveals the advanced knowledge and technical expertise of the ancient technologists who utilized locally available raw materials to achieve the desired results. We hope that further investigation of samples from the basilica of bishop Ioannes, as well as other mosaics in Parthicopolis, will enhance our understanding of the provenance and techniques employed in the production of mortar and mosaic tesserae in the Roman and Early Byzantine city.

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