

ANALYTICAL CHARACTERIZATION OF AN OTTOMAN OPUS SECTILE MOSAIC FLOOR FROM THE DELTA REGION, EGYPT

OTTOMÁN OPUS SECTILE MOZAIKPADLÓ ANALITIKAI VIZSGÁLATA AZ EGYIPTOMI DELTAVIDÉKRŐL*

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Abstract

This study reports a recent analytical study of the main components of an opus sectile mosaic floor from an Ottoman bath (hammam) in the delta region of Egypt, that dates back to 1748 CE. Samples of the decorative elements of the mosaic floor including white stone, pottery mosaic pieces, black stone and setting bed mortar from the mosaic substrate were collected and analyzed. The microscopic features of the samples were examined by an optical USB digital microscope and their petrographic characteristics were evaluated by a polarized light microscope. The morphological and chemical composition of the samples were determined by a scanning electron microscope provided with an X-ray microanalyzer (SEM-EDX). The crystalline phases contained in the samples were measured by X-ray powder diffraction analysis (XRD). The results have shown that the mosaic floor was constructed using a white marble which consists of multi-sized calcite crystals with minor amounts of coesite. The pottery mosaic pieces are composed of quartz, hematite and albite. The black stone was identified as a volcanic rock of basalt which consists of andesine, anorthite and accessory quartz. A traditional lime mortar composed of quartz and calcite was used as a setting bed mortar for the mosaic pieces. Furthermore, the results showed the detection of some salt minerals which reflects the salt weathering that occurs in the site. The obtained results provided useful information on the technical structure of the studied mosaic and will be used to select appropriate materials for its restoration.

Kivonat

Jelen tanulmány egy 1748-ból származó, az egyiptomi deltavidéken épült török fürdő (hammam) opus sectile mozaikpadlóján végzett analitikai vizsgálatok eredményeit ismerteti. A mozaik fehér kőzet, kerámia, fekete kőzet díszítőelemeinek és alapozóhabarcsának mintázását és vizsgálatát végeztük el. A mikroszkópos megfigyeléseket egy USB digitális mikroszkóppal, míg a kőzettani vizsgálatokat petrográfiai mikroszkóppal végeztük. A morfológiai és kémiai összetételei mérések pásztázó elektron mikroszkóppal párosított energiadiszperzív röntgenspektrométerrel (SEM-EDX) történtek. Az ásványos összetételt röntgen pordiffrakciós analízissel (XRD) határoztuk meg. Eredményeink alapján megállapítható, hogy a mozaikpadlót polikristályos kalcitból és coesitből álló, fehér márványelemek felhasználásával készítették. A kerámia anyagú elemek kvarc, hematit és albit összetételűek. A fekete mozaikdarabokat bazaltként azonosítottuk (andezin, anortit és nyomnyi kvarc). Hagyományos, kvarc és kalcit összetételű mészhabarcsot használtak a mozaik alapozására. Emellett a mozaik alkotórészeiben sófázisokat is azonosítottunk, ami a mozaikpadló mállottsági állapotát jelzi. Vizsgálatainkkal hozzájárultunk a mozaikszerkezet készítésének megismeréséhez és restaurálásának, a megfelelő anyagok kiválasztásának folyamatához.

KEYWORDS: OTTOMAN BATH; DELTA-EGYPT, MOSAIC FLOOR; SEM-EDX; XRD; MARBLE; BASALT; LIME MORTAR

KULCSSZAVAK: TÖRÖK FÜRDŐ; DELTAVIDÉK, MOZAIKPADLÓ; SEM-EDX; XRD; MÁRVÁNY; BAZALT; MÉSZHABARCS

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Introduction

Mosaic was an artistic technique that widely used in some ancient civilizations to decorate floors and walls. It is likely that the application of mosaic floors started from the 2nd millennium BCE and spread around the Mediterranean Basin from the 4th century BCE (Pachta & Stefanidou 2018). Worthy to note that a mosaic tiled floor was reported in a Ptolemaic public bath discovered in front of the Karnak temple complex in Upper Egypt (Marey Mahmoud et al. 2011). Mosaic floors dating from the 4th century BCE showed a significant development of the pebble technique set in a mortar, usually made with slaked lime mixed with volcanic materials. In the early Middle Ages, a form of mosaic floor which consisting of a geometrical design composed of multi-marble pieces was developed. Opus sectile was one of the ancient types of marble pavements with regular geometrical shapes. It was usually produced by cutting thin sections of colored marbles and other decorative stones. In the Middle Ages, this type of pavement was still famous, called Opus Alexandrinum. As stated by Vitruvius (On Architecture, Vol. VII, 1934), mosaic floors are classified according to their purpose of application and they usually made of two to four layers (Puertas et al. 1994). They were based mainly on pebbles or crushed brick and lime, sand, brick dust or other pozzolanic materials.

Many archaeological buildings in the Eastern world are decorated with several types of architectural ornaments including mosaics. Some of these buildings are the public baths or hammams. The hammam is a type of Turkish steam bath that widely spread in many locations of the Ottoman Empire such as in the Middle East and South-eastern Europe (Sibley 2008). Ottoman baths are composed mainly of cold and warm/hot rooms. The large domed cold chamber (usually known in Arabic as mashlah) was often combined with a changing room. While the hot room typically consisted of a central domed space flanked by up to four iwans (vaulted spaces used as an entrance). The corners between these iwans are often occupied by smaller domed chambers, which were used for private bathing. Usually, the centre is occupied by a large heated marble table (a navel stone), for customers to lie on it. A notable importance was given to the interior of the public Ottoman baths with many domes and vaults. In some cases, the bath buildings were built in form of a double-bath type which contained separate sections for men and women. The men's section is always bigger and more extensively decorated (Büyükdigan 2003). In some examples, hammams have uncommon sections such as a towel drying place, and in other baths, few spaces were built for immersion into water for people who cannot stand the heat (Yenice & Ararat 2022).

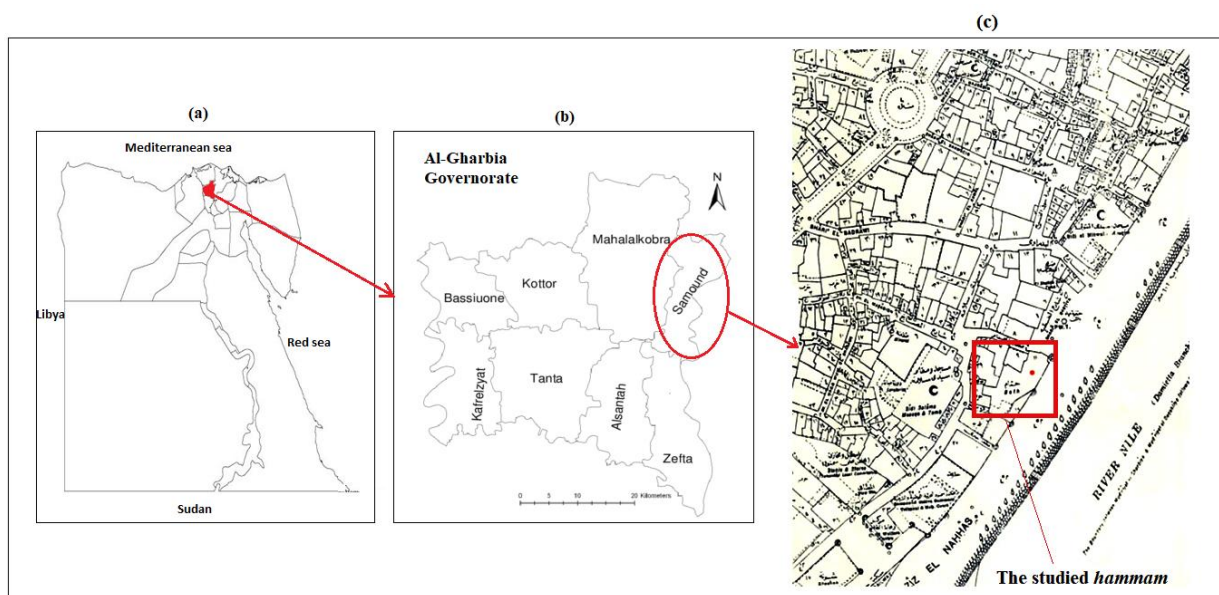


Fig. 1.: a) Map of Egypt shows the delta region, b) the governorate of Gharbia and the city of Samannoud are highlighted, c) location of the studied hammam in the city of Samannoud.

1. ábra: a) A deltavidék Egyiptom térképén. b) Gharbia kormányzóság és Samannoud városa. c) A vizsgált fürdő (*hammam*) Samannoudban.

A number of analytical studies have been performed on ancient mosaics around the Mediterranean basin. In his study of an Ottoman ceramic tiles mosaic from the Sabil of Mustafa Sinan (1630), Omar (2022) stated that the ceramic tiles were burnt at temperatures between 900 and 1000 °C. A mosaic floor from the Küçük Tavşan Adası church (Bodrum, Turkey) (from the 6th century CE) was studied and the results revealed the presence of calcite, crushed bricks, some quartz and plagioclase crystals (Pelosi & Santamaria 2009). A mosaic floor composed of three layers from Madaba in southwest Jordan was analyzed, by XRD and SEM-EDX, and micritic calcite in

addition to lime mortar were identified (Arinat et al. 2020).

The present study aims to report the first analytical methodology conducted on an opus sectile mosaic floor from an Ottoman bathhouse from the delta region of Lower Egypt. The used analytical techniques included optical and polarized light microscopes, scanning electron microscope-energy dispersive X-ray spectrometry (SEM-EDX) and X-ray diffraction analysis (XRD). The obtained results provided a comprehensive understanding of the materials used in the studied mosaic and will be considered when applying a restoration intervention.



Fig. 2.: a) The studied *hammam*, b) entrance of the hammam, c) view of the cold room, d) view of the hot room.
2. ábra: a) A vizsgált *hammam*, b) a bejárat, c) a langyos helyiség, d) a forró helyiség.

The studied monument

The hammam of Ibrahim Siraj Al-Din (Reg. No. 10357) is located in the city of Samannoud, Gharbia Governorate (about 113 km to the north of Cairo) (Fig. 1). It is considered one of the oldest and most complete Islamic baths in Egypt (Fig. 2). This bath is a rare standing monument in the city of Samannoud. The hammam was constructed in 1162 AH /1748 CE by Hajj Younis Marai Al-Taraas, one of the wealthy men of Samannoud. By 1821, the bath was transferred to the new owner Ali Bey Badrawi and it was known as the 'Great Bath'. Later, the bath was sold to Ibrahim Bey Siraj Al-Din, one of the most famous businessmen in Samannoud, and the bath has been associated with his name until now. The north-eastern façade of the hammam is the main façade and there is a rectangular door in the centre of the entrance with a simple triple pointed arch, surrounded by a rectangular opening for lighting and ventilation. The entrance to the hammam leads to a vestibule, which is topped by a guard terrace. It includes a curved vestibule, which has a floor paved with mosaics and marble tiles. The cold hall (mashlah), which is the first reception

hall, is a square area with a central marble fountain. This fountain is surrounded by three iwans while in the past there were four iwans and one of them was removed for urban infrastructure works in the surrounding area. The warm hall is distinguished by its mosaic floor and dome and it has a terrace for resting and a door leading to the hot hall. The final room is the hot bath, which consists of a main octagonal hall, that leads to four perpendicular iwans with pointed arches. The iwans are surrounded by an octagonal court with a fountain in the middle. The bath floors from the entrance to the hot hall are decorated with multi-colored mosaics (Fig. 3.).

Previous restoration works of the hammam

The first architectural restoration work for the bath was carried out in the period from 1996 to 1998, when newer additions to the original bath building were removed, and all the carved brick decorations in the entrance were revealed. In the period from 2000-2001, the pavement was completely lifted then reinstalled in the same places after insulation was put beneath them.

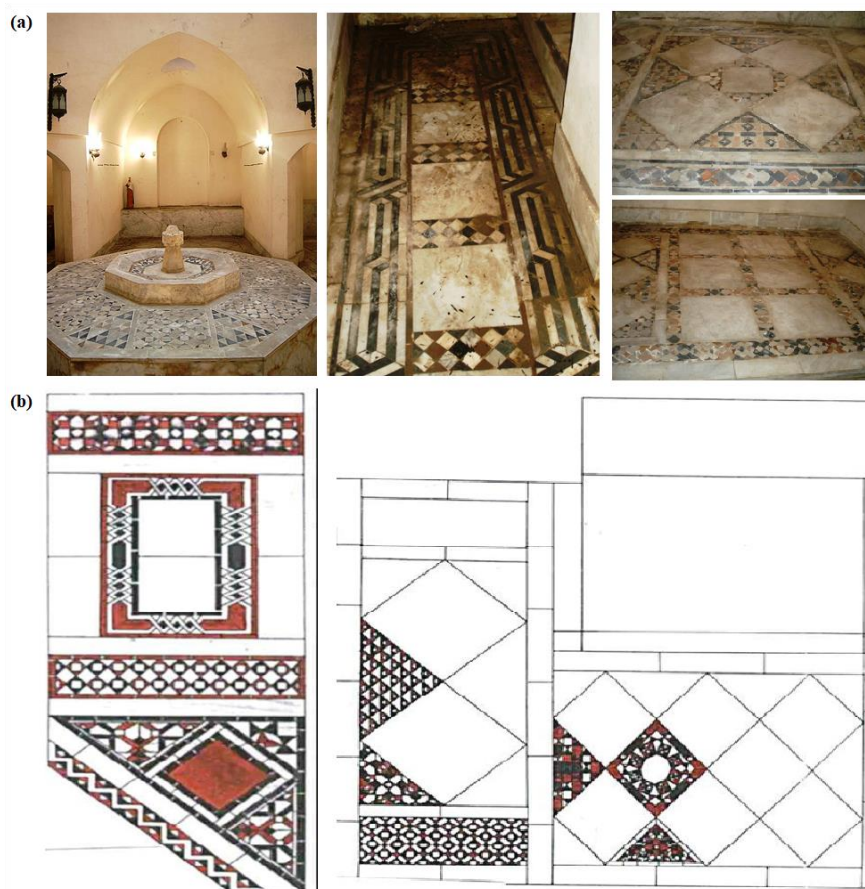


Fig. 3.: a) Details of the marble mosaic elements, b) Auto Cad drawings of the geometric units of the mosaic.

3. ábra: a) A hammam márvány mozaik elemei. b) A mozaik geometrikus egységeinek rajza.

Materials and methods

Samples

Samples that represent the main materials used in the studied mosaic floor were carefully selected and studied. Some of them were taken from the iwan which is located between the hot private bath and medium hot bath (the warm bath) and also from the marble fountain. Five small-size pieces (with approx. size of 1 to 2 cm²) of marble, pottery mosaic pieces, black stone and the setting bed mortar were subjected to a round of analytical methods. **Table 1** shows the description of the studied samples and their locations are highlighted on the ground plan of the hammam (**Fig. 4**).

Analytical methods

Initial visual examinations on the samples were performed using a “DNT” digital mobile USB microscope. This microscope allows capturing images with an accuracy of 1 µm and magnifications up to 500x. Thin-sections (with a thickness of approximately 30 µm) prepared on the studied samples were examined with a Nikon Eclipse-E600 polarized light microscope (PLM) supported with a PixeLINK PL-A623 digital camera. The morphology of samples and their chemical analysis were determined by a Quanta FEI 3D 200i environmental scanning electron microscope attached to an EDX analyzer (thermofisher pathfinder). The operating conditions were acceleration voltage of 30 kV, resolution for Gun= 1 nm. The crystalline phases contained in the samples were determined by a Philips analytical X-ray diffractometer type PW 1710X. The patterns were measured at 40 kV and 30 mA and the powdered samples were scanned in the range of 0–60° (2θ) using a monochromatic Cu–Kα radiation source at wavelength of 1.54060 Å. An X’Pert high score software matching was applied to identify the contained mineral phases.

Results

Microscopic examination and petrography of samples

The microscopic images obtained on the white stone (sample A) showed the appearance of clear white crystals. Furthermore, a thin orange-brown layer was observed on the surface, probably developed due to deterioration processes (**Fig. 5a**). The examination of the sample under cross and plane-polarized lights showed cloudy to white color multi-sized crystals which appear in a rhombic or scalloped shape. The examination of the section under the cross-polarizers (on the left) shows elongated and anisotropic shape grains. The plated calcite crystals (CaCO₃) with different sizes showed granoblastic with equidimensional shapes. Their interference colors are from white to gray and sometimes the thin edges appear as bright colors.

The sample clearly showed a cleavage under the plane-polarized light while a typical lamellar twinning was observed under the cross-polarized light (**Fig. 5b**).


The microscopic examination of the pottery mosaic pieces (sample B) showed a heterogeneous structure containing holes, impurities, fine cracks and clusters (**Fig. 6a**). Also, signs of biological damage and salt efflorescence were observed. The petrography of the sample, under the plane-polarized light (on the right), shows a dark red color with texture contains round-sharp edged quartz crystals, while under the cross-polarized light (on the left), the sample appears with a brownish-yellow color, probably due to iron oxides pigmentation. More, many feldspar crystals are scattered with a cloudy color tending to yellow (**Fig. 6b**). In case of the black stone (sample C), dark and pale gray grains with white and orange appearance were noticed (**Fig. 7a**). The petrographic observations on the sample showed a white to cloudy color and opaque areas, and under the plane-polarized light, it shows separation/cleavage, while under the cross-polarized light, several interferences appeared with white to grey, greenish, bluish and reddish colors. The crystals in the section appeared flat and compressed with some blades. They also appear as long and short prismatic crystals. The presence of siliceous minerals and the lamellar twinning of plagioclase feldspars are characteristics for the basic components of igneous and metamorphic rocks (MacKenzie & Guilford 1980) (**Fig. 7.b**). The microscopic examination of the setting bed mortar (sample D) showed siliceous grains with different sizes. Also, some dark particles of charcoal or vesiculated volcanic fragments are visible within the white binder. Some interstitial voids together with salt crystals appeared clearly in the mortar (**Fig. 8a**). Under the plane-polarized light, the quartz aggregates appear colorless with some fine cracks. The binding lime material appears in brown color, and the pores or air spaces appear in yellow, while under the cross-polarized light, interference colors from white to grey are observed (Balksten 2007) (**Fig. 8b**).

Morphology and microanalysis of samples

SEM investigation of the marble sample (**Fig. 9a**) showed a firm compacted structure. EDX microanalysis of the sample revealed a major concentration of calcium (Ca) with traces of silicon (Si) and aluminum (Al). The investigation of a cross-section of the sample (**Fig. 9b**) showed an irregular encrustation with an average thickness= 20 µm. The EDX analysis of this layer showed elements of calcium (Ca), silicon (Si), phosphorus (P), aluminum (Al), magnesium (Mg), sulphur (S), iron (Fe), chlorine (Cl) and sodium (Na).

Table 1: The studied samples and their description.

1. táblázat: A vizsgált minták és leírásuk.

Sample	Description	Photographic description
A	White marble sample from the mosaic structure (approx. dimensions: 1x1.5 cm ²)	
B	Pottery mosaic piece (approx. dimensions: 1x1 cm ²)	
C	Black stone sample (approx. dimensions: 1x1 cm ²)	
D	Setting bed mortar sample (approx. dimensions: 1x2 cm ²)	
E	Repair mortar sample (approx. dimensions: 1x2 cm ²)	

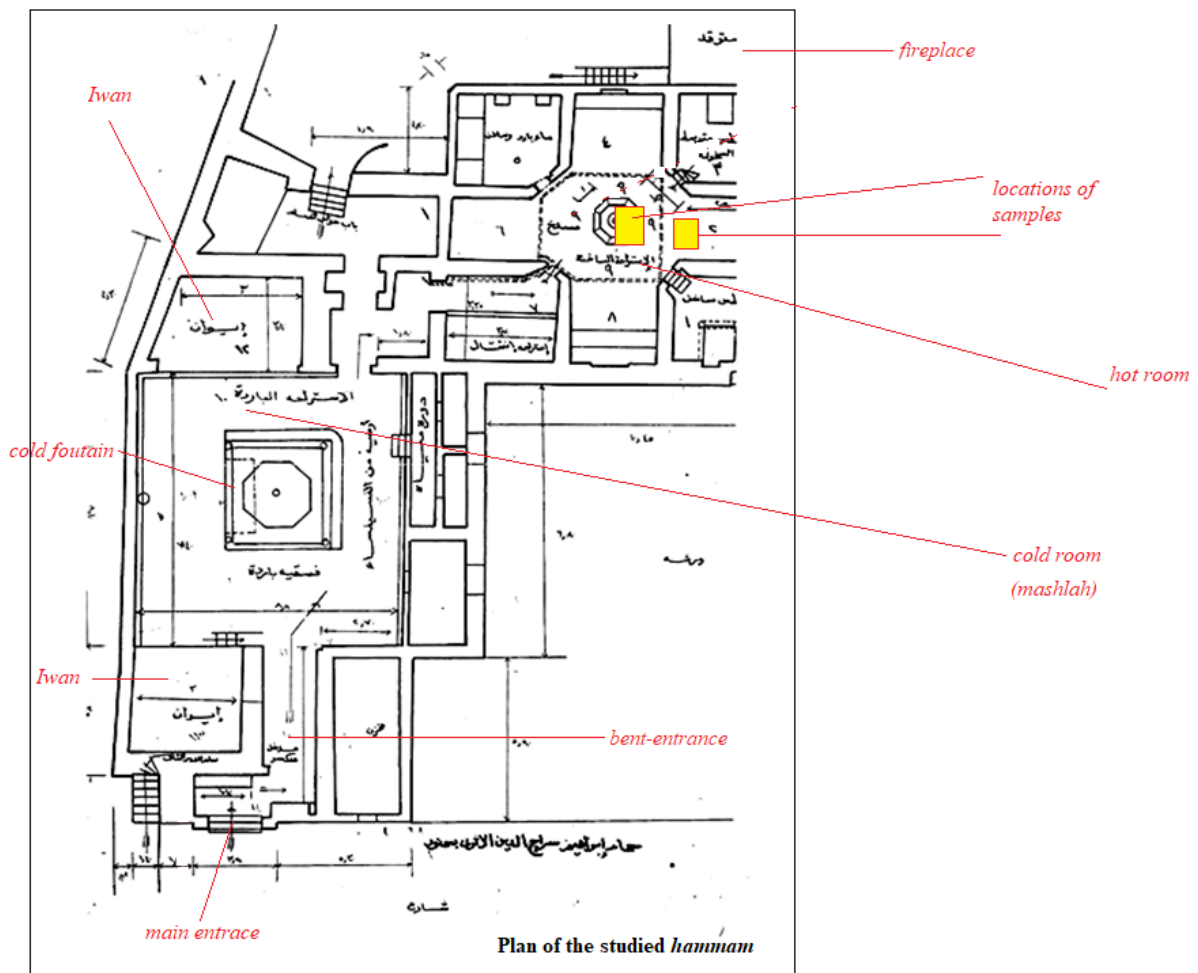


Fig. 4: A ground plan of the studied *hammam* and locations of the studied samples are highlighted.

4. ábra: A vizsgált *hammam* alaprajza és a mintavétel helyei.

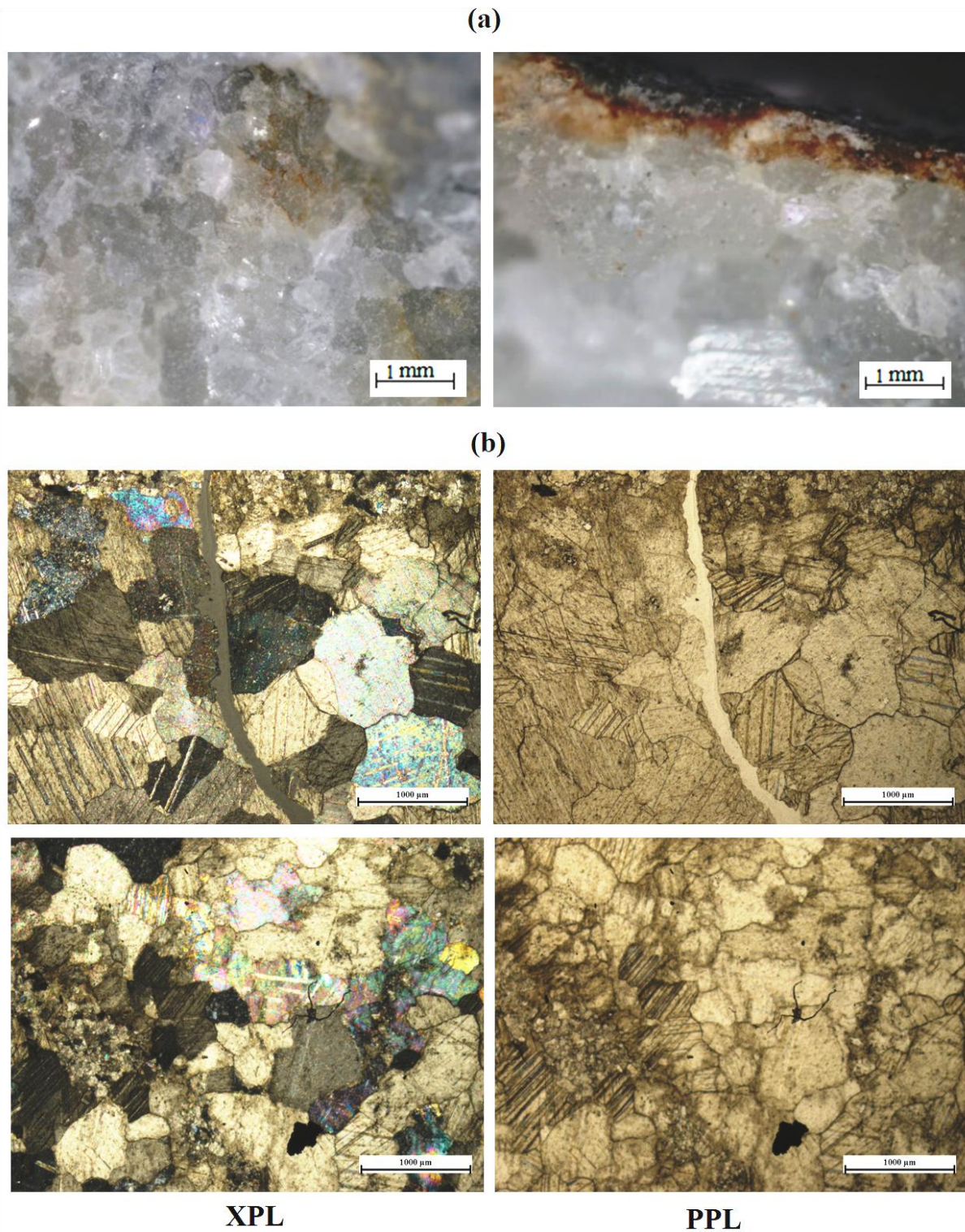


Fig. 5: a) Microscopic images obtained on the marble samples, b) Petrographic images obtained on the marble thin-sections (left: under cross-polarized light; right: under plane-polarized light).

5. ábra: A márványminta a) mikroszkópi képei és b) petrográfiai mikroszkópos vékonycsiszolati képei (bal: XPL; jobb. PPL).

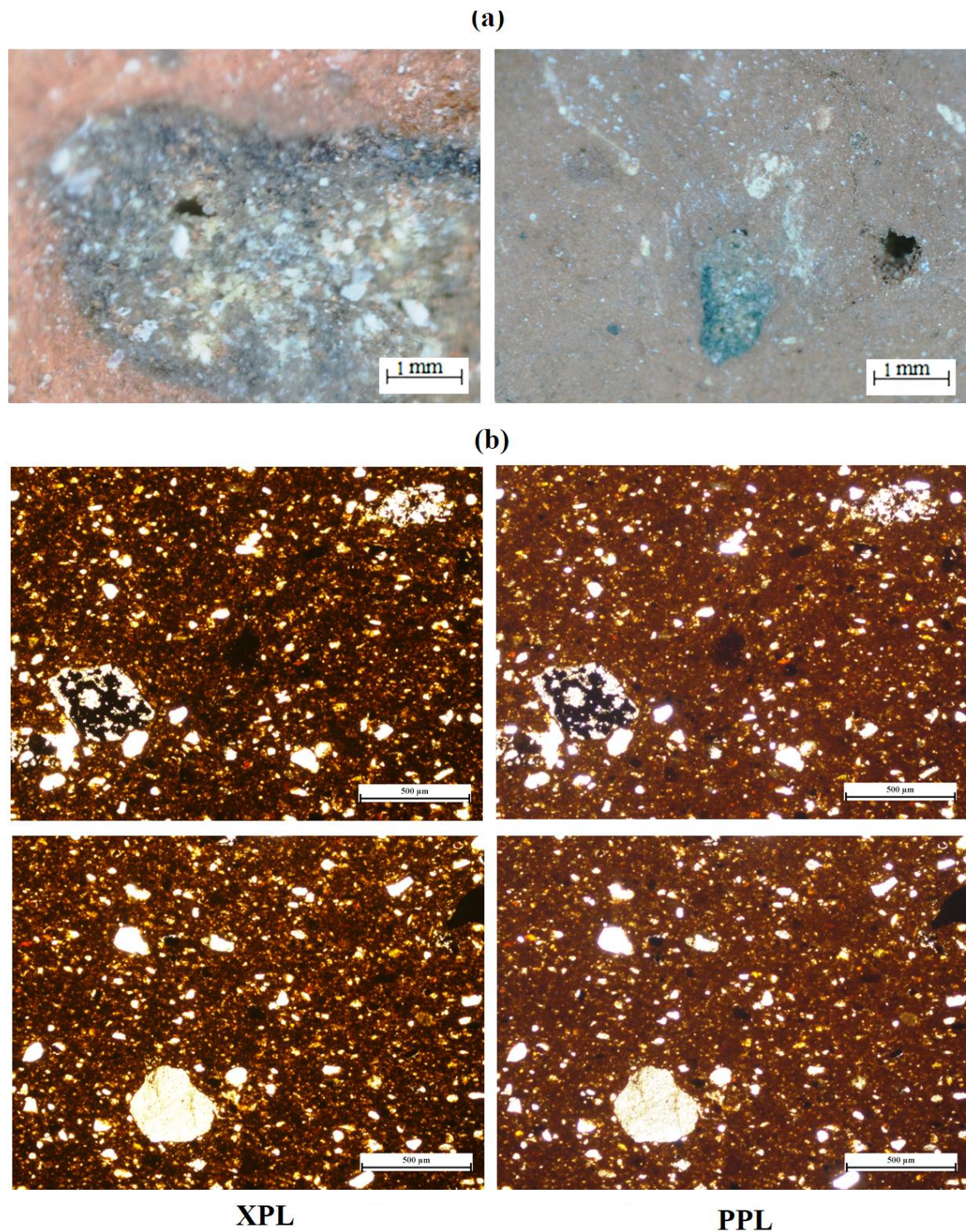


Fig. 6: a) Microscopic images obtained on the pottery samples, b) Petrographic images obtained on the pottery thin-sections (left: under cross-polarized light; right: under plane-polarized light).

6. ábra: A kerámiaminta a) mikroszkópi képei és b) petrográfiai mikroszkópos vékonycsiszolati képei (bal: XPL; jobb: PPL).

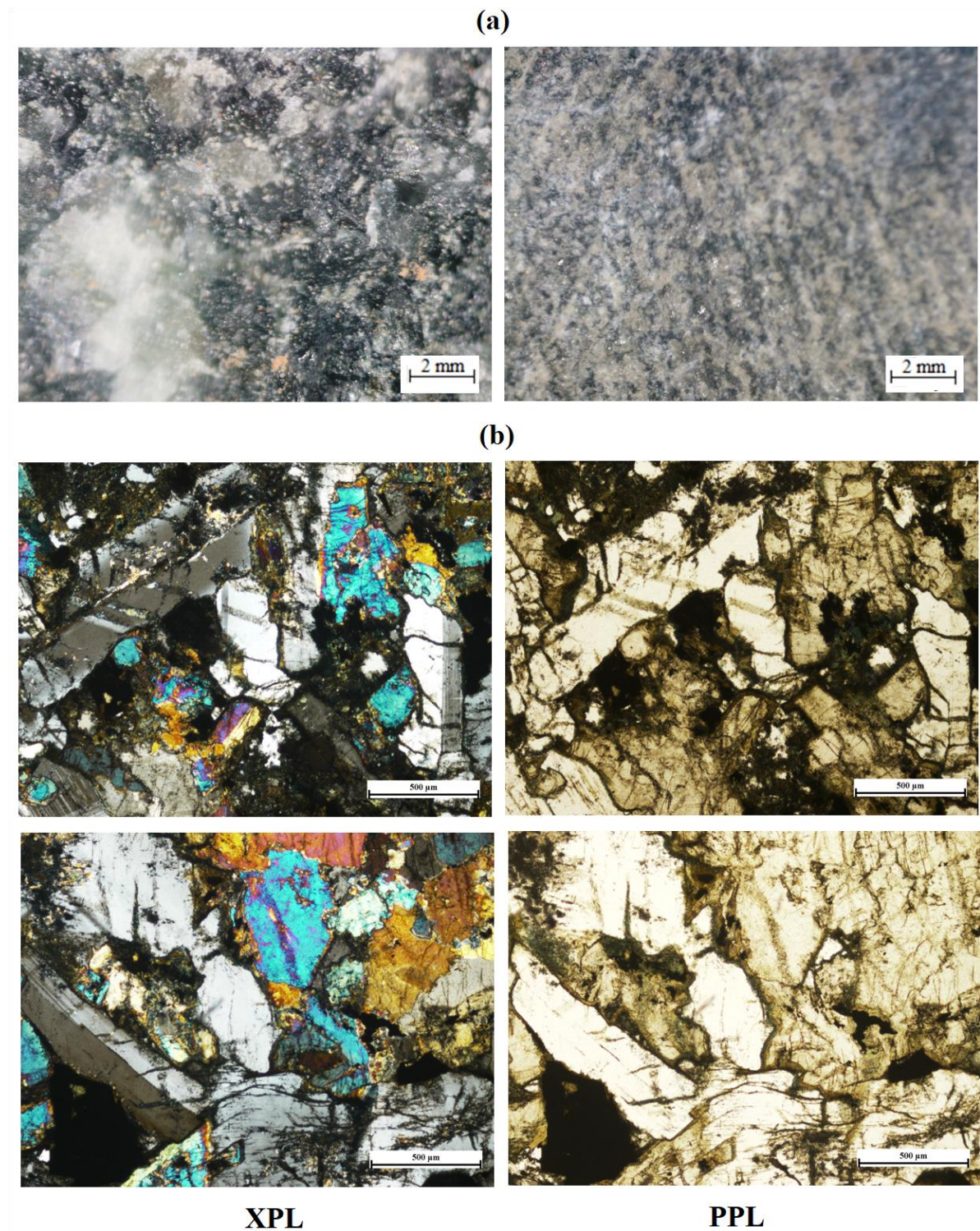


Fig. 7: a) Microscopic images obtained on the black stone sample, b) Petrographic images obtained on the basalt thin-sections (left: under cross-polarized light; right: under plane-polarized light).

7. ábra: a) A fekete kőzetminta mikroszkópi képei. b) A bazalt kőzet petrográfiai mikroszkópos vékonycsiszolati képei (bal: XPL; jobb: PPL).

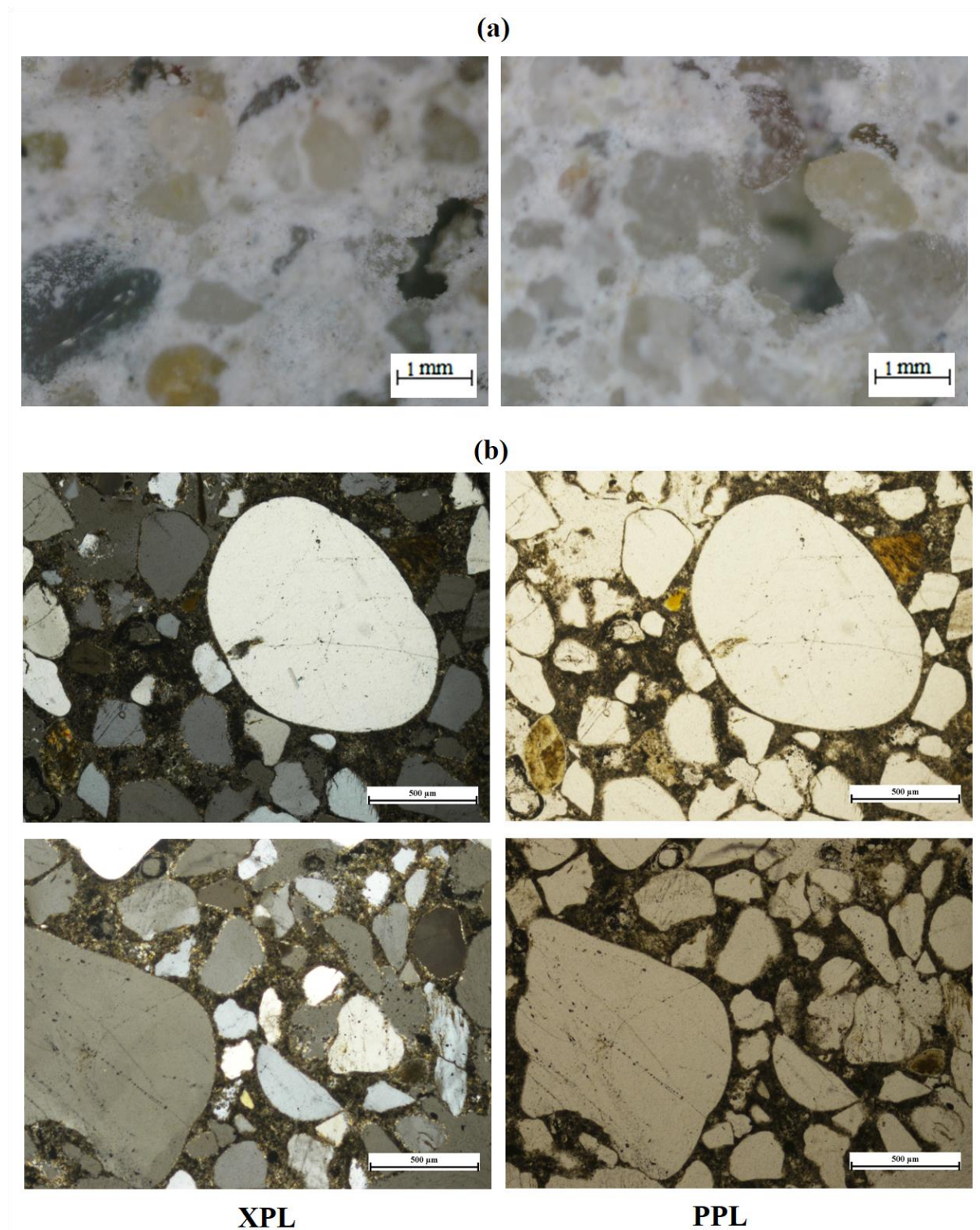


Fig. 8: a) Microscopic images obtained on the setting bed mortar, b) Petrographic images obtained on the mortar thin-sections (left: under cross-polarized light; right: under plane-polarized light).

8. ábra: a) A beágyazó habarcs mikroszkópi képei és b) petrográfiai mikroszkópos képei (bal: XPL; jobb: PPL).

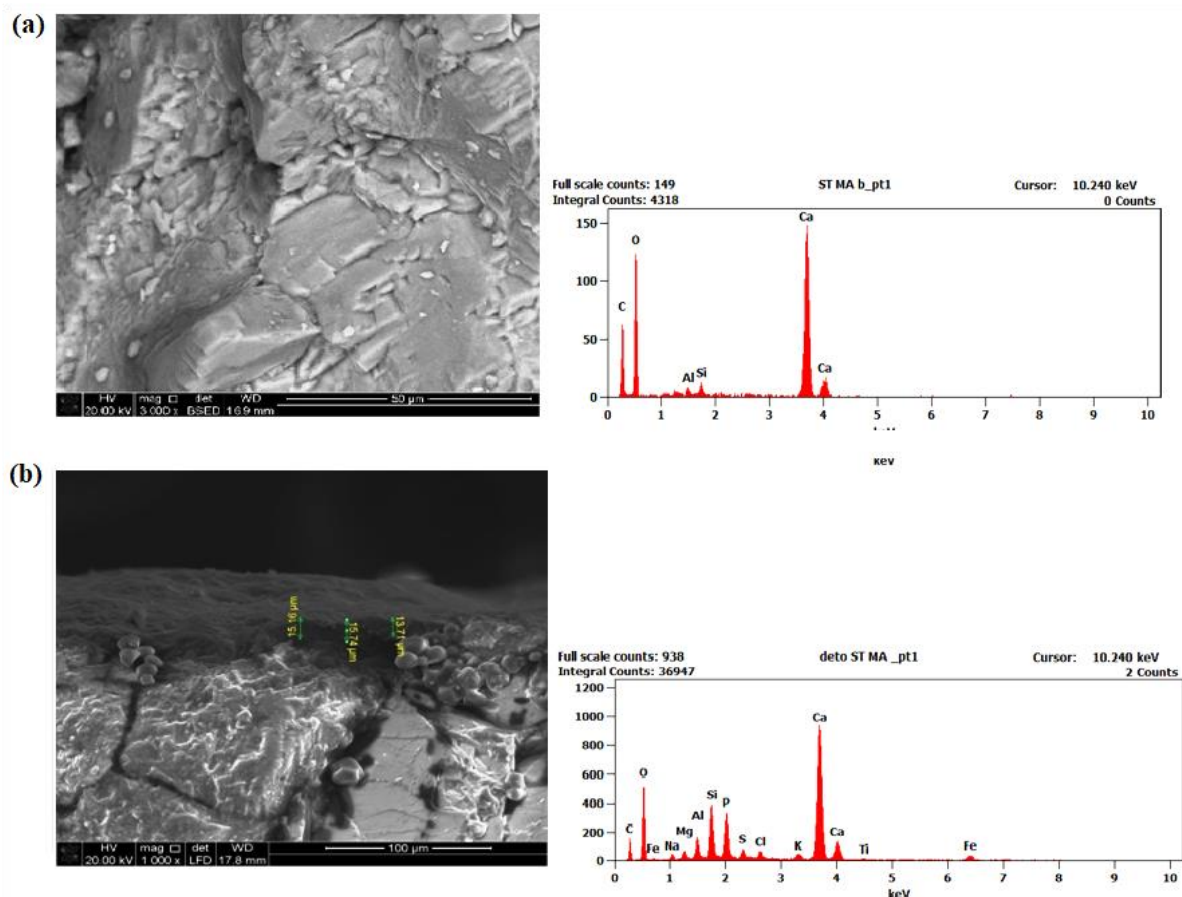


Fig. 9: a) SEM-SE micrograph (3000x, scale bar= 50 μm) and EDX spectrum obtained on the marble sample, b) SEM-SE micrograph (1000x, scale bar= 100 μm) and EDX spectrum obtained on a cross-section of the encrustation formed on the marble surface.

9. ábra: a) A márványminta SEM-SE felvétele (3000x, méretarány= 50 μm) és EDX spektruma. b) A márvány felületi bevonatának SEM-SE felvétele (1000x, méretarány= 100 μm) és EDX spektruma.

The occurrence of these elements suggests that the layer is composed of chloride and sulphate salts together with biological and iron oxide deposits. The morphology of the pottery mosaic pieces showed a heterogeneous surface with a number of fractures. EDX analysis of the sample detected elements of silicon, aluminium, iron, magnesium, sodium, potassium (K) and titanium (Ti) (**Fig. 10a**). The morphology of the black stone sample appears as laminated large crystals with some cracks. The analysis of the sample showed the presence of major concentrations of silicon and aluminium with minor occurrence of calcium, magnesium and sodium with traces of titanium, iron and potassium (**Fig. 10b**).

SEM investigation of the setting bed mortar showed fine aggregates with large quartz grains, and its chemical analysis contains calcium, silicon, sodium, chlorine, aluminium, magnesium and iron (**Fig. 10c**). The detection of silicon and aluminium is probably attributed to the clayey limestone type used to prepare the mortar (Ball et al. 2024). While

the high concentrations of Na and Cl reflect the crystallization of halite salt.

Mineralogical characterization of samples

Table 2 summarizes the XRD results reported for the studied samples. The analysis of the white stone sample showed calcite (CaCO_3) as the major component together with a minor amount of coesite (a form of SiO_2). Taking into account the petrographic examination of the sample, this suggests that marble was used in the studied mosaic. XRD analysis of the pottery mosaic pieces (sample B) showed the presence of quartz (SiO_2), hematite (Fe_2O_3) and sodium feldspars (albite, $\text{NaAlSi}_3\text{O}_8$). XRD analysis of the black stone (sample C) revealed minerals of andesine $[(\text{Na,Ca})(\text{Si,Al})_4\text{O}_8]$, anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) and accessory quartz. The analysis of the setting bed mortar sample showed crystalline phases of quartz and calcite, which confirms the application of a typical lime mortar. The analysis of an additional mortar (Sample E) used in a previous restoration of the mosaic showed the presence of mullite

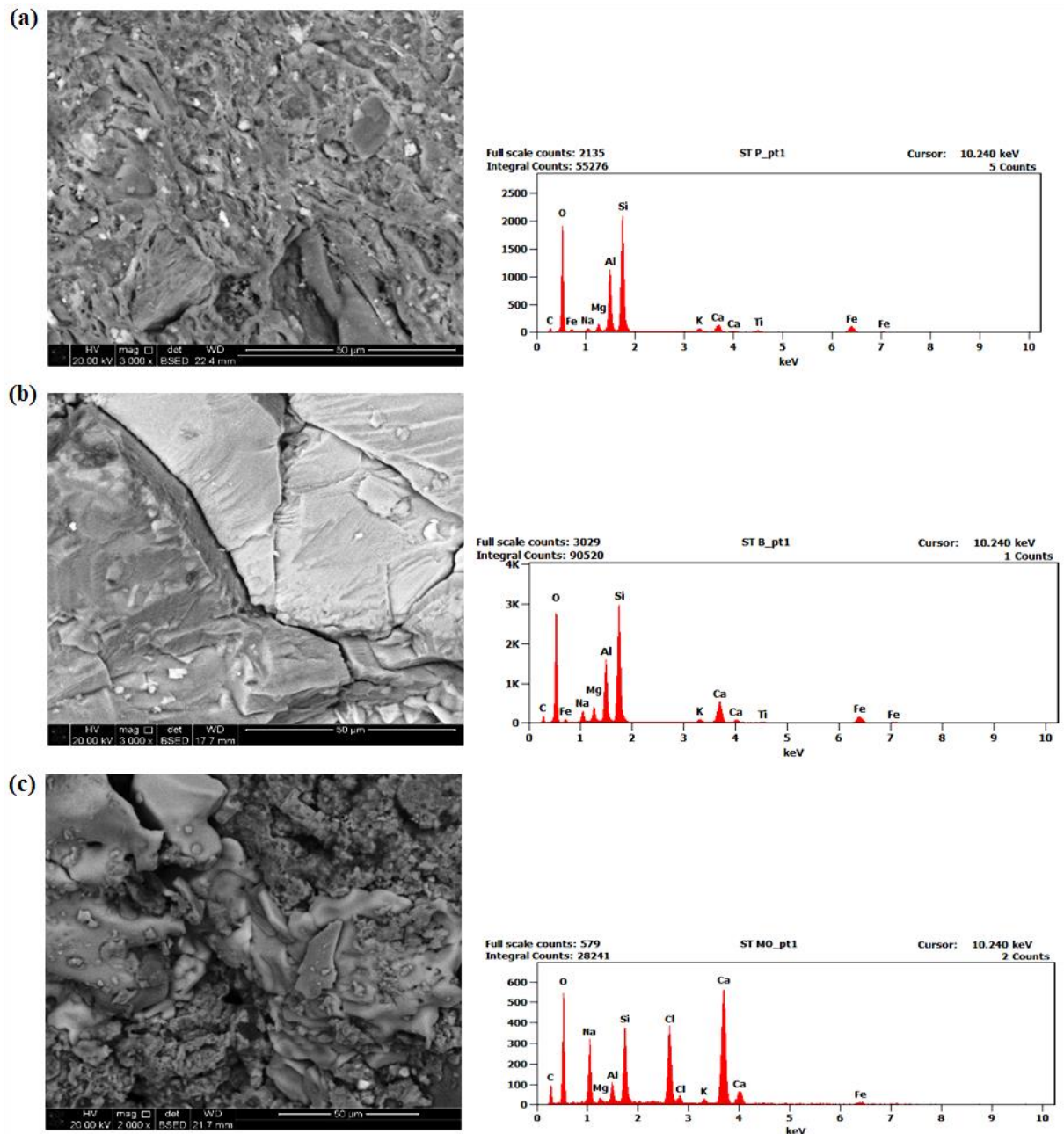


Fig. 10: a) SEM-SE micrograph (3000x, scale bar= 50 μm) and EDX spectrum obtained on the pottery sample, b) SEM micrograph (3000x, scale bar= 50 μm) and EDX spectrum obtained on black stone sample, c) SEM micrograph (2000x, scale bar= 50 μm) and EDX spectrum obtained on the mortar sample.

10. ábra: a) A kerámiaminta SEM-SE felvétele (3000x, méretarány= 50 μm) és EDX spektruma. b) A fekete kőzetminta SEM-SE felvétele (3000x, méretarány= 50 μm) és EDX spektruma. c) A vakolatminta SEM-SE felvétele (2000x, méretarány= 50 μm) és EDX spektruma.

($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$), a silicate mineral resulting from firing aluminosilicate-based materials), coesite, gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), niter (KNO_3) and calcite. It is suggested that a mortar based on gypsum, lime

and aluminosilicate material was used in previous restoration works of the mosaic, carried out between 1996–2000.

Table 2: The crystalline mineral phases measured by XRD on the studied samples.**2. táblázat:** A vizsgált minták ásványos összetétele XRD analízis alapján.

Crystalline phase	Mineral formula	Sample A	Sample B	Sample C	Sample D	Sample E
Quartz	SiO ₂	–	+++	+	+++	–
Calcite	CaCO ₃	+++	–	–	++	++
Coesite	SiO ₂	++	–	–	–	+++
Hematite	Fe ₂ O ₃	–	++	–	–	–
Albite	NaAlSi ₃ O ₈	–	++	–	–	–
Andesine	(Na,Ca)(Si,Al) ₄ O ₈	–	–	+++	–	–
Anorthite	CaAl ₂ Si ₂ O ₈	–	–	++	–	–
Gypsum	CaSO ₄ ·2H ₂ O	–	–	–	–	++
Mullite	3Al ₂ O ₃ ·2SiO ₂	–	–	–	–	++
Niter	KNO ₃	–	–	–	–	++

– = not determined; + = traces; ++ = minor constituent; +++ = major constituent.

Discussion

Marble pieces

Based on XRD and PLM analyses, marble is the main ornamental material used in the studied mosaic. Usually, remnant marble chips from marble panels and tiles applied for decorating the walls in the Islamic monuments are used to prepare the mosaic. Marble is a metamorphic rock that is characterized by a coarse-grained texture and is formed by the re-crystallization of sedimentary carbonate rocks under the influence of heat and pressure (Dipasquale et al. 2016). The color of marbles, including white, pink, yellow, brown, green or black is determined by the contained minerals and impurities. Quarries of marble in Egypt are found in El-Mokattam hills in Cairo, Gebel el-Silsila near Aswan, and Wadi Hammamat in the Eastern Desert (Kandil & Selim 2011).

Pottery mosaic pieces

Pottery sherds and ceramic pieces were used frequently in ancient mosaics. Likely the use of tesserae made of pottery is well applied from the Hellenistic times and throughout the Roman period. It seems that red pottery was used during the Mamluk era (1250–1517 CE) as an alternative material for the red marble, probably for economic purposes (El Beleihy 2006). A number of black and red pottery tesserae from the end of the 4th century CE was discovered at the Amheida site at Dakhla Oasis of Egypt (Nuovo & Prell 2020). A ceramic mosaic located in the Virgin Mary Church (1185 CE) at Cairo was studied and its state of preservation was evaluated by some analytical methods included XRD, SEM-EDX and FTIR (Omar et al. 2024). The ancient Egyptian pottery was made using Nile silt or clay rich in iron oxides together with other additives (straw and limestone) (Lucas 1945). This mixture is then blended with an amount of water and shaped to the desired form

followed by a firing process in kilns at variable temperatures. The mineralogical analysis of the studied pottery pieces showed the presence of hematite which suggests a firing temperature of 950 °C.

Basalt pieces

XRD results of the black stone samples showed the presence of crystalline minerals, such as andesine and anorthite, that occur in basic igneous rocks. These plagioclase feldspar minerals formed in igneous rocks, such as basalt. Badawy (2004) studied several basalt samples by XRD from the temple at Abu-Sir, temple of Ptah at Memphite and from Tell Basta, the results revealed minerals of olivine ((Mg,Fe)₂SiO₄) and several feldspar minerals. In his study of basaltic fragments from Abu Sir, Egypt, Hefni (2022) mentioned the detection of plagioclase feldspar of labradorite ((Ca,Na)(Si,Al)₄O₈) and augite ((Ca,Mg,Fe)₂(Si,Al)₂O₆). Basalt quarries in Egypt are spread in many locations including the Faiyum in the Western Desert, the Haddadin basalt in Northern Egypt, along the Cairo–Suez road, Abu Roash, and the Bahariya (Klemm & Klemm 2001; Mallory-Greenough et al. 2007; Harrell & Storemyr 2009).

Setting bed mortar

The results showed that the main components of the studied mortar are quartz and calcite which confirm that a traditional lime mortar was used to fix the mosaic tesserae. Also, crushed chalk limestone may be intentionally added to the produced mortar for an economic purpose. Lime is usually produced by burning limestone blocks to produce quicklime (CaO) which is then treated with water to form the slaked lime (Ca(OH)₂). The carbonation of the slaked lime by CO₂ gas leads to the formation of calcium carbonate (CaCO₃) (Balksten 2007; Ashby & Jones 2013). The use of burned clayish additives

for lime mortars has been reported since about 3000 BC, but they have become more widespread as a pozzolanic additive in the Roman Empire (Marey Mahmoud et al. 2024). According to Hamarneh & Abu-Jaber (2017), a typical mosaic floor is prepared by applying multi-layers. The main layers are based mainly on coarse lime mortar mixed with gravel, crushed brick or pozzolana. Upon this layer, a fine mortar is applied which consists of marble dust and sand mixed with lime. Then, the mosaic tesserae are fixed over a setting bed lime mortar. In our case, the stratigraphic order of the mosaic floor, from bottom to top, included a compacted layer based on gravels, sand and stone fragments then a second layer of gravels followed by the ground mortar layer which was used to fix the mosaic pieces (the thickness of these pieces ranged between 2.5 cm to 7 cm while in some areas it reached 12 cm). The thickness of this structure ranged between 30–40 cm, while after the restoration interventions applied to the mosaic, as previously mentioned, the thickness was reduced to 15 cm.

Conclusions

In this approach, samples of a mosaic floor from an Ottoman bath (*hammam*) located at the delta region of Egypt were analyzed. The petrographic, morphological and mineralogical characteristics of the mosaic structure were determined and evaluated. Well, the studied bath is considered an important example for the surviving complete Islamic baths in Egypt. The analytical methodology performed on the studied mosaic allows us a better understanding on the materials and technique used to create the mosaic. The results revealed the use of coarse-grained marble which consists of calcite and coesite. More, pottery mosaic pieces were used to create the mosaic floor together with employing basalt as decorating materials in the studied mosaic. Pieces of the mosaic were fixed using a traditional lime mortar. Some scholars mentioned that the thickness of this layer can reach 2 to 4 cm (Moro & Puija 2010). It is noteworthy that some salt phases (e.g. halite, gypsum and niter) were detected in the studied samples which reflect the salt attack due to the infiltration of groundwater from the nearby irrigation lands and canals beneath the mosaic substrate. Thus, a restoration intervention that includes the prevention of water seepage to reach the architectural ornamental elements inside the bath is a priority.

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Contribution of authors

Rehab Z. Adly. Hussein Marey Mahmoud Conceptualization, Investigation, Formal analysis, Writing – Review & Editing Original Draft. **Rehab Z. Adly. Wael Z. El Beleihy** Field Investigation. **Rehab Z. Adly. Hussein Marey Mahmoud.** Data Curation.

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