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Technological and provenance aspects of Umayyad and Ayyubid-Mamluk pottery from Umm as-Surab, north-eastern Jordan: A multi-method approach.

Khaled Al-Bashaireh*[1], Maen Omoush[1], Mahmoud Al-Kofahi[2], Pierre-Marie Blanc[3], Piero Gilento[4]

[1]Department of Archaeology, Faculty of Archaeology and Anthropology, Yarmouk University, Jordan.
[2]Physics Department, College of Arts and Sciences, Baker University, USA.
[3]Archéologie du Proche-Orient hellénistique et romain (APOHR), Centre National de la Recherche Scientifique (CNRS), University Paris 1 Panthéon-Sorbonne, UMR7041, France.
[4]Archéologie du Proche-Orient hellénistique et romain (APOHR), University Paris 1 Panthéon-Sorbonne, UMR7041, France.

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Abstract

This research deals with an archaeometric study of the pottery of the Umayyad (661-750AD) and Ayyubid-Mamluk (1171-1250AD, 1250-1517 AD) periods excavated from the Umm as-Surab archaeological site (north-eastern Jordan), using a multi-analytical approach, consisting of thin-section petrography, X-ray powder diffractometry, X-ray fluorescence spectrometry and thermal gravimetry. The data collected on ceramic fabric, raw materials, and chemical and mineralogical compositions were used to shed light on the provenance of the potsherds and reconstruct various aspects of their production technology, such as production recipes (base clay versus tempers), firing temperature and atmosphere. Chemical data were statistically treated using a multivariate method. The cluster analysis was performed using the software package of SPSS version 25 and the squared Euclidean distance in the Ward's method. The results indicate that the samples were locally produced using the available raw materials: few samples have different recipes that might indicate a different source for them. The production technology was well controlled, using ferruginous calcareous and non-calcareous clays mixed with quartz and limestone, among others, non-plastic inclusions and fired at temperatures between 750 and 950°C.

Keywords: Islamic pottery, Umm as-Suarb (Umm el-Surab), Jordan, production technology, provenance, high-temperature mineral phase.

1. Introduction

The potsherds, referable to the Umayyad (661-750AD) and Ayyubid-Mamluk (1171-1250AD; 1250–1517 AD) periods, were unearthed from the upper layers of 2018 excavations in sector 2 of area A; located between the topographic units TU24 and TU29, at Umm as-Surab (or Umm el-Surab, north-eastern Jordan) (Figures 1-2). The joint archaeological excavation, carried out by Yarmouk University (Jordan) and the University of Paris 1-Panthéon Sorbonne, and the CNRS - the French Center for the Scientific Research, (France), aimed to: i) deeply understand the history of this part of the site which has witnessed continuous occupational phases from the Roman till the Medieval (Ayyubid- Mamluk) Islamic periods; and ii) compare the occupational phases of the growth and distribution of occupations of the whole site, and more generally to reflect on the settlement the dynamics of the entire region, i.e. the Jordanian Ḥawrān. The excavations highlighted the occupation phase of the Ayyubid-Mamluk periods, which is still little known and studied in other nearby sites, such as Umm el-Jimal (Osinga, 2017). The archaeometric study of some representative Umayyad and Ayyubid-Mamluk pottery samples from Umm as-Surab aims to better understand their production technology, in terms of selection and provenance of raw materials, production recipes and firing technology (atmosphere and temperature) during the Umayyad, Ayyubid and Mamluk periods. The technological features will be compared to those of Tal al-Husn (Otoom, 2019), Dohaleh (Al-Tawalbeh, 1996), Hayyan al-Mushrif (Al-Bataineh, 2003), and Al-Bediah (Al-Bataineh, 2005) to reveal the similarities (or differences) of the potters' technologies and define possible skill connections and exchanges during the same periods.

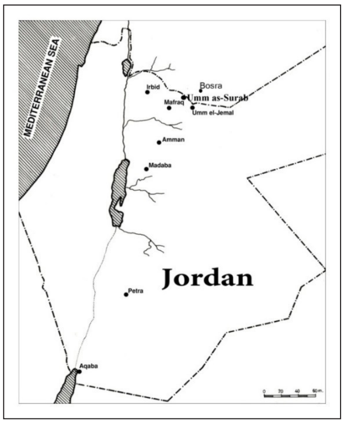

Figure 1. Geographical location map of the archaeological site of Umm as-Surab.

* Corresponding author e-mail: khaledsm@email.arizona.edu

Figure 2. Aerial image showing the location of the excavated area A (red rectangle) between TU24 and TU29. (Image by Piero Gilento elaborated on an aerial image of the Spanish Archaeological Mission in Jordan, courtesy of Antonio Almagro, CSIC-Spain).

2. Umm as-Surab Archaeological Site

Umm as-Surab (MEGA Jordan n. 2806) is located in north-eastern Jordan, close to the border with Syria, and within the basaltic plateau of Harrat Ash Shaam that covers the north-eastern Jordan. It is about 13 km north-west of the city of Mafraq and about 12 km north of Umm el-Jimal, the most important archaeological site in Mafraq governorate (Figure 1).

Umm as-Surab stemmed its importance from its location close to Bosra (south-eastern Syria) and on a directory of the "Via Traiana Nova" from Bosra to Gerasa (Anastasio et al., 2016). Basalt is the main, and almost the only, building stone used in the construction of its buildings that have been dated by architectural, archaeometric and typological studies, at least to the Roman, Byzantine and Islamic periods (Parenti, 2012). However, various Nabataean and Greek inscriptions were identified and cataloged at the beginning of the 20th c. AD by the Princeton Archaeological Expedition to Syria (Butler, 1909). Lithics and inscriptions found in the surrounding areas, especially in the wadis (ephemeral river beds), showed that the area was inhabited during the Iron Age (King, 1989). Houses and churches at the site indicate that it reached its peak during the Byzantine Period (4-7th c. AD) and the rehabilitation of the church of Sts. Sergius and Bacchus into a mosque indicates its occupation during the Muslim times (King, 1983a; Gilento, 2014).

This church represents the most important and preserved structure at the site. It is an apsed church with three naves and slightly south-east oriented (Figure 2), and dated to AD 489, based on a dedicatory inscription inscribed on the lintel of the main entrance, currently not in situ (Butler, 1909).

Various archaeological researches were conducted at the site during the 1930s (Bartoccini, 1941), 1960s (Mittmann,1966), 1980s (King, 1983b), in 2002 (Bucarelli, 2007), and during the period between 2008 and 2012 (Parenti and Gilento, 2010; 2012). More recently, new projects have started in 2017 (the Jordan Hawrān Archaeological Survey), and in 2018 the joint project between Yarmouk University, Paris1-Panthéon Sorbonne and the CNRS.

3. Materials and methods

A set of 28 potsherds were selected from the pottery collection excavated from area A: the Umayyad potsherds are 6 (namely SRB19, SRB22, SRB23, SRB27, SRB32, SRB33), while the rest of the potsherds are Ayyubid-Mamluk (Figure 3).

Figure 3. Photographs of the Umm as-Surab (Jordan) studied potsherds.

Most of the Umayyad potsherds are made by wheel and have bodies with light colors of buff, pink, grey and white, which resemble the characters of the Umayyad pottery (Sauer, 1982; Merkel, 2019; Bes et al., 2020). The Ayyubid-Mamluk pottery potsherds are coil and wheel-shaped and decorated. The Hand Made Painted Potteries (HMPP) are largely dominant comprising jars, juglets and pitchers (with one handle). They are decorated in black, brown or dark red lines and geometric motives by the freestyle or freehand brushwork. The HMPP which originated as early as the late 11th century AD became most popular from the 12th c. AD to the 15th century AD and widely distributed throughout Jordan archaeological sites and other regions in the Levant (Peterson, 2018; Barfod et al., 2019; Walker, 2012). The main geometric decorations of the potsherds include spirals, either round, square or triangular lines (see samples SRB6, SRB7, SRB9, SRB10, SRB11, SRB12, and SRB14), parallel and vertical lines (SRB6, SRB9, and SRB15), triangles (SRB7, SRB8, SRB11, and SRB12) and tilted squares (SRB9 and SRB15).

Because most of the pottery findings are fragments, having variable sizes, the selection strategy aimed at choosing the most suitable potsherds of identifiable form which would represent the Umayyad and Ayyubid-Mamluk pottery recorded in the excavated area (Table 1). The samples were classified into Umayyad and Ayyubid-Mamluk groups according to their stratigraphic layers which display phases related to the Islamic settlement in the excavated area. The selection was based also on their decoration, color, size, etc. Although many of the unearthed potsherds could not be attributed to a specific vessel form; some of them represent jars, bowls, and small juglets (Figures 3-4). The selected potsherds are mainly rims (9 potsherds), bodies (4 potsherds), bases (6 potsherds), nicks (4 potsherds), and handles (5 potsherds) (Table 1). The description of the samples is given in Table 1.

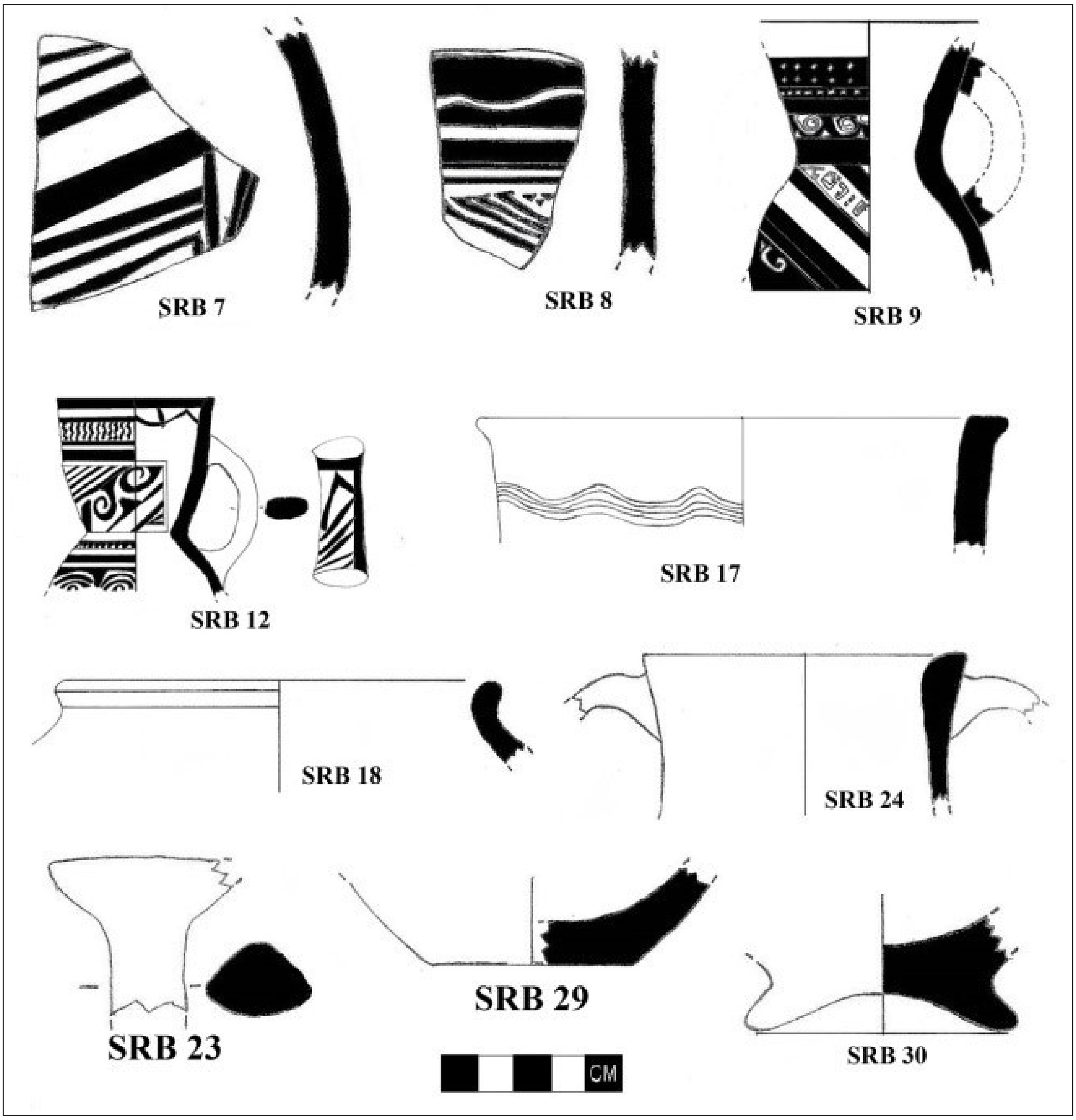

Figure 4. Decorative motives of selected potsherds from Umm as-Surab, Jordan.

All the potsherds were analyzed according to a multi-analytical approach. They were firstly brushed and washed to reduce possible contamination from the archaeological soil. A small part of each sample was used for thin section preparation and the rest was ground in an agate mortar for the mineralogical, thermal and chemical analyses by X-ray powder diffraction (XRPD), thermal gravimetry (TGA) and energy dispersive X-ray fluorescence (EDXRF).

Thin sections were prepared according to the standard procedure discussed by Camuti and McGuire (1999) and examined using a Leitz 7062 model polarizing microscope at the laboratories of the Faculty of Archeology and Anthropology at Yarmouk University. XRD patterns were obtained by the analysis of powders from whole samples using a Rigaku X-ray diffractometer with an Ultima IV (185mm) Goniometer under the following conditions:

scanning 2θ: 5–60°, Max Power 1.8KW, Cu Ka radiation (1.5418 Å), 40 kV and 40 mA energy. Thermal gravimetric analyses (TGA) were performed by Netzsch TG 209F1 Iris instrument supported by the Netzsch Proteus software. Samples were heated from 20 to 900 °C under a nitrogen atmosphere at a heat rate of 3 °C/min. The relative mass loss of the samples was recorded. The XRPD and TG analyses were carried out at the Pharmaceutical Research Center at the Jordan University of Science and Technology.

XRF analyses were carried out under vacuum using the Rigaku NEX CG spectrometer at the Physics Department, Baker University, Kansas, USA. Five grams of each sample in powder form were used to prepare 30 mm pressed pellets using a 25-ton hydraulic press (samples 9 and 18 could not produce the needed 5 grams). The spectrometer uses advanced Cartesian geometry EDXRF for rapid qualitative and quantitative elemental analysis of major and minor atomic elements. It has a simplified user interface and uses a novel software called "EZ Analysis" developed by Rigaku which reduces the need for standards and use the Fundamental Parameter Method (FPt) for the analysis of XRF spectra. This method is based on two calibrations: the MCA energy calibration, and the intensity's library calibration. In the MCA calibration, a standard containing known concentrations of Sn, Cu, and SiO2 is used to identify the relationship between the energy of the characteristic peaks and the corresponding channel numbers in the spectrum. In the intensity's library calibration, 99.99% pure standards of Cu, Sn, and SiO2, were used to identify the relationship between peak profiles (count numbers) and the corresponding concentrations of the elements based on a sensitivity library measurement intensity. The RIGAKU NEX-CG spectrometer used in the analysis uses a RIGAKU's Patented ULTRA CARRY filter method that brings the limits of detection of most metals down to 20ppb (0.02ppm) and better. The results reported are as determined by the software of the system. X-rays from the primary source in NEX CG are used to bombard four targets made of Al, Cu, Mo, and RX9 (an alloy of several metals) to allow optimal irradiation for all elements in the samples. However, because of the spectrometer limitations, sodium and the lighter elements were not measured. The spectrometer uses a 3D geometry to detect the characteristic x-rays for the elements in the sample.

4. Results and discussion

A general description of the samples is presented in Table 1. The texture varies from fine silt to very coarse sand, while the voids are rare to common and vary in size from <1 to about 3mm. The thickness of the samples varies from about 0.5cm to about 2.5cm. Five samples (SRB8, SRB17, SRB22, SRB29, SRB31) show a sandwich-like structure (Nodari et al., 2004) with a black or grey core bracketed by creamy to brown-reddish outermost portions of the body. This known feature most probably indicates firing at low heating rates in a kiln of partial opening and in a reducing atmosphere at the initial stage and oxidizing one at the end (Gosselain, 1992; Nodari et al., 2004; Maritan et al., 2006; Daszkiewicz and Maritan, 2017; De Bonis et al., 2017). However, the same result can be obtained by firing the potsherds in an oxidizing atmosphere with high amounts of organic materials (Rye, 1981; Maritan et al., 2006; Bong et al., 2008).

4.1 Petrography

A summary of the petrographic description of the samples is illustrated in Figure 5 and presented in Table 1. The petrographic examination showed similar types of inclusions, mainly consisting of quartz grains (Figure 5) and fragments of micritic limestone (Figures 5C, E, F), with some grog (Figures 5E, F) and basalt grains (Figure 5D) of sub-angular to angular boundaries, forming a well-sorted grain size distribution. The coarse grains of quartz are sub-angular to angular indicating deliberate addition after their crushing, while the rounded fine quartz grains indicate their natural presence in the clay used in manufacturing the potsherds. The wavy extinction, exhibited by quartz grains, resulted from production processes of firing or/and crushing. The reddish color of some samples resulted from hematite detected by XRD analysis, indicates firing under an oxidizing atmosphere (Rice, 1983). The elongated vesicles (channels and planar voids), partially filled with secondary calcite (Figure 5H), mainly represent secondary fissures, cavities or voids left after the burning out of organic materials like straws (Figures 5E, F). At higher magnification on the microscope, foraminifera (Figure 5 I) was noticed in several samples and a crystal of Gehlenite (Figure 5J) was noticed in sample 30, indicating a high firing temperature, see below.

Based on the amounts of quartz inclusions, the samples could be classified in four main groups: Group 1- with low quartz (5-15%) (samples SRB14, SRB23, SRB28, SRB29, SRB32); Group 2- with moderate quartz (16-30%) (samples: SRB6, SRB7, SRB8, SRB12, SRB15, SRB16, SRB24, SRB25, SRB30); Group 3- with rich quartz (31-40%) (samples: SRB9, SRB10, SRB11, SRB13, SRB17, SRB19, SRB20, SRB21, SRB26, SRB27, SRB31); Group 4- with very rich quartz (>40%) (samples: SRB18, SRB22, SRB33), (Figure 5, see table 1 for details).

According to the grain-size of the quartz inclusions, two different fabrics can be distinguished: fine-medium (Figure 5A) and fine-coarse fabrics (Figure 5B). Samples SRB7, SRB9, SRB18, SRB19, SRB24, SRB25, SRB26 and SRB30 have fine-medium fabric while the rest of the samples have fine-coarse fabric (Figure 5, see Table 1for more details). The fine-medium fabric has optically active and homogeneous groundmasses of brown to dark brown color in plane polarized Light (PPL) and light brown to dark brown in Crossed Polarized Light (XPL). The samples of the fine-coarse fabric have different percentages of the non-plastic inclusions, and in PPL their groundmass color varies from brown and dark brown to very dark brown, while in XPL it varies from light brown and brown to yellowish and reddish brown.

These results show that most of the Umayyad potsherds (4 of 6) were made of rich (SRB19, 27) to very rich (SRB 22, 33) quartz inclusions, and all of them (except SRB19) have fine-coarse fabrics. On the contrary, the Ayyubid-Mamluk samples have fine-coarse and medium-coarse fabrics and their quartz contents range between low to very rich.

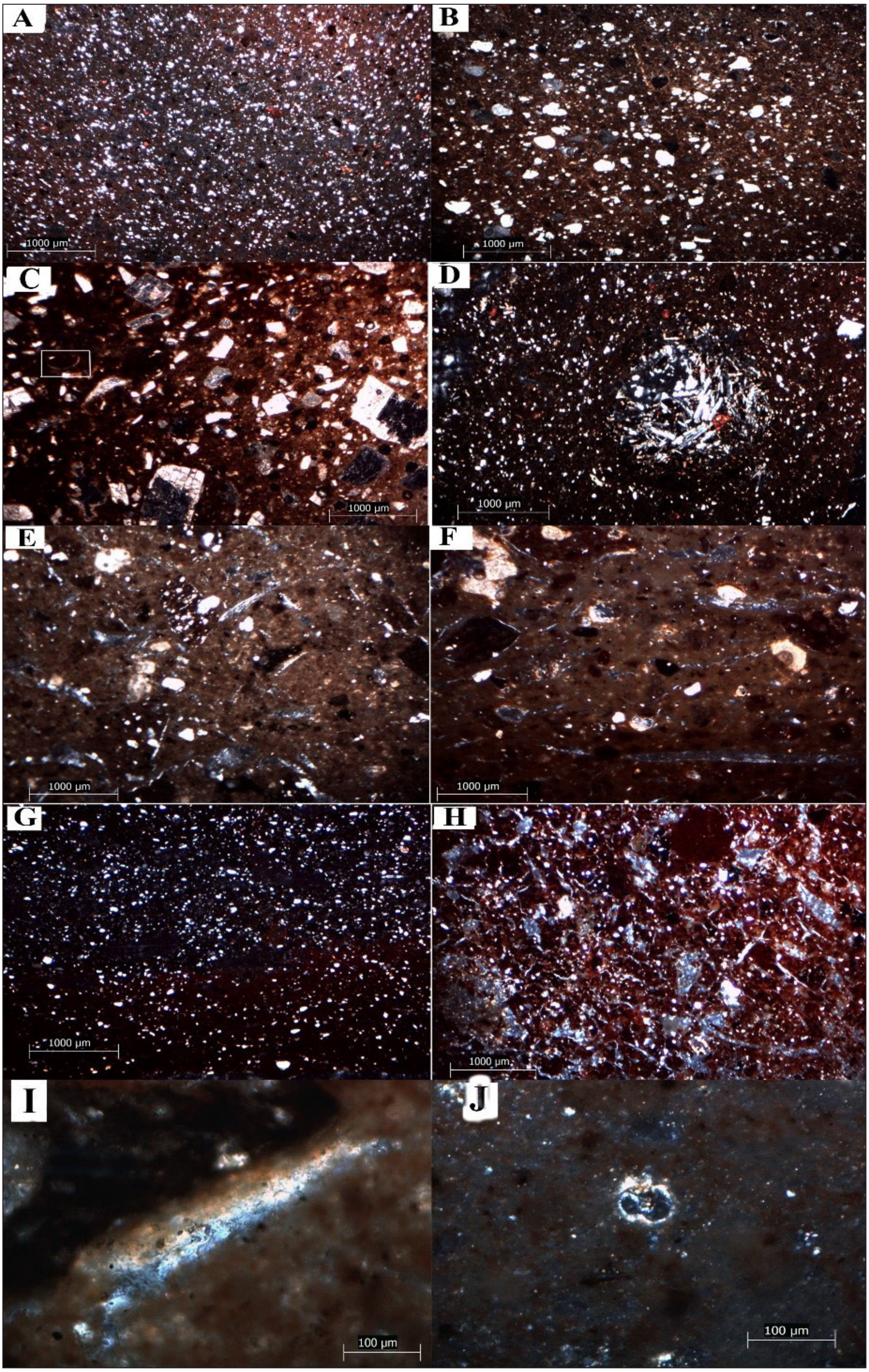

Figure 5. Photomicrographs showing different petro-fabric of the studied pottery sherds under cross-polarised light (XPL). A. Very rich in quartz (Group 4) and fine-medium fabric (SRB 18). B. Moderate in quartz (Group 2) and fine-coarse fabric (SRB 16). C. Scarce in quartz (Group 1), very coarse abundant limestone-tempered and bivalve-bearing (SRB 29). D. Rich in quartz (Group 3) and very coarse basalt-tempered (SRB 17). E. Moderate in quartz (Group 2) and grog-tempered (SRB 30). F. Scarce in quartz (Group 1) and longitudinal voids remnants of burnt straws (SRB 28). G. Very rich in quartz (Group 4) and grey core ware (SRB 22). H. Rich in quartz (Group 3) and abundant voids (SRB 9). I. Gehlenite in sample 30, and J. foraminifera in sample 32.

Table 1. Brief macroscopic and, petrographic description, parallels,firing temperature, and XRD results of the studied potsherds (Qz=quartz, G=Gehlenite, F= Feldspar, C= Calcite, H=Hematite, D= Diopside, Mj= major, Mn= minor, Tr= trace, Ab= absent, Qz. G. S.=Quartz grain size, very high > 40%, high (30-40%), moderate (15-30%), low (5-15%), scarce (3-5%), rare < 3%, very fine < 63µ, fine 63µ-0.5mm, medium 0.5-1mm, coarse 1-2mm, verycoarse > 2mm).

Sample No, Context, Period	Pottery type/shape,color, (parallels).	Minerals by XRD			Firing T.	Inclusions (abundance %)	Grain Size/shape	Notes
		Mj	Mn	Tr/ Ab				
SRB6 SRB.341.14 Ayyubid-Mamluk	Rim/body, small jar. Ware: 7.5YR (7/3) pink. Decoration 5YR(3/2) dark reddish brown.(Avissar and Stern, 2005: 114, fig. 47; Gabrieli et al., 2014: 200, fig.5, b,c,d; Barfod et al., 2019: 150, fig. 11. 5:J16-Tc-67-18).	Qz, G	F, C, H, illite	D	900- 950	Quartz (20), Gr 2, Grog (5)	Fine-coarse/ Sub rounded-Sub angular	Fine-coarse fabric, few micritic limestone granules, calcite fills boundaries of some fissures, iron oxide staining. Dark brown PPL and brown color XPL.
SRB7 SRB.320.5 Ayyubid-Mamluk	Body, jar. Ware: YR(5/3) reddish-brown. Decoration: 7.5YR(3/1) very reddish-grey. (Avissar and Stern, 2005: 114, fig. 47, Lichtenberger and Raja, 2016: 67, fig. 3).	Qz, F, C	G, H	D, Illite	800-850	Quartz (16), Gr 2 Grog (4)	Fine-medium/ Sub rounded-Sub granular Fine/ Sub rounded	Fine-medium fabric, few micritic limestone granules, calcite fills boundaries of some fissures, iron oxide staining. Very dark brown PPL and dark brown-brown XPL.
SRB8 SRB.320.13 Ayyubid-Mamluk	Rim/body, jar. Ware: 2.5YR (6/6) light red. Core: 7.5YR (5/3) brown. Decoration: 7.5YR (2.5/1) black.(Avissar and Stern, 2005: 114, fig. 47, Lichtenberger and Raja, 2016: 67, fig. 3).	Qz,	F, C, G, H	D, illite	800-850	Quartz (25), Gr 2 Micritic limestone (5), basalt (2)	Fine/Sub rounded-rounded/ Subangular Very coarse/ Sub rounded-rounded	Fine-coarse fabric, secondary calcite fills boundaries of some fissures, very coarse basalt grains, iron oxide staining. Dark brown PPL and reddish-brown XPL.
SRB9 SRB.340.9 Ayyubid-Mamluk	Neck/handle/Body, Jar or Juglet. Ware: 5YR (5/4) reddish brown. Decoration: 5YR(3/1) very gray. (LaGro, 2002: 92, fig. 3.50, Avissar and Stern, 2005: 114, fig. 47).	Qz, F	C, H	G, Illite	800-850	Quartz (32), Gr 3 Grog (3), basalt (1)	Fine/ Sub rounded-Sub angular Medium/Sub rounded	Fine-medium fabric, unimodal grain size, voids and residues of abundant organic matter of longitudinal shape (straw), iron oxide staining. Very dark brown PPL and reddish-brown XPL.
SRB10 SRB.326.20 Ayyubid-Mamluk	Body/ jar Ware 7.5YR(5/1) gray. Decoration: 2.5YR(3/1) very reddish gray.(Gabrieli et al., 2014: 200, fig.5.b, c,d, Lichtenberger and Raja, 2016:83, table 8.b).	Qz, F, C	G, H	D, illite	800-850	Quartz (30), Gr 2 Micritic limestone (20), Grog (5), Basalt (1)	Fine/Sub rounded-rounded Medium–very coarse/ Sub rounded Coarse/ Sub rounded Fine, surrounded	Fine- coarse fabric, bimodal grain size, few grog, secondary calcite fills boundaries of cracks and fissures, residues of organic matter of longitudinal shape, iron oxide staining. Dark brown-black PPL and dark brown XPL.
SRB11 SRB.376.11 Ayyubid-Mamluk	Rim/body, small jar. Ware: 10YR (7/6) yellow. Decoration: 2.5YR(4/3) reddish brown.(Avissar and Stern, 2005: 114, fig. 47, Gabrieli et al., 2014: 200, fig.5.b, c,d, Lichtenberger and Raja, 2016: 83, table 8.b; Peterson, 2017: 69, fig.4: J13-D-g-2).	Qz,	C, F, H	G, Illite	800-850	Quartz (30), Gr 2 Micritic limestone (10), Grog (5), Basalt (1)	Fine-coarse/ Sub rounded-Sub angular Fine-very coarse/ Sub rounded, Fine-coarse/ subrounded Fine, rounded	Fine-coarse fabric, bimodal grain size, fractured quartz, secondary calcite fills boundaries of some fissures and residues of organic matter of longitudinal shape(straw), iron oxide staining, some argillaceous granules. Dark brown PPL and brown XPL.
SRB12 SRB.310.2 Ayyubid-Mamluk	Neck/body, small jar. Ware: 7.5YR (7/4) pink. Decoration: 10YR(3/1) very dark grey. (LaGro, 2002: 71, fig. 3.6, Avissar and Stern, 2005: 114, fig. 47).	Qz, G, C, F	H	D, illite	850-900	Quartz (25), Gr 2 Micritic limestone (5)	Fine-coarse/ Sub rounded-Sub angular Medium/ subrounded	Fine-coarse fabric, bimodal grain size, fractured quartz, secondary calcite fills boundaries of some fissures and residues of organic matter of longitudinal shape (straw), iron oxide staining, some argillaceous granules. Brown PPL and light brown–brown XPL.
SRB13 SRB.340.4 Ayyubid-Mamluk	Body, jar. Ware: 5YR (6/6) reddish yellow. Decoration: 5YR (4/2) dark reddish gray. (Barfod et al., 2019: 149, fig. 10, 4:J16-Td-13-15).	Qz, F	G, C, H	D, Illite	800-850	Quartz (30), Gr 2 Micriticlimestone(15) Grog (5), Basalt (1)	Fine/Rounded-Sub angular Fine-coarse/ Sub rounded Coarse/sub rounded-subangular Fine, sub-rounded	Fine- coarse fabric, bimodal grain size, secondary calcite fills boundaries of some fissures, iron oxide staining, residues of organic matter of longitudinal shape (straw). Dark brown PPL and brown XPL.

Continue Table 1

Sample No, Context, Period	Pottery type/shape,color, (parallels).	Minerals by XRD			Firing T.	Inclusions (abundance %)	Grain Size/shape	Notes
		Mj	Mn	Tr/ Ab				
SRB14 SRB.320.17 Ayyubid-Mamluk	Body, jar. Ware: 10YR (7/3) pale brown. Decoration: 5YR(2.5/6) dark reddish brown.(Avissar and Stern, 2005: 114, fig. 47 Gabrieli et al., 2014: 208, fig. 9a,b; Barfod et al., 2019: 148: fig. 8, J16-Tc-53-2).	Qz, C, G, F	H	D, illite	900-950	Quartz (12), Gr 1 Micritic limestone(13), Grog (10)	Fine-coarse/ Sub rounded-Subangular medium-coarse/ Sub rounded coarse/sub-rounded	Fine-coarse fabric, bimodal grain size, secondary calcite fills boundaries of fissures, iron oxide staining. Brown PPL and light brown XPL.
SRB15 SRB.340.3 Ayyubid-Mamluk	Neck/body, jar. Ware: 7.5 YR (6/6) reddish-yellow. Decoration: 5YR(2.5/1) black. (Avissar and Stern, 2005: 89, fig. 38).	Qz, C	G, F, H	D, Illite	800-850	Quartz (20), Gr 2 Micriticlimestone(15) Grog (5), basalt (1)	Fine/ Rounded- Subangular Fine-coarse/rounded Fine /rounded	Fine-coarse fabric, bimodal grain size, few basalt, grog and argillaceous granules, secondary calcite fills boundaries of some fissures and residues of organic matter of longitudinal shape, iron oxide staining. Dark brown PPL and light brown-brown XPL.
SRB16 SRB.327.18 Ayyubid-Mamluk	Rim/body, jar. Ware: 7.5YR (7/6) reddish yellow. (McPhillips and Walmsley, 2007: 152, fig. 13:1).	Qz, G	F, C, H	D, Illite	850-900	Quartz (20), Gr 2 Micritic limestone (15) Grog (10)	Fine-coarse/ Sub rounded-Subangular Coarse/ Subangular- Sub rounded Fine/rounded	Fine-coarse fabric, bimodal grain size, wavy extinction and fractured quartz, secondary calcite fills boundaries of some fissures, iron oxide staining. Light brown- yellowish-brown PPL and brown XPL.
SRB17 SRB.341.19 Ayyubid-Mamluk	Rim/neck/body, crater (basin). Ware: 2.5YR (6/6) light red. Core: 10YR (5/1) gray.(McPhillips and Walmsley, 2007: 154, fig. 14:3).	Qz	F, H, C	G, Illite	<800	Quartz (40), Gr 3 Basalt (10)	Fine/ Sub rounded-Subangular Very coarse/ Subangular-angular	Fine-coarse fabric, bimodal grain size, wavy extinction and fractured quartz, secondary calcite fills boundaries of some fissures, argillaceous grains, iron oxide staining. Brown PPL and dark brown XPL.
SRB18 SRB.301.6 Ayyubid-Mamluk	Rim/neck/body, jar. Ware: 2.5YR (5/6) red.	Qz,	F, C, H	G, illite	800-850	Quartz (50), Gr 4 Basalt (1)	Fine-coarse/ Sub rounded-Granual Fine rounded	Fine-medium fabric, unimodal grain size, wavy extinction and fractured quartz, secondary calcite fills boundaries of some fissures and residues of organic matter of longitudinal shape (straw), iron oxide staining, two clays brown and grey. Dark brown PPL and brown-reddish brown XPL.
SRB19 SRB.376.4 Umayyad	Rim/neck, bowl. Ware: 5YR (5/4) reddish brown. (McNicoll et al., 1982: 168, plate 144.5, Sauer and Herr, 2012: 518. Fig.4:4:13).	Qz	C, F, H	G, illite	800-850	Quartz(40), Gr 3 Micriticlimestone(5) Grog (5), basalt (1)	Fine/ Sub rounded-rounded Fine/ sub rounded Fine/ subrounded	Fine–medium fabric, fine grog and basalt, unimodal grain size, voids and residues of organic matter of longitudinal shape, iron oxide staining. Brown-orange brown PPL and light brown-brown XPL.
SRB20 SRB.368.1 Ayyubid-Mamluk	Rim/body, jar. Ware 7.5YR(7/8) reddish yellow. (Sauer, 1982. 334: fig.7).	Qz, F	G, C,	H, D, Illite	800-850	Quartz (30), Gr 2 Micriticlimestone(8) Grog (2)	Fine-coarse/ Sub rounded-Subangular Sub rounded Medium/subrounded	Fine-coarse fabric, fractured quartz, bimodal grain size, few fine grog, bad mixing, iron oxide staining, secondary calcite fills boundaries of some fissures. Dark brown-grey PPL and greyish brown XPL.

Continue Table 1

Sample No, Context, Period	Pottery type/shape,color, (parallels).	Minerals by XRD			Firing T.	Inclusions (abundance %)	Grain Size/shape	Notes
		Mj	Mn	Tr/ Ab				
SRB21 SRB.317.6 Ayyubid-Mamluk	Rim/body, jar. Ware: 5YR (7/4) pink. (McPhillips and Walmsley, 2007: 154, fig. 15:3).	Qz	F, C, G,	H, D, illite	800-850	Quartz (40%) Gr 3	Fine-coarse/ Sub rounded-sub angular	Fine-coarse fabric, bimodal grain size, fractured quartz, few fine grog, secondary calcite fills boundaries of some fissures and residues of organic matter of longitudinal shape (straw), iron oxide staining. Dark brown PPL and brown XPL.
SRB22 SRB.374.10 Umayyad	Loop handle, jar . Ware: 10YR (5/8) red. Core: 2.5Y (4/1) dark gray.	Qz	C, F, H	G, Illite	<800	Quartz (40-50%) Gr 4 Grog (1), basalt (1)	Fine-coarse/ Sub rounded-Sub angular Fine sub-rounded	Fine-coarse fabric, bimodal grain size, fractured quartz, few fine grog and basalt, secondary calcite fills boundaries of fissures and residues of organic matter of longitudinal shape (straw), iron oxide staining. Two parts, lower: dark reddish-brown and upper: greyish brown PPL; and lower: reddish-brown – dark red; and upper dark grey XPL.
SRB23 SRB.376.23 Umayyad	Loop handle, jar. Ware 2.5YR (5/6) red. Outside: YR(4/3) reddish brown. (Almagro et al., 2000: 449, fig.15: 5).	C	Qz,	F, H, G, illite	<800	Quartz (10), Gr 1 Limestone (40)	Fine/ rounded Very coarse/angular Sub angular- angular	Fine-very coarse fabric, bimodal grain size, fractured quartz, secondary calcite fills boundaries of fissures and residues of organic matter of longitudinal shape (straw), iron oxide staining. Light brown- light Orange-brown PPL and brown – light brown XPL.
SRB24 SRB.320.15 Ayyubid-Mamluk	Rim/handle/Body, jar. Ware: 7.5YR (6/3) light brown. (McPhillips and Walmsley, 2007: 151, fig. 11:3).	Qz, G, F, C	H, Illite	D	900-950	Quartz (25), Gr 2 Basalt (1)	Fine/ Sub rounded Fine-rounded	Fine-medium fabric, fractured quartz, few plagioclase grains, abundant fissures and cracks, iron oxide staining. Dark brown PPL and brown XPL.
SRB25 SRB.314.9 Ayyubid-Mamluk	Handle, jar. Ware: 2.5YR (6/6) dark yellow. (Barfod et al., 2019: 151, fig. 14 a-b, 7: J16-Uc-1-13).	Qz, G, C, F	H, Illite	D	900-950	Quartz (20), Gr 2 Micritic limestone (5)	Fine-medium/ Sub rounded-rounded Fine-medium/ Sub rounded	Fine-medium fabric, unimodal grain size, few basalt and grog grains, secondary calcite fills boundaries of voids and residues of organic matter of longitudinal shape (straws), iron oxide staining. Orange-brown PPL and light brown-light reddish-brown XPL.
SRB26 SRB.341.2 Ayyubid-Mamluk	Handle, jar. Ware: 2.5YR (6/8) light red. (McPhillips and Walmsley, 2007: 154, fig. 14:2).	Qz	C	F, H,G, illite	<800	Quartz (40), Gr 3 Micritic limestone (5), grog (1)	Fine-medium/ Sub rounded Fine-medium/ Sub rounded	Fine-medium fabric, bimodal grain size, wavy extinction and highly fractured quartz, secondary calcite fills boundaries of voids. Dark brown-reddish brown PPL and brown XPL.
SRB27 SRB.372.10 Umayyad	Handle/rim, cooking pot. Ware: 2.5YR (4/1) dark gray. (Almagro et al., 2000: 449, fig.15:1).	Qz		C, F, H, G, Illite	<800	Quartz (40), Gr 3 Micritic limestone (5), grog (1)	Fine-coarse/ Sub rounded-Sub angular Medium–coarse/Sub rounded	Fine-coarse fabric, bimodal grain size, wavy extinction and highly fractured quartz, fine-grained basalt, iron oxide staining. Very dark brown-grey PPL and dark grey- black XPL.

Continue Table 1

Sample No, Context, Period	Pottery type/shape,color, (parallels).	Minerals by XRD			Firing T.	Inclusions (abundance %)	Grain Size/shape	Notes
		Mj	Mn	Tr/ Ab				
SRB28 SRB.340.17 Ayyubid-Mamluk	Base/ body, plate. Ware: 10YR(7/4) very pale brown. Decoration 7.5YR (4/2) brown.(Peterson, 2018: 143, fig.5).	G, Qz, C, F	H, illite	D	900-950	Quartz (15), Gr 1 Micritic limestone (12) Grog (15), Basalt (1)	Fine/ Sub rounded-Subangular Fine-coarse/ Sub rounded Fine-very coarse/ Sub rounded Fine, Sub-rounded	Fine-coarse fabric, bimodal grain size, secondary calcite fills boundaries of cracks, voids, and residues of organic matter of longitudinal shape (straws), iron oxide staining. Dark brown PPL and light brown - dark brown XPL.
SRB29 SRB.340.2 Ayyubid-Mamluk	Base/body, bowl. Ware: 7.5YR (7/4) pink Core: 2.5YR (4/1) dark gray.	C	Qz,	F, H, G, illite	<800	Quartz (10), Gr 1 Primary calcite (35), Basalt (1)	Fine-coarse/ Sub rounded Medium – very coarse/ Sub angular- angular. Fine, sub-angular	Fine-very coarse fabric, bimodal grain size, few plagioclase, bivalve fossils, secondary calcite fills boundaries of void, iron oxide staining. Very dark brown-black PPL and brown- dark brown XPL.
SRB30 SRB.341.17 Ayyubid-Mamluk	Base/body, plate. Ware: 5YR (7/4) pink.	Qz, G, C, F	H, Illite	D	900-950	Quartz (18), Gr 2 Micritic limestone (5) Grog (7)	Fine –frequently medium/ Sub rounded-rounded Fine- frequently medium/ Sub rounded-Sub angular Medium/ Sub angular-angular	Fine-medium fabric, bimodal grain size, secondary calcite fills boundaries of cracks and fissures, residues of organic matter of longitudinal shape, (the presence of two types of clay indicates bad type), iron oxide staining. Light brown- yellowish-brown PPL and light brown - brown XPL.
SRB31 SRB.320.9 Ayyubid-Mamluk	Base, bowl. Ware: 2.5YR (6/6) light red. Core: 2.5YR (4/1) dark gray. (Bagatti, 1947: figs 53: 5,10. Tel abu-Gourdan; Franken and Kalsbeek, 1975: 166-167, figs. 50, 51).	Qz, C, G	F, H	D, illite	850-900	Quartz (25), Gr 2 Micritic limestone (5), basalt (1)	Fine-coarse/ Sub rounded-sub angular Fine- very coarse/ Sub rounded –rounded. Fine, rounded	Fine-coarse fabric, bimodal grains size, fractured quartz, few plagioclase and basalt grains, few grog, secondary calcite fills boundaries of cracks and fissures, residues of organic matter of longitudinal shape, iron oxide staining. Dark brown PPL and dark reddish-brown XPL.
SRB32 SRB.340.3 Umayyad	Base/body, bowl. Ware: 5YR (5/4) reddish brown. Decoration: 10YR (4/2) light red	Qz, G, C, F	H, Illite	D	900-950	Quartz (7), Gr 1 Micritic limestone (16) Grog (1)	Fine-medium/Sub rounded-Subangular Fine- coarse /Subangular-Sub rounded	Fine-coarse fabric, bimodal grain size, fractured quartz, secondary calcite fills boundaries of cracks, few grog, voids and residues of organic matter of longitudinal shape, iron oxide staining. Brown – yellowish-brown PPL and light brown- dark brown XPL.
SRB33 SRB.374.1 Umayyad	Base/body, plate. Ware: 2.5YR (4/2) light red	Qz	F, C	H, G, illite	<800	Quartz (50), Gr 4 Micritic limestone (2)	Fine- coarse/ Sub rounded-Subangular	Fine-coarse fabric, bimodal grain size, wavy extinction and highly fractured quartz, fine-grained basalt, iron oxide staining. Dark brown PPL and dark reddish brown XPL.

4.2 Chemical analysis

The XRF results are presented in Table 2. The potsherds are distinguished by very high variability in the concentration of silica, ranging between 21% (sample SRB29) and 70.5% (sample SRB27), and that of calcium oxide, which is quite low (1.76-4.49%) in few potsherds, and higher in others ranging between 7.3% (sample SBR19) and 64% (sample SBR29). The disparity of the calcium oxide contents is displayed in the ternary system of Figure 6 where the values are mainly scattered toward the quartz–Calcite border line within the silica - diopside – gehlenite, and silica (quartz) - gehlenite - anorthite areas, except two samples SRB23 and SRB29, indicating the use of mostly calcareous raw materials in the manufacture of the samples.

The results show that the Umayyad potters mainly used low calcium and high silica raw materials in the production of most of their potsherds (four out of six); while to the contrary, Ayyubid-Mamluk potters used high calcium raw materials in the production of most of their potsherds. These results agree with the function of the studied samples and their decorations. Calcium-rich materials increase the workability of the object and produce better quality for bright surface and modifications (Noll 1991; Emami et al., 2008).

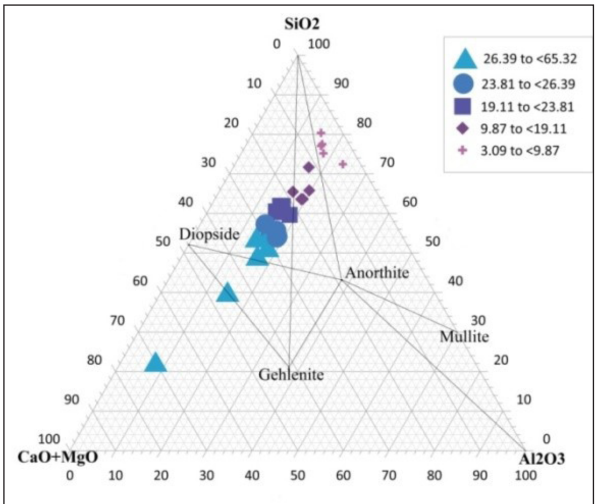

Figure 6. $CaO+MgO-SiO_2-Al_2O_3$ ternary diagram showing the distribution of the studied samples within sub-triangles(the values in the index are of the CaO concentrations).

Table 3. Chemical analysis (in %) of major and minor elements determined by XRF, LOI stands for loss of ignition).

	SiO_2	CaO	Fe_2O_3	MgO	Al_2O_3	K_2O	P_2O_5	TiO_2	MnO	Cr_2O_3	Co_2O_3	V_2O_5	NiO	ZnO	LOI 1050 (550)°C
SRB6	48.7	23.8	5.6	2.0	15.0	2.5	0.49	1.02	0.09	0.03	0.02	0.02	0.01	0.01	4.51(1.20)
SRB 7	56.1	13.2	5.6	2.2	16.7	3.6	0.87	1.04	0.07	0.03	0.02	0.03	0.01	0.01	2.10(0.50)
SRB8	55.4	12.3	8.2	3.2	13.7	3.1	0.75	1.37	0.16	0.03	0.03	0.03	0.01	0.02	5.36(1.10)
SRB10	53.6	16.6	7.9	3.2	13.1	2.5	0.65	1.27	0.19	0.03	0.03	0.03	0.01	0.01	4.65(3.80)
SRB11	52.3	17.7	7.5	3.5	12.9	3.2	0.55	1.16	0.16	0.02	0.03	0.02	0.01	0.01	7.39(3.30)
SRB12	49.4	22.1	5.9	1.7	15.5	3.2	0.44	1.00	0.07	0.02	0.02	0.02	0.01	0.01	5.60(1.10)
SRB13	53.0	15.9	8.2	3.2	13.5	2.8	0.79	1.36	0.20	0.03	0.03	0.03	0.01	0.01	4.49(1.10)
SRB 14	43.8	28.8	5.9	1.6	14.6	2.7	0.43	0.95	0.10	0.02	0.02	0.01	0.01	0.01	10.84(6.80)
SRB 15	52.5	18.5	7.2	2.8	13.3	2.7	0.79	1.25	0.13	0.03	0.03	0.03	0.01	0.02	5.87(3.10)
SRB 16	53.8	18.5	4.4	1.3	16.6	2.4	0.69	1.16	0.04	0.02	0.01	0.02	0.01	0.01	5.21(3.40)
SRB 17	57.6	1.76	13.3	1.3	18.8	2.9	0.67	2.67	0.21	0.03	0.04	0.06	0.01	0.02	3.4(2.85)
SRB 19	60.2	7.3	9.4	2.6	13.9	3.0	0.55	2.07	0.18	0.03	0.03	0.04	0.01	0.02	6.06(2.60)
SRB20	60.8	12.2	3.3	1.3	18.1	1.9	0.41	1.44	0.03	0.02	0.01	0.03	0.00	0.01	4.34(2.00)
SRB21	57.7	14.1	4.5	1.4	17.5	2.1	0.54	1.24	0.06	0.03	0.02	0.03	0.01	0.01	4.72(1.40)
SRB22	66.1	3.47	8.0	2.0	14.2	2.7	0.74	1.71	0.19	0.03	0.03	0.04	0.01	0.02	3.96(1.20)
SRB23	35.8	39.4	6.5	1.0	12.9	2.5	0.23	0.97	0.08	0.03	0.02	0.02	0.01	0.02	25.62(3.10)
SRB24	47.9	25.0	6.6	3.5	12.4	2.1	0.46	1.01	0.13	0.02	0.03	0.02	0.01	0.01	5.22(3.50)
SRB25	47.4	22.5	6.3	1.5	16.2	3.6	0.51	0.97	0.08	0.02	0.03	0.02	0.01	0.01	6.47(4.40)
SRB26	68.0	4.59	4.4	1.5	16.3	2.6	0.39	1.52	0.06	0.03	0.02	0.02	0.01	0.01	2.36(1.60)
SRB27	70.5	3.86	4.6	1.5	15.1	2.1	0.29	1.46	0.07	0.03	0.02	0.03	0.01	0.01	1.89(0.90)
SRB28	45.9	25.7	5.9	1.8	15.7	1.9	1.11	0.97	0.07	0.03	0.02	0.02	0.01	0.02	6.38(2.00)
SRB29	21.0	64.0	2.7	1.3	7.06	2.5	0.24	0.41	0.04	0.01	0.01	0.01	0.01	0.01	36.12(1.90)
SRB30	48.2	24.2	5.7	2.2	14.7	2.7	0.35	1.02	0.06	0.02	0.02	0.02	0.01	0.01	6.22(2.90)
SRB31	49.1	21.5	7.1	2.9	12.2	3.9	0.51	1.15	0.16	0.02	0.02	0.03	0.01	0.01	9.87(9.60)
SRB32	48.2	22.6	6.2	2.2	16.5	2.0	0.60	0.94	0.09	0.02	0.02	0.02	0.01	0.01	4.83(2.60)
SRB33	69.5	2.66	9.3	1.4	12.9	1.1	0.29	1.99	0.25	0.04	0.04	0.04	0.01	0.01	0.70(0.61)

Al_2O_3 concentrations that range between 12.2% (sample SRB 31) and 18.8% (sample SRB 17); (sample 29 is an exception (7.06%); most probably reflect the samples' content of clays and feldspar, which was detected by XRD analysis. Fe_2O_3 concentrations vary from 2.74% (sample SRB 29) to 13.3% (sample SRB 17); the high values most probably reflect the presence of iron content in the form of hematite (detected in XRD analysis) in the tempers or clays derived from the volcanic rock minerals spread in the Umm as-Surab area. The pyroxene and other volcanic rock minerals and dolomite present in the clays or tempers are possible reasons for the concentration of MgO, that ranges between 0.961% (sample SRB 23) and 3.51% (sample SRB 11). K_2O concentrations are in a moderate range between 1.12% (sample SRB 33) and 3.84% (sample SRB 31), the higher concentrations might be related to a high content of K-feldspar and clay minerals (Iordanidis et al., 2009; İssi et al., 2011). These alkalis may act as fluxes during firing, promoting sintering and vitrification. Other oxides concentrations could be seen in Table 2.

It could be inferred that potters were conscious of producing potsherds that will not withstand high temperatures. The potsherds are low refractory since all the sums of the concentrations of K_2O, Fe_2O_3, CaO, MgO and TiO_2 oxides in all the samples are more than 9% (Ravisankar et al., 2014).

The first group of the multivariate analysis shown in (Figure 7) and characterized by CaO ≥ 21.1% and SiO2 ≤ 49.4% contents, consists of 11 potsherds; while the second group consists of 15 potsherds characterized by CaO ≤ 18.5% and SiO2 ≥ 52.3% contents. The results show that all the 4 plates and 6 jars (in addition to 1 bowl) are included in the first group, while 11 jars (in addition to 2 bowls, 1 pot, 1 crater) are included in the second group. The Umayyad plate and one of the two jars belong to the first group, while the two Umayyad bowls, the pot and the second jar belong to the second group. The Ayyubid-Mamluk jars are included in both groups; the three plates and one bowl belong to the 1st group, while the crater belongs to the 2nd group.

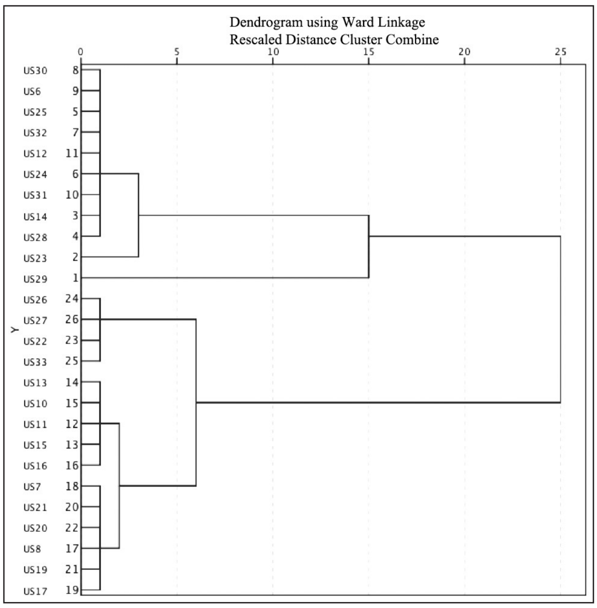

Figure 7. Pottery sample dendrogram based on Ward's method and squared Euclideandistance(The cluster analysis was performed using the software package of SPSS version 25 and the squared Euclidean distance in the Ward's method).

4.3 XRD results

The results of the XRD analysis generally agree with the petrographic and chemical analyses. The main mineral phases recurring in most of the samples are calcite, quartz, gehlenite, feldspar, diopside and hematite (Figure 8). The iron mineral of hematite found in most of the samples indicate an oxidizing firing atmosphere of the samples (Van der Weerd et al., 2004).

Quartz diffraction peaks are intense in all the samples, except in samples SRB23 and SRB29 in which they are moderate (Figure 8: SRB23). The diffraction peaks of gehlenite, calcite and feldspar are more variable; and therefore, more useful in the classification of the samples into four groups (A-D) as shown in Figure 8.

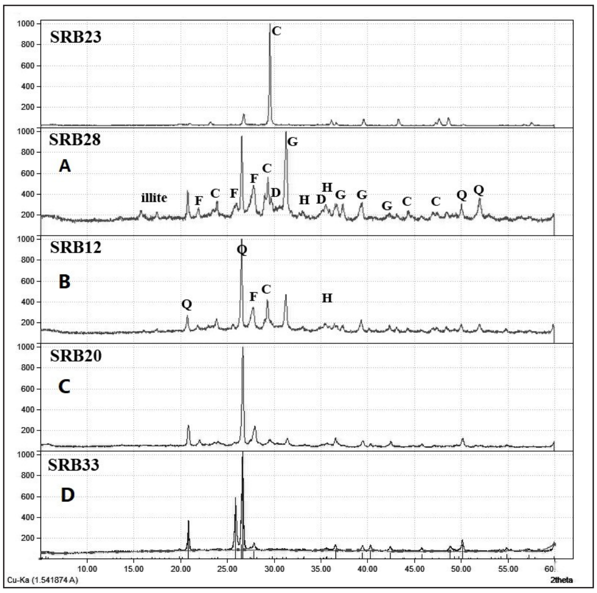

Figure 8. XRD patterns of pottery samples from Umm as-Surab, Jordan showing the samples' difference in their content of minerals. (Q= quartz, F= feldspar, C= calcite, G= gehlenite, H= Hematite, D = diopside).

Gehlenite ($Ca_2Al_2SiO_7$) is a sorosilicate mineral of the melilite family and forms in pottery during the firing process at temperatures in the range of 800-950°C from the reaction between silica and alumina, and the lime of carbonate phases (Maggetti, 1982; Noll, 1991; Duminuco et al., 1998; Cultrone et al., 2001). The pyroxene mineral diopside ($CaMgSi_2O_6$) starts to form at a temperature around 900°C (Maritan et al., 2006; Grammatikakis et al., 2019). Therefore, in group A, the high amount of gehlenite and low amount of diopside (see Figure 8: SRB28) indicate that samples (SRB6, SRB14, SRB24, SRB25, SRB28, SRB30, SRB32) were fired at temperatures around the upper limit of the above-mentioned temperature range (900-950°C). The XRD results are supported by the microscopic examination that observed at high magnification a gehlenite crystal at the carbonate-silicate interface in sample 30 (Figure 5I). The medium amount of gehlenite and absence of diopside in the samples of group B (SRB12, SRB16, SRB31) (Figure 8: SRB12) indicates a firing temperature between 850 and 900°C. The low-intensity peaks of gehlenite in the samples of group C (SRB7, SRB8, SRB9, SRB10, SRB11, SRB13, SRB15, SRB18, SRB19, SRB20, SRB21) (Figure 8: SRB20) indicates a firing temperature between 800 and 850°C, while the very low-intensity peaks (or absence) of gehlenite in the samples of group D (SRB17, SRB22, SRB23, SRB26, SRB27, SRB29, SRB33) (Figure 8, SRB33) indicates a firing temperature around or below 800ºC. It is worth noting that the intensity of Gehlenite peaks and the concentration of CaO have a positive relationship (Table 2), indicating more free CaO at a higher temperature to react with silica and alumina.

The calcite peaks indicate an incomplete decomposition, which starts at around 650ºC and ends at around 900-1100ºC, depending on the calcite grain size and the kiln's heating rate (Trindade et al., 2009). Therefore, the calcareous clay, limestone coarse inclusions and/or rapid heating might be the probable reasons for the $CaCO_3$ presence in several samples although fired at temperatures up to 950ºC. The two samples (SRB23 and SRB29) of group D (Figure 8: SRB23) have very high-intensity peaks of calcite, because of their content of high calcareous (marl) clay and very coarse limestone inclusions.

The XRD results show that 5 of the 6 Umayyad potsherds (SRB19, SRB22, SRB23, SRB27, SRB33) belong to the D-group, i.e. were fired at temperatures below 800ºC, while the sixth sample SRB32 (A-group), was fired at a temperature between 900-950ºC. The function of these samples does not imply the resistance to thermal shocks. However, the cooking pot SRB27 has very low CaO content and high amount of inclusions which increase its thermal shock properties (Papachristodoulou et al., 2006; Hein et al., 2008). The potter was probably aware of the larger thickness of SRB32 than the other Umayyad potsherds, therefore he added lower amount of inclusions and fired it at a higher temperature.

The results show that the Ayyubid-Mamluk potsherds were fired at higher temperatures than those of the Umayyad ones. The Ayyubid-Mamluk handmade painted jars, except samples (SRB 6, 14) fired at 900-950ºC, were fired at 800-900ºC, while the unpainted jars (SRB 16, 24, 25) were fired at 850-950ºC. It is most probable that Ayyubid-Mamluk raised the firing temperature to these values to reduce the jars' porosity and permeability. The two Ayyubid-Mamluk plates were fired at 900-950ºC, while the Umayyad plate was fired below 800ºC. On the contrary, the two Umayyad bowls were fired at higher (or similar) temperatures (800-950ºC) than the three Ayyubid-Mamluk ones (<800-900ºC).

4.4 Thermogravimetric (TG) analysis

The thermogravimetric (TG) curves show to some extent similar patterns of weight loss during the gradual increase of the firing temperature of the potsherds from room temperature to 900ºC. All the samples showed different percentages of gradual weight losses when heated (Figure 9), but the weight losses were significant within the temperature ranges between (0-200 °C and 600-850 °C), and for few samples between (400-550ºC). Characteristic patterns are shown in Figure (9B-C).

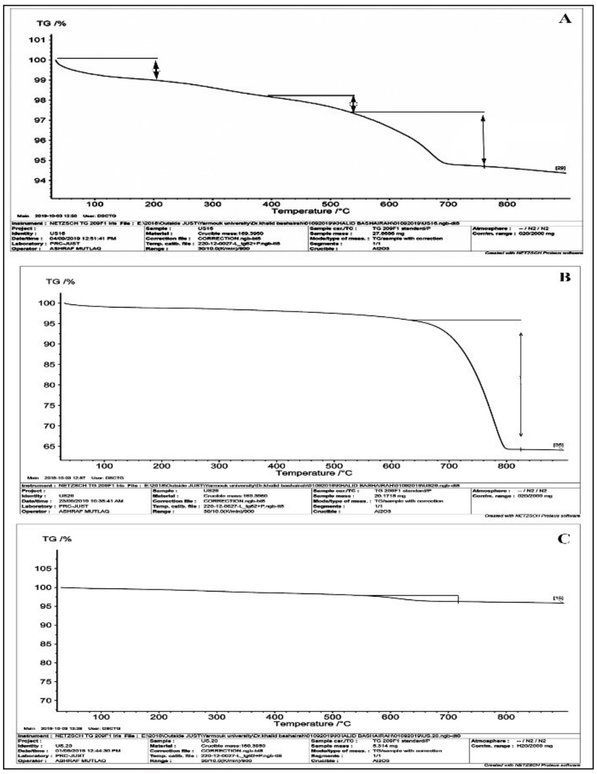

Figure 9. Themogravimetric diagrams of Umm as-Surab potsherds. The common pattern of most samples (A), characteristic patterns of samples SRB23, SRB29, SRB32 (B), and SRB20, SRB26 (C).

In general, the gradual weight losses could be attributed to the evaporation of water molecules also adsorbed at the mineral surface, at the low-temperature range (between 0 and 100 °C), the dehydration of adsorbed water in smectite-like minerals (120-200°C), the decomposition of organic material between 400 and 600°C, and the dehydroxilation of clay minerals between 550 and 950°C (wide range depending on the type of phyllosilicate), the decomposition of calcite between 650 and 850°C (Moropoulou et al., 1995; Drebushchak et al., 2005). All the above samples from both groups show the decomposition of calcite evidenced by the mass loss at temperatures between 650-900ºC indicating a firing temperature below 850-950ºC. Furthermore, the TG analyses do not show the clear decomposition of clay materials between 550-650ºC indicating firing the potsherds at temperatures above 650ºC (Findik et al., 2014). The TGA results agree with the chemical and XRD mineralogical analyses where the samples of low CaO concentration (or calcite content) show less weight loss than the samples of higher CaO concentration (or calcite content), when heated at temperatures between 600-900ºC.

5. Raw materials and their source

It is possible to shed light on the sources of the raw materials used in the production of the potsherds by correlating the mineralogical composition and fossils found in the limestone and other added inclusions to the possible raw materials deposited in the surroundings of the archaeological site. The recipe of pottery production comprises the clay and non-plastic inclusions of sub-angular to angular quartz and sub-rounded to angular limestone. They also contain crushed ceramic (grog) in different amounts. However, the most noticeable inclusions are the fine rounded basalt grains present in several samples, large angular basalt grains in several ones, and fossil traces in others (Figure 5). These petrographic components are consistent with the geology of the Umm as-Surab area, which is covered by Harrat Ash-Sham basalt rocks and soils and has outcrops of alluvium and wadi sediments (Figure 8) including clays, Pleistocene sediments, and Umm Rijam Chert Limestone (Garaibeh, 2003). Therefore, the presence of the fine basalt grains in the clay resulted from weathering and erosion of the basalt surrounding the site, while the larger angular crushed basalt grains were deliberately added to the clay paste. Similarly, crushed limestone grains were deliberately added. The fossiliferous Umm Rijam Chert Limestone comprising several kinds of fossils and outcropping about 8 km from Umm as-Surab are the probable source of the limestone and fossil inclusions noticed in the samples. The geological map of the region (Figure 8) shows possible clay and sand quarries within the Pleistocene alluvium and wadi sediments distributed in the region, since few of them are close to Umm as-Surab. All of this data suggests a local origin of the potsherds since they are formed of local raw material available in the region.

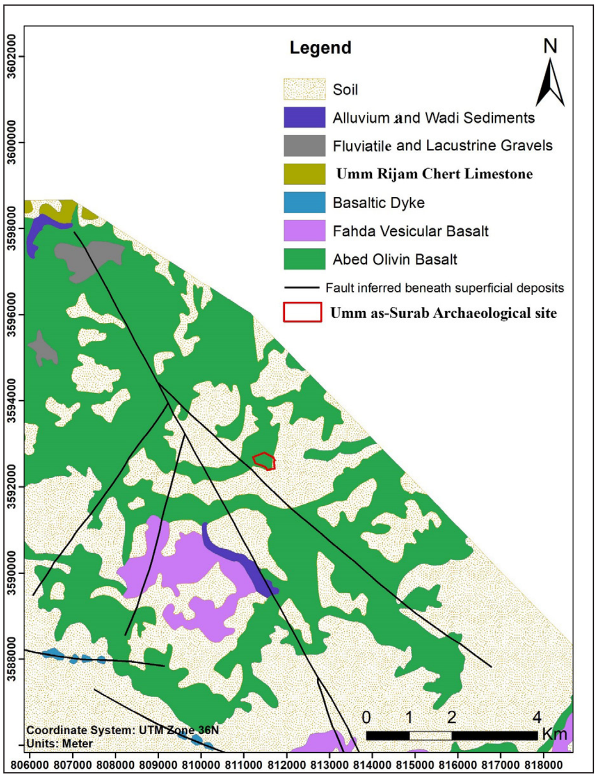

Figure 8. Figure 8. The geological map of Umm as-Surab area showing the probable sources of the raw materials.

6. Conclusions

The application of multidisciplinary analyses to study the pot samples, collected at Umm as-Surab archaeological site, northeast Jordan, offered more data on the production technology of the Umayyad and Ayyubid-Mamluk pottery in the area. The results show disparities in the concentration of their mineralogical and chemical composition reflecting different production recipes of the samples. The results could be attributed to several reasons: probable use of different sources of raw materials, the use of clays of the moderate and high content of carbonates, the addition of different amounts of non-plastic inclusions, varying firing conditions, and/or the import of wares from nearby workshops.

The Umayyad tableware potsherds appeared to contain clays of low carbonates and high silica contents and were fired at temperatures below than 850°C to resist thermal shocks (Papachristodoulou et al., 2006; Hein et al., 2008), while several of the Mamluk-Ayyubid water jars that contain higher amounts of carbonates and moderate to high content of silica were fired at temperatures around 800-950°C to reduce their permeability and porosity. Cooking wares were also manufactured by the addition of higher amounts of inclusions to the clay paste, as in sample SBR 27 (Tite el., 2001). However, it is also possible to achieve these properties in the ceramic body by mixing two or more different clays instead of adding inclusions (Neff et al., 1988).

The results agree with other studies on Umayyad and Ayyubid-Mamluk pottery. Most recently, Otoom (2019) found that the Umayyad potsherds of her study were imported to Tell al-Husn from other neighboring workshops, probably from Gerash and were fired at temperatures between 800 and 900oC. The recipes used in the production of the Umm as-Surab potshers disagree with those of the Ayyubid-Mamluk potsherds from Dohaleh, Hayyan al-Mushrif and Al-Bediah archaeological sites, examined by Al-Tawalbeh (1996), Al-Batainah (2003) and Al-Bataineh (2005), respectively. At Umm as-Surab, the potsherds could be distinguished by the presence of non-plastic basalt grains and absence of dolomite; while, the potsherds of Dohaleh and Hayyan al-Mushrif could be distinguished by the presence of non-plastic dolomite grains and absence of basalt.

The results show technological differences in ceramic production between the Umayyad and Ayyubid-Mamluk periods, which could be reflected in their historical and social contexts. While the tradition of Umayyad ceramic production was concentrated in urban centres such as Bosra or Jerash, with a large commercial exchange network, the Ayyubid-Mamluk ceramic was, to the contrary, mainly produced by workshops on a local scale.

From a macroscopic point of view, the Umayyad pottery of Umm as-Surab shows similarities to the pottery findings at the urban site of Bosra, located only 12 km to the northeast of Umm as-Surab. Administratively, Umm as-Surab followed Bosra during the Byzantine period, and most likely it remained under Bosra's economical and social influence during the Islamic periods.

However, the most interesting data for the settlement history of this site come from the ceramic context of the Ayyubid-Mamluk period, confirming the data of the settlement trends of other research projects, which concern the western part of Jordan, i.e. the area included between Irbid and the Yarmouk River (Walker, 2005; 2007). The data from ceramic studies of the eastern part of northern Jordan, on the contrary, have shown so far a paucity of information on the Middle-Islamic period, as the case of Umm al-Jimal (Osinga, 2017).

The Umm as-Surab research project, therefore, opens up a new moment of reflection on the dynamics of the population of the countryside in the Islamic Middle Ages. The ceramic analyses show that the production is mostly local but, in any case, with a good knowledge of production technologies. A comparison with ceramic assemblages from other sites in the region, such as those of Dohaleh, Hayyan al-Mushrif and Al-Bediah, confirms this hypothesis. Despite a rather local productive activity, the occupation of Umm as-Surab in the Ayyubid-Mamluk period demonstrates a historical context favourable to a revitalization of the countryside, supported by economic and social stability of the Mamluk sultanate which is reflected in an occupation program and exploitation of geological and agricultural resources at a larger scale.

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