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ARCHAEOMETRIC AND TYPOLOGICAL STUDY OF UMAYYAD POTTERY SAMPLES FROM TAL AL-HUSN ARCHAEOLOGICAL SITE, NORTH JORDAN

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Abstract:
This study aimed to identify the types and forms of selected Umayyad pottery samples from the archaeological site of Tal Al-Husn, determine the raw materials and firing technologies used in their production, and identify the provenance of these materials. The samples were first classified based on their types and then analyzed using scientific methods to investigate their chemical and mineralogical properties. The results of the descriptive study indicate that a variety of pottery types were produced at Tal Al-Husn during the Byzantine period, continuing into the Umayyad period. Additionally, there was significant diversity in terms of forms, pastes, rims, bases, decorations, and slips. The scientific analysis revealed that most of the studied samples were imported, as their raw materials did not match the local lithology of Tal Al-Husn and its surrounding areas. The closest source of these materials is the Jerash region. The Umayyad potters used a fast wheel to shape cooking pots and tableware, with cooking pots fired in an oxidizing atmosphere and the tableware pots in a reducing atmosphere, with some samples exhibiting mixed firing conditions. These items were fired at temperatures ranging from 950 to 1050 ºC. In contrast, jars and basins were fired in a reducing atmosphere at temperatures between 800 and 950 ºC.

1. Introduction

The study of archaeological pottery is served as a valuable indicator of the cultural, economic, and technological development of ancient civilizations. By tracing the evolution of pottery forms, researchers can estimate the relative dating of archaeological sites. This is particularly evident when examining pottery production techniques, which reflect not only industrial and cultural advancements but also the economic strength of a region, as evidenced by the widespread distribution of pottery. Such distribution suggests trade and exchange between different regions [1]. Pottery is characterized by its light weight, low production costs, the availability of raw materials, and its durability compared to organic materials. The development of pottery marked a significant stage in human history, as its forms, manufacturing techniques, and decorative styles evolved to meet the growing demands of daily life [2]. Initially, pottery was hand-formed, later evolving to include molding, wheel throwing, and other techniques. After forming, some items were fired, such as plates and jugs, while others, such as large jars, were simply sun-dried [3]. The pottery makers at the beginning of the Umayyad period continued to use techniques and traditions inherited from the Byzantine period [4,5]. However, over time, distinctive characteristics of Umayyad pottery began to emerge. These included the use of high-quality, impurity-free clay, superior firing techniques, and smoother textures. Local production of decorated plates and dishes increased, especially Jerash bowls and tableware [6]. Umayyad pottery also became thicker compared to its Byzantine predecessors. Surface treatments were applied through ribbing on the body of the vessel or by decorating with painted designs, often in red or brown, in the form of straight, wavy, or geometric lines [3,6,7]. For example, in Jerash, gritty reddish-orange, brown, and dark grey fabrics with freehand white-painted designs were common [8]. Large vessels for storage or water typically featured flared or thick rims, round handles on the shoulders, and flat bases. Smaller vessels had simple outward-slanting rims, varied neck shapes, and flat bases [7-9]. Typological studies of pottery—through classification, drawing, description, and analysis of its shapes, clay color, and decorations—allow researchers to estimate its dating [10]. In contrast, scientific laboratory analyses, which examine the internal composition of the pottery paste using physical and chemical mineral techniques, help identify its components (e.g., clay and added materials), as well as the manufacturing techniques (e.g., firing temperature and environment) used in pottery production. From this, it is possible to infer the type of kilns employed [11]. By combining both typological and scientific methodologies, a greater depth of information can be gained, offer a more comprehensive understanding of the society that produced and used these artifacts. This study aims to examine the pottery styles and their evolution during the Umayyad period at the Tal Al-Husn archaeological site in northern Jordan. It seeks to identify the raw materials and manufacturing techniques used, as well as determine the geographical source of the pottery—whether it was locally made or imported—through the mineralogical and chemical analysis of selected samples.

2. Tal Al-Husn

Tal Al-Husn is located approximately 5 km south of the city of Irbid, in northern Jordan, fig. (1). It rises about 13 meters above the surrounding flat terrain [12,13].

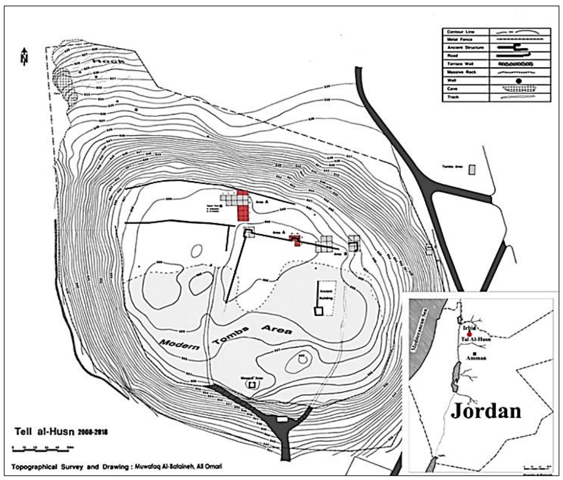

Figure (1) location map of Tal Al-Husn archaeological site and contour map of excavated site and the squares from which study samples were taken from the residential area (Area A) squares: (O6, O7, L6, L7, K6, K7, J6, J7, F16, F17, E16)

The site is named *Tal Al-Husn* due to the Umayyad military fortress located at the top of the hill, which was recently uncovered by Yarmouk University during excavation seasons in 2008 and 2009 [12]. The tell and its surrounding area have held significant importance throughout ancient history, serving as a major settlement site since the Chalcolithic period (4000 BCE). It saw intensive settlement during the three phases of the Late Bronze Age (1550-1200 BCE), due to the region's reputation for agriculture and its strategic military importance, which attracted the interest of ancient Egyptian kings. The site also played a role during the Iron Age (1200-539 BCE), as well as the Hellenistic and Roman periods. During the Byzantine period, the area saw further settlement, as evidenced by the presence of caves, water wells, a Roman pool to the southwest of the modern town of Al-Husn, and rock-hewn tombs and Byzantine churches. This settlement continued into the Islamic periods, particularly the Umayyad period, as evidenced by the remains of the fortress, mosque, and Umayyad houses [12,14,15]. Geologically, the rocks discovered at the site and its surrounding area, in terms of composition and geological formation, belong to the Ajloun Group (older), the Balqa group, and Holocene deposits. The Ajloun group primarily consists of limestone, with a succession of limestone or dolomite rocks interspersed with yellowish and greenish marl, containing a wide variety of fossils throughout [16-18]. The Balqa group, on the other hand, consists of various types of sedimentary rocks in a stratigraphic sequence from bottom to top: chalk, flint, phosphate, shale, marl, and chalk. It is capped by a succession of chalk, flint, and limestone, with carbonaceous rocks (marl, limestone, and dolomite) making up the majority of the group [16-18].

3. Study Samples and Their Archaeological Context

Excavations conducted by the archaeology department of at Yarmouk University over five seasons uncovered numerous archaeological remains, architectural fragments, and artifacts, as previously mentioned. During the 2018 season, additional remains were revealed, particularly in the Umayyad residential area, which yielded a significant number of pottery fragments. From these, 16 pottery shards were selected from square units in Area A, fig. (1) to form the study sample. The samples were chosen based on similar clay compositions, with damaged fragments excluded. The number of selected samples was proportional to the total groups, ensuring that the shards represented all types of pottery vessels discovered. These shards were dated to the Umayyad period based on their archaeological context, stratigraphic sequence, and comparable examples, tab. (1). The pottery fragments were categorized into three groups based on the function of the vessels, fig_s. (2 & 3): cooking pots (four shards), basins (two shards) and jars (three shards), tableware (two shards of jugs, two shards of bowls, two shards of plates, and one shard of a cup).

Table (1) description, parallel examples, and archaeological context of the study samples

S. No.	Description	*Parallel Examples	Archaeological Context	
			Square#	*locus#*
H9	Shard of a cooking pot lid, with an inward sloping rim, internal diameter 22 cm, external diameter 23 cm, thickness 3-4 mm. The paste is brown (3/4, 7.5YR) with small white particles and low porosity. The exterior surface is decorated with circular ribs, and the interior has a black added slip. Made with a fast wheel and well-fired.	Al-Salamain (2001: 284, fig. (99): 210) [20]	J6	006
H15	Shard of a cooking pot (casserole), with an inward sloping rim and a handle attached to the body. Internal diameter 13 cm, external diameter 14 cm, thickness 4-5 mm. The paste is brown (2/4, 7.5YR) with small white particles and low porosity. The exterior surface is rough with signs of use. Made with a fast wheel and well-fired.	Smith (1973: plate 45) [21]	O6	001
H18	Shard of a Cooking pots (jar), with an inward sloping rim and a handle added later. Internal diameter 22 cm, external diameter 23 cm, thickness 5 mm. The paste is dark gray (1/4, 10YR) with small white particles and high porosity. The exterior surface is rough, with burn marks from use. Made with a fast wheel and well-fired.	Al-Salamain (2001: 270, fig. (85): 179, 180) [20]	J6	009
H27	Shard of a Cooking pots (jar), with an S-shaped rim. Internal diameter 13 cm, external diameter 14 cm, thickness 2 mm. The paste is red (6/4, 2.5YR) with small white particles and low porosity. The exterior surface is smooth with signs of use. Made with a fast wheel and well-fired.	Brown (1983: fig. 54 (15)) [22], Al-Kusha (1999: 43, fig. (8): 3) [23]	J7	001
H35	Part of a cooking pot, with a flat base and part of the body. Thickness varies from 9-15 mm. The paste is light brownish gray (2/6, 2.5Y) with small white particles and high porosity. The exterior surface is rough with a yellowish added slip on the inside. Handmade and well-fired.	Najjar (1989: 315, fig. 6: 23) [24]	L7	003
H50	Part of a cooking pot, with a T-shaped rim and a decorative strip on the edge. Internal diameter 21 cm, external diameter 23 cm, thickness 6-15 mm. The paste is gray (1/6, 2.5Y) with small white particles and high porosity. The exterior surface has fine incised lines. Made by hand and well-fired.	Watson (1992: Catalogue, fig. (6): 47) [25], Al-Rayahi (1994: 235, fig. (9): 3) [26]	L7	003
H67	Part of a storage jar, with a neckless rim attached directly to the body. Internal diameter 21 cm, external diameter 27 cm, thickness 8-17 mm. The paste is gray (1/5, 2.5Y) with small white particles and low porosity. The exterior is decorated with a single row of finger impressions. Made by hand and well-fired.	Taxel and Fantalkin (2011: 91, fig. (3): 1) [27], Obaidat (2010: 157, fig. (5): 7) [28]	K6	005
H91	Part of a jar, with a round rim turned outward. Internal diameter 8 cm, external diameter 9 cm, thickness 3-5 mm. The paste is reddish yellow (6/6, 5YR) with small white particles and high porosity. The exterior has circular ribs, and the interior has a matching slip. Made with a fast wheel and well-fired.	Najjar 91989: 315, fig. (6): 26)0 [24]	L6	008
H101	Part of a jar, with a round rim turned outward and neck. Internal diameter 10 cm, external diameter 11 cm, thickness 3-4 mm. The paste is gray (1/6, 2.5Y) with small white particles and low porosity. The exterior has circular ribs, and the interior has a	Tushingham (1972, fig. (6): 30) [29]	K7	001

	matching gray slip. Made with a fast wheel and well-fired.			
H123	Part of a large pitcher, with a round rim. Internal diameter 8 cm, external diameter 9 cm, thickness 3 mm. The paste is very pale brown (3/7, 10YR) with small white particles and low porosity. The surface is smooth. Made with a fast wheel and well-fired.	Smith (1973: plate 1151) [21]	J6	000
H127	Part of a large pitcher, with a round rim turned outward. Internal diameter 8 cm, external diameter 9 cm, thickness 2-3 mm. The paste is light red (8/6, 2.5YR) with small white particles and low porosity. The exterior surface has circular ribs and a matching red slip. Made with a fast wheel and well-fired.	Kennedy and Freeman (1995: 65, fig. (29): 32) [30]	L7	003
H176	Part of a bowl, with a round rim. Internal diameter 7 cm, external diameter 8 cm, thickness 1-2 mm. The paste is gray (1/5, 10YR) with high porosity. The exterior and interior surfaces have a pale brown slip. Made with a fast wheel and well-fired.	Smith (1973: plate 32: 221) [21]	L6	005
H186	Part of a bowl, with an inward sloping rim. Internal diameter 11 cm, external diameter 12 cm, thickness 2-3 mm. The paste is light yellowish brown (4/6, 10YR) with small white particles and low porosity. The exterior surface has wavy lines painted in brown over a yellowish red slip. Made with a fast wheel and well-fired.	McNicoll et al. (1982: 61, plate 140: 3) [31]	J6	006
H168	Part of a cup, with a round rim. Internal diameter 8 cm, external diameter 9 cm, thickness 2-3 mm. The paste is very pale brown (4/7, 10YR) with low porosity. The exterior and interior surfaces have a reddish yellow slip. Made with a fast wheel and well-fired.	Obaidat (2010: 157, fig. (5): 1) [28]	J7	001
H95	Part of a plate, with a wide, outward-sloping rim. Internal diameter 15 cm, external diameter 18 cm, thickness 4 mm. The paste is light red (6/6, 2.5YR) with small white particles and low porosity. The exterior and interior have a light gray slip. Made with a fast wheel and well-fired.	Smith (1973: plate 30: 1157) [21]	K6	007
H99	Part of a plate, with a vertical inward-sloping rim and a protruding edge. Internal diameter 21 cm, thickness 2 mm. The paste is light reddish brown (4/6, 2.5YR) with small white particles and low porosity. The exterior and interior have a light red slip. Made with a fast wheel and well-fired.	Kareem (1999: 200, fig. (10): 19) [32]	L6	009

Similar examples*: the references used for comparison are based on previous works, such as Al-Salamain [20] and Smith [21].* ***Archaeological context****: includes the specific square and stratigraphic layer where the samples were found, which helps in determining their approximate historical period.*

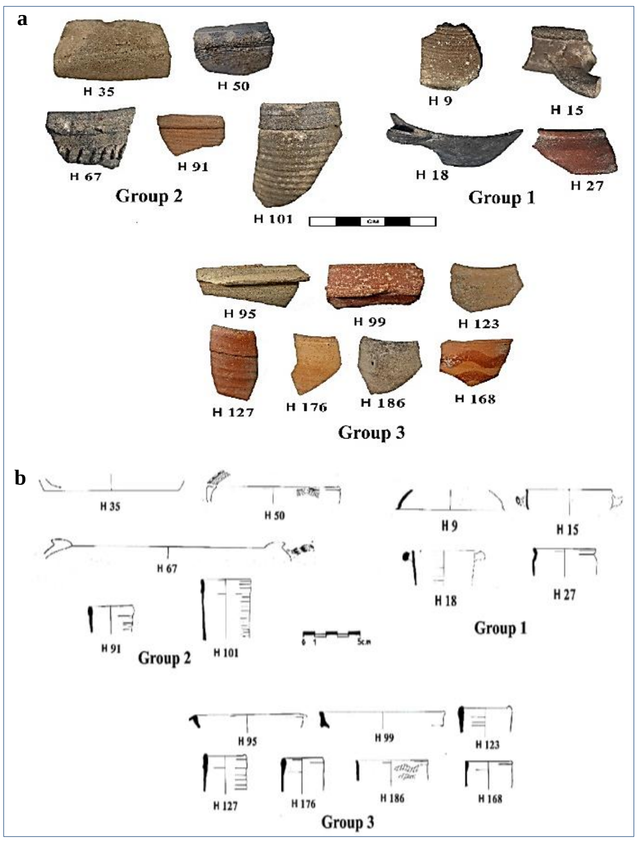

Figure (2) **a.** the study samples group 1 (cooking pots), group 2 (basins and jars) and group 3 (tableware), **b.** drawing of the study samples showing the different types of pottery sherds

4. Methodology

After sorting and classifying the pottery fragments into groups based on type, we studied the parts of the pottery vessels, documented the fractures, and provided a comprehensive description. The fragments were then digitally photographed. These groups underwent mineralogical and chemical analysis to examine the properties of the pottery, including the type of paste, added materials, firing temperature, and the type of kilns used in the firing process. Sample solutions were prepared following the method of Hughes et al. [19] and chemically analyzed in the laboratories of the College of Archaeology and Anthropology at Yarmouk Univ., using an atomic absorption spectrometer (model: Analytikjena-Contr AA 800). Furthermore, microscopic slides of the study samples were prepared and examined with a polarized light microscope (Leica) in the same college's laboratories. Finally, a portion of each sample was ground and analyzed by X-ray diffraction (XRD) using a Rigaku device at the Pharmaceutical Studies Center at the Jordan University of Science and Technology. The following operating conditions were used: X-ray material: Cu-Kα, maximum power: 1.8 KW, maximum voltage: 40 kV, maximum current: 40 mA, angle range: 0°-60°.

5. Results

5.1. *Descriptive analysis*

The descriptive study of the ceramic pieces revealed various features of the vessels. Cooking vessels contained openings with inward-sloping rims (H9, H15, H18), S-shaped openings (sample H27), and loop handles with a horizontal cross-section (samples H15, H18). The paste of some pottery pieces contained small white grains, which analysis identified as quartz. Most samples had a low-porosity, well-kneaded, and coarse paste, with colors ranging from red to brown, indicating firing in an oxidizing environment [33]. However, the paste of sample H18 was distinguished by high porosity, poor kneading, and a gray color, suggesting firing in a reducing environment. In terms of surface treatment, the exterior of sample H9 featured ribbing with a circular cross-section and a black coating [7,8]. The surfaces of the pottery had a rough texture with traces of use and were well-fired, made using the potter's wheel. The cooking pots included a T-shaped opening, as seen in sample H50, while the storage jars were characterized by a neckless design, with the body and rim directly attached, and round, outward-folded rims (samples H91, H101). Both cooking pots and storage jars shared a flat base (sample H35) and the presence of small white grains in their paste. The paste of the cooking pots was characterized by high porosity and poor kneading, while that of the storage jars had low porosity and good kneading. The paste of both types of vessels was predominantly gray, indicating firing in a reducing environment, except for jar H91, which had a yellowish-red paste. Regarding surface treatment of the cooking pots, the rim featured a decorative band made from the same paste as the vessel, with the rim folded inward using fingers. The upper surface of sample H50 had incised decoration, consisting of fine grooves made with a comb, forming wavey lines. Some storage jar pieces displayed two rows of finger impressions on the exterior, suggesting that the maker was likely female (H67). Ribbing with a circular cross-section was common on the exterior of storage jars (H91, H101), and a coating of the same type of paste was applied to both the interior and exterior surfaces [8]. The cooking pots were shaped by hand, while the jars were formed using a fast wheel, with all pieces being well-fired. Tableware, including pitchers, bowls, cups, and plates, featured a variety of rim shapes, such as round openings (samples H123, H127 from the pitchers; H176 from the bowl; H168 from the cup), inward-sloping thin rims (bowl H186), outward-sloping rims (plate H95), and vertical rims (plate H99). The paste of most pieces contained small white grains, with low porosity and good kneading. The color of the paste ranged from light brown to red, indicating firing in an oxidizing environment [33]. The bowl H176 had a distinct paste with high porosity, poor kneading, and a gray color, indicating firing in a reducing environment. The pitcher H127 had a ribbed surface with a circular cross-section, and geometric decorations consisting of two wavey lines painted in brown on a yellowish-red added coating, a style common during this period [7]. Except for pitcher H123, all of the studied tableware vessels had coatings on both their inner and outer surfaces, in colors such as light red, light brown, yellowish-red, and gray, generally indicating good firing. The potter used a fast wheel to shape these pieces.

5.2. *Chemical analysis*

The results of the chemical analysis, tab. (2), showed that the paste of the cooking vessels (Group 1) contains a generally low amount of lime (CaO < 3%), a relatively high amount of iron oxide (Fe_2O_3 = 4.18-9.02%), and a low amount of alumina (Al_2O_3 = 8.96-12.51%). The silica content was relatively high (SiO_2 = 69.99-78.92%). Sample H27 was an exception, as it contained a medium amount of lime (CaO = 9.53%) and the highest amount of potassium (K2O = 2.08%). Likely due to the combustion of organic materials added to the paste, which left longitudinal voids in this sample.

Table (2) the chemical analysis results (%) of the study samples by the atomic absorption spectrometer (AAS).

Group	Sample #	SiO_2	Al_2O_3	Na_2O	K_2O	Fe_2O_3	CaO	MgO
Cooking pots	*H9*	76.58	10.19	0.49	1.18	7.85	2.03	1.68
	H15	76.65	9.19	0.50	1.14	9.02	2.28	1.24
	H18	78.92	8.96	0.33	0.80	7.35	2.07	1.50
	H27	69.99	12.51	0.20	2.08	4.18	9.53	1.51
Jars and Basins	*H35*	73.18	12.88	0.22	1.38	5.22	6.10	1.02
	H50	72.36	11.88	0.21	1.43	5.44	7.46	1.22
	H67	70.87	13.34	0.26	1.74	5.25	4.48	1.06
	H91	66.06	19.12	0.20	1.83	4.03	7.70	1.06
	H101	72.60	18.73	0.13	2.25	3.63	1.69	0.97
Tableware	*H123*	69.99	12.51	0.20	2.08	4.18	9.53	1.51
	H127	62.43	22.37	0.18	2.98	4.64	6.16	1.24
	H176	65.41	16.05	0.21	2.77	5.33	8.24	1.99
	H186	65.82	18.45	0.20	2.12	4.12	8.13	1.15
	H168	73.66	16.39	0.31	3.40	4.23	0.90	1.11
	H95	69.64	13.87	0.25	2.03	4.73	8.30	1.18
	H99	70.32	14.55	0.56	2.84	6.39	3.32	2.02

The paste of the basins and jars (Group 2) contained a medium amount of lime (CaO = 4.48-7.70%) and a moderate amount of iron oxide (Fe_2O_3 = 3.63-5.44%). The alumina content was divided into two groups: moderate (Al_2O_3 = 11.88–13.34%) and high (Al_2O_3 = 18.73-19.12%). The silica content was relatively high (SiO_2 = 66.06-73.18%). Notably, samples H91 and H101 (fragments of storage jars) had a high alumina content and a low iron oxide content. Sample H101 also had a low lime content. The chemical analysis results for the paste of the tableware (Group 3), tab. (2), revealed that these samples were relatively heterogeneous. The pitcher and bowl samples (H176 and H186) contained moderate amounts of lime (CaO = 6.16-9.53%), while the plates and bowls had varying amounts of lime (CaO = 3.32-8.30%). The paste of the cup sample contained the lowest amount of lime (CaO = 0.90%) and the highest amount of iron oxide (Fe_2O_3 = 6.39%), similar to the paste of the cooking vessels. All samples in this group contained higher levels of potassium (K_2O = 2.3-3.40%) compared to previous groups, likely due to the combustion of organic materials added to the paste, which resulted in longitudinal voids in the samples. The pastes of these samples contained moderate amounts of iron oxide (Fe_2O_3 = 4.12-5.33%), and alumina content ranged from moderate to high (Al_2O_3 = 12.51-22.37%). The silica content was relatively high (SiO_2 = 62.43-73.66%).

5.3. *Petrography and XRD analysis*

Petrographic analysis results, tab. (3), revealed that the cooking vessels samples (Group 1) appeared under the microscope in shades of brown and red, with iron oxide present in the form of pigments. The pastes of these samples exhibited a bimodal grain size pattern and a texture ranging from fine to coarse. The non-clay particles made up 30% to 50% of the composition. Quartz was the dominant mineral phase, comprising 25% to 45% of the total content. The quartz particles ranged from fine to coarse in size, with shapes that were semi-rounded to angular, fig. (4). There was evidence of wavy extinction in the quartz grains, and some showed cracks. Some samples contained a few rounded, fine fractures of micritic lime, a few longitudinal voids, and secondary calcite in the voids.

Table (3) petrographic analysis results of the samples under polarized light microscope and mineral content as determined by XRD.

Cookware	S. No.	Color	Grain size pattern	Texture	Total non-clay Content (%)	Non-clay grains	Notes	*Mineral content based on XRD results
H9	brown	D. brown	Binary	Fine-Coarse	30	Quartz	Wavey extinction and some grains have broken surfaces. Iron oxide (staining).	Major: Qz. Trace: Pl, Mul, Cal, Di
H15	L. brown	gray to brown			35	Quartz	Wavey extinction. Iron oxide (staining). Some calcite grains.	Major: Qz. Trace: Pl, Mul, Cal, Di
H18	brown	V. D. brown			40	Quartz, Micrite	Wavey extinction. Iron oxide (staining). Some voids. Secondary calcite in some voids.	Major: Qz. Trace: Pl, Mul, Cal, Di
H27	red to brown	red			50	Quartz	Wavey extinction and some grains have broken surfaces. Iron oxide (staining). Some longitudinal voids.	Major: Qz. Trace: Pl, Mul, Cal, Hem, Di
H35	brown to Gray	D gray			50	Quartz, Micrite	Clear wavey extinction and some grains have broken surfaces. Iron oxide (staining). Secondary calcite on some grain edges.	Major: Qz. Trace: Pl, Mul, Cal, Di
H50	gray	D gray			50	Quartz, Micrite	Clear wavey extinction and some grains have broken surfaces. Iron oxide (staining). Secondary calcite on some grain edges.	Major: Qz. Trace: Pl, Mul, Cal, Di
H67	gray to brown	gray			35	Quartz, Micrite	Wavey extinction and some grains have broken surfaces. Iron oxide (staining). Secondary calcite on grain edges. Some voids in the sample.	Major: Qz. Minor: Pl Trace: Mul, Cal, Di
H91	L. brown to yellow	brown to gray		Fine-Coarse	25-30	Quartz	Wavey extinction and some grains have broken surfaces. Iron oxide (staining). Few voids in the sample. Some micritic lime grains.	Major: Qz. Trace: Pl, Mul, Cal, Di
H101	gray	gray to brown			25-30	Quartz	Wavey extinction and some grains have broken surfaces. Iron oxide (staining). Few voids in the sample. Some micritic lime grains.	Major: Qz. Trace: Pl, Mul, Cal, Di
H123	gray	gray to brown			45	Quartz, Micrite	Wavey extinction. Iron oxide (staining). Foraminifera microfossils present.	Major: Qz. Minor: Cal. Trace: Mul, Pl, Hem, Di.
H127	brown	brown to red			25-30	Quartz	Wavey extinction. Iron oxide (staining). Longitudinal voids from straw burning. Some micritic lime grains.	Major: Qz. Trace: Mul, Pl, Cal, Hem, Di
H176	L. gray	gray	Monogenetic	Fine-Medium	35	Quartz, Chalkstone	Some broken grains. Secondary calcite on grain edges. Staining. Iron oxide (staining). Foraminifera microfossils within chalkstone.	Major: Qz. Minor: Pl, Mul, Cal. Trace: Di
H186	L. brown	gray to brown	Binary	Fine-Coarse	35	Quartz	Some broken grains. Iron oxide (staining). Few voids in the sample. Some course micritic lime grains.	Major: Qz Trace: Pl, Mul, Cal, Di
H168	brown	brown to gray			40	Quartz	Very visible wavey extinction, smooth quartz grains. Iron oxide (staining). Secondary calcite on grain edges. Few voids. Some micritic lime grains.	Major: Qz. Trace: Pl, Mul, Cal, Di
H95	brown	brownish red	Monogenetic	Fine-Medium	25	Quartz, Micrite	Some broken grains. Iron oxide (staining). Few voids in the sample. Secondary calcite on grain edges.	Major: Qz. Minor: Pl, Mul, Cal Trace: Hem, Di
H99	L. brown	red to brown		Fine	35	Quartz	Some broken grains. Iron oxide (staining). Few voids in the sample.	Major: Qz. Trace: Pl, Mul, Cal, Hem, Di

***Qz**: Quartz, **Cal**: Calcite, **Pl**: Plagioclase, **Di**: Diopside, **Mul**: Mullite, **Hem**: Hematite*

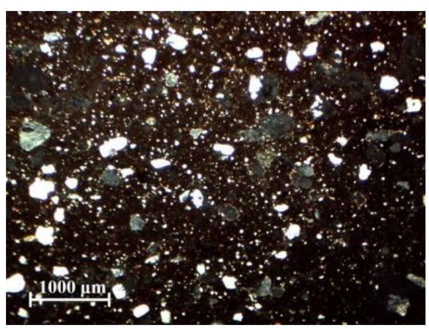

Figure (4) photomicrograph of the bimodal texture pattern in cooking vessel samples, sample H18, CPL.

Petrographic analysis results for the basins and jars samples (Group 2) showed similar colors under the microscope, ranging from brown to gray. The samples exhibited a bimodal texture and a grain size ranging from fine to coarse, with non-clay materials comprising 25% to 50% of the paste. The jar pastes contained a lower amount of non-clay materials. Quartz remained the dominant non-clay component (25%-35%), with particle sizes ranging from fine to coarse and shapes from semi-rounded to angular to sub-angular, fig. (5-a). Micritic lime fractures formed the second type of non-clay material, accounting for no more than 15% (samples H35, H50, H67), with fine grains and occasional coarse grains, exhibiting shapes from semi-rounded to sub-angular, fig. (5-b). Secondary calcite was found along the edges of some grains, fig. (5-c), while some quartz grains had fractured surfaces with clear wavy extinction, fig. (5-d). Some samples also contained voids.

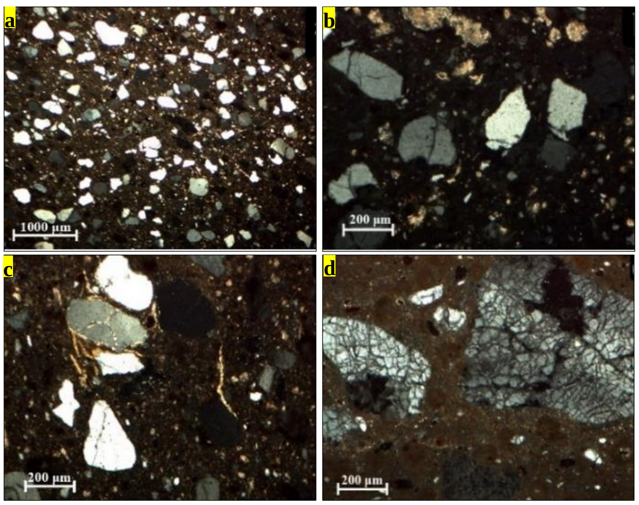

Figure (5) *CPL* microscopic image from pot and jar samples, **a**. a bi-modal texture pattern, sample H35, **b**. micritic lime grains, sample H50, **c**. secondary calcite around the edges of some grains, sample H35, **d**. broken quartz grains, sample H91.

Tableware samples (Group 3), shown in tab. (3), exhibited similar colors under the microscope, ranging from brown to red and gray. The samples varied in grain size homogeneity. Samples H95, H99, and H176 displayed a homogeneous pattern with fine to medium grain sizes, and the non-clay material content in their pastes ranged from 25% to 35%. Quartz grains made up 15% to 30%, with fine to medium grain sizes and shapes ranging from circular to sub-circular, fig. (6-a). These samples also contained fine fragments of micritic lime (5-15%). However, Merkel [34] found that the pastes of the Umayyad pottery of Jerash were prepared of 10-30% fine to medium poorly sorted quartz and 2-5% finer micrite limestone fragments mixed with non-calcareous clay. On the other hand, samples H168, H186, H123, and H127 exhibited a bimodal grain pattern with fine to coarse grains, and the non-clay material content ranged from 30% to 45%. Quartz grains were the main component (25%-40%), with fine to coarse grain sizes and shapes ranging from sub-circular to angular, fig. (6-b). Some quartz grains had fractured surfaces and exhibited wavy extinction, fig. (6-c). Some samples also contained voids, including longitudinal voids caused by the combustion of straw, fig. (6-d). Secondary calcite was observed along the edges of the samples and around some grains, and some samples contained microfossils (foraminifera), fig. (6-e).

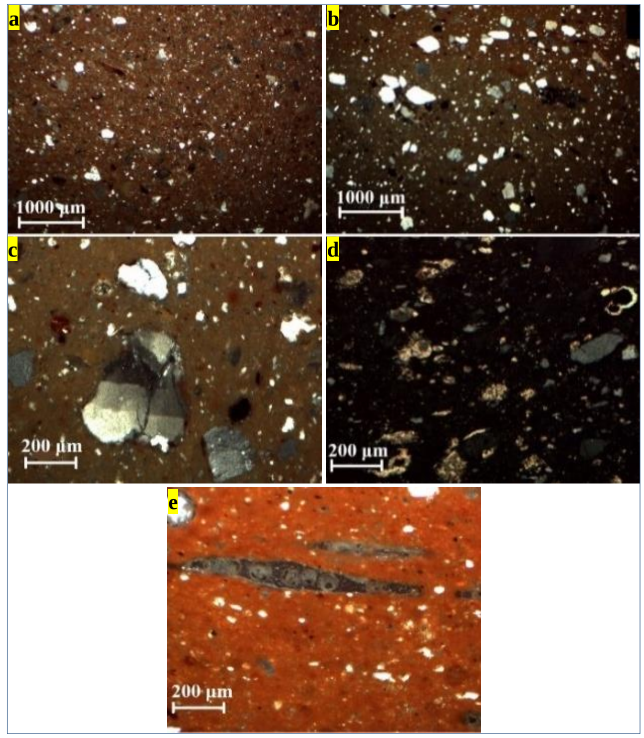

Figure (6) *CPL* microscopic image of samples from tableware group; **a**. homogeneous pattern (fine), sample H95, **b**. heterogeneous pattern, sample H168, **c**. the strongly visible wavey extinction in fire quartz, sample H168, **d**. longitudinal voids resulting from straw burning (*Straw impression*), sample H127, **e**. microscopic fossils of foraminifera, sample H176.

XRD results confirmed the findings from the petrographic analysis, tab. (3), revealing that all study samples contained quartz as primary mineral, with calcite, plagioclase, mullite, and diopside as rare minerals, fig. (7-a, b & c). Meanwhile, the samples of jugs and plates contained hematite as a rare mineral, fig. (7-d).

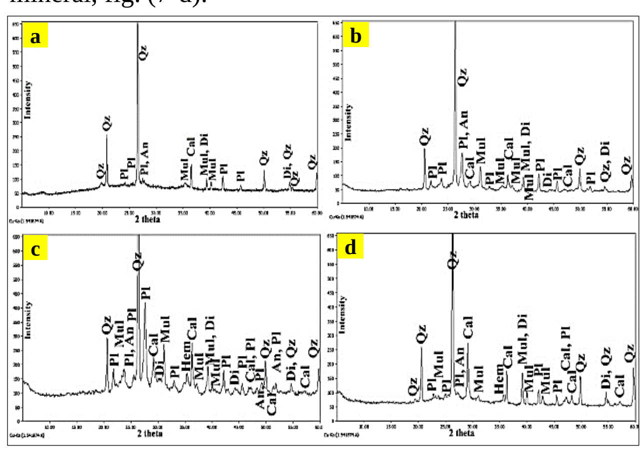

Figure (7) XRD patterns of analytical results and mineral phases in the studied samples. **a**. sample H9, **b**. sample H91, **c**. sample H95, **d**. sample H123. (*Qz: Quartz, An: Anorthite, Pl: Plagioclase, Mul: Mullite, Cal: Calcite, Hem: Hematite, Di: Diopside*).

6. Discussion

6.1. *Raw materials and their provenance*

Based on these results, it appears that the pastes of the studied ceramic pieces are heterogeneous in terms of the clay type used. The Umayyad potter employed two types of clay: non-calcareous, ferruginous clay for making cooking vessels and cups. This suggests the potter's awareness of raw materials suitable for each vessel's function. Cooking vessels are exposed to frequent heating and cooling, and non-calcareous clay improves the vessel's ability to withstand high temperatures and prevents cracking [35,36]. The exception is sample H27 from the cooking vessels, which contained a medium amount of lime (CaO = 9.53%), indicating it was likely made in a different workshop near Tal Al-Husn or imported from outside the site [37]. For making cooking pots, storage jars, and tableware, the potter used medium-calcareous, ferruginous clay. These vessels are not exposed to high temperatures, so the potter crafted relatively thick walls in the jars and cooking pots to match their intended purposes—transport, storage, and display [37,38]. The exceptions are sample H101 from the storage jars, made of non-calcareous clay with low lime content (CaO = 1.69%), and sample H99 from the plates, also made of non-calcareous clay with low lime content (CaO = 3.32%). This variation is clearly illustrated in the ternary diagram for alkali and alkaline earth oxides, SiO_2, and Al_2O_3, fig. (8).

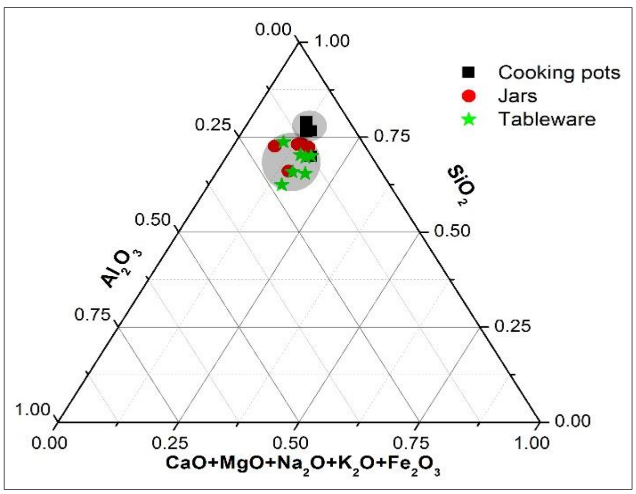

Figure (8) a 3D plot showing the distribution of the study samples according to their chemical composition, which reveals the clustering of the samples into two groups: the cooking vessels in one group and the remaining vessels in another group.

All the study samples exhibited a bimodal grain size pattern (except for the plates and bowl sample number H176). This can be explained by the fact that coarse grains were intentionally added by the pottery maker [39,40] to increase the plasticity, cohesion, and improve the thermal properties of the product. In contrast, the plate samples and the H176 bowl sample showed a unimodal grain size pattern, indicating that quartz, with its fine texture and circular or sub-circular shape, occurred naturally with the clay and was not added [38,39]. Quartz was found in the highest proportions of added materials (20%-45%) in bimodal samples, with clear sharp boundaries and cracks in the grains, as well as wavey extinction. This suggests that it was ground and intentionally added by the maker and mixed with the clay to improve thermal properties by increasing heat resistance, as seen in cooking vessels, as well as to reduce porosity and plasticity of the clay, and limit shrinkage during firing. The presence of some voids in the samples indicates that straw was added to the clay, and when it burned, these voids remained, oriented in the direction of the potter's wheel, confirming its use in production. As for calcite, it has two sources: one secondary, found along the edges of some samples and around some grains, resulting from deposition in the burial environment; the other is micritic lime (in small amounts), which occurred naturally with the clay [5]. In general, the intentionally added quartz is not found in the region of Al-Husn and its surroundings, fig. (9) [17, 18], indicating that the studied pieces are not locally made, particularly since no pottery kilns have been uncovered at the site The closest possible source is the Jerash region, where sandstone is found to the south [18]. In fact, several pottery kilns have been excavated from Jerash, which were dated to Umayyad and Abbasid periods, such as the kilns around the North Theater, Artemis Temple, and the potter kilns complex to the north of the Decumanus [41-43].

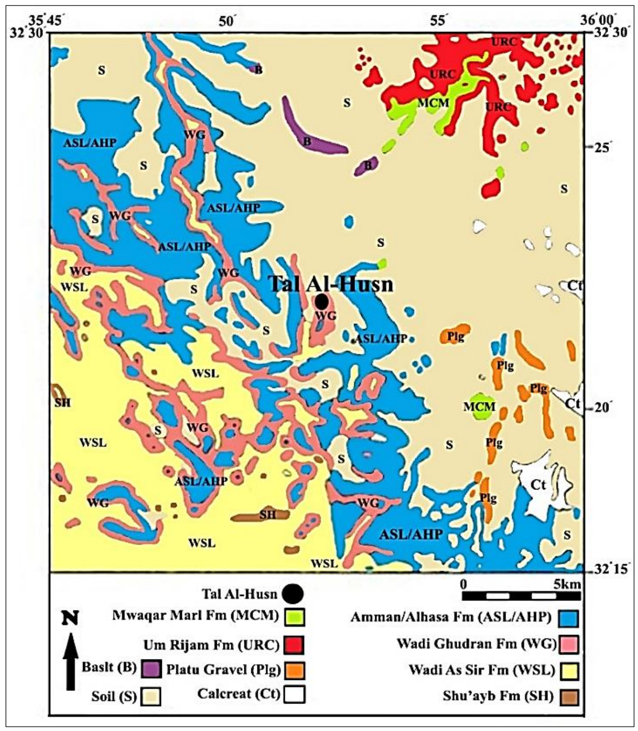

Figure (9) a geological map showing the rock formations in the study area; modified (After: Mohd, 2000 and Abdelhamid, 1995).

6.2. *Firing technology*

The decomposition of calcite ($CaCO_3$) during pottery firing leads to the formation of new minerals in limestone clay at temperatures above 800°C, depending on the type of clay and added materials. The formation of these minerals is linked to specific temperatures, and the resulting minerals are influenced by the furnace atmosphere and firing temperature [35]. Upon reviewing the XRD analysis results, tab. (3) and fig. (7), it was found that the samples generally contain the mineral diopside, which forms at firing temperatures of 900-950°C, and mullite, which forms at temperatures above 1050°C, in small amounts. The presence of calcite in the results can be interpreted as having precipitated in cracks from the burial soil, known in this case as secondary calcite. Hematite, responsible for the reddish coloration, typically indicates an oxidizing firing environment [5,39,40]. From the above, it can be concluded that the pottery maker fired cooking pots, jugs, dishes, yogurt containers, and cups at temperatures ranging from 950 to 1050°C. This firing range was likely used because the high temperatures impart increased hardness and thermal resistance to the ceramics. The minerals formed at these temperatures, such as mullite and diopside, are heat-resistant. This is also true for sample H27, which was fired at a temperature above 900°C, surpassing the decomposition temperature of calcite ($CaCO_3$). By firing at high temperatures, the pottery became resistant to thermal shock and cracking due to calcite decomposition. The ceramics were also made with thin walls, allowing for easier heat transfer from the outside to the inside. This further emphasizes the pottery maker's understanding of the intended purpose of the pottery, which was frequent reheating. Jars and pots were fired at temperatures ranging from 800 to 950°C, as minerals generally form at slightly lower temperatures (50-100°C lower) in a reduced environment compared to an oxidizing firing environment [44,45]. These pots also had relatively thick walls, which suited their use for transport, storage, or display [35, 37]. Cooking utensils and tableware pottery were fired in an oxidizing environment, resulting in clays with shades of brown and red, while pots, jars, and specific pieces of jugs (H123) and yogurt containers (H176) were fired in a reducing environment, resulting in clays with shades of gray.

7. Conclusion

Based on the previous results, it can be concluded that the Umayyad potter used non-calcareous, iron-rich clay and added a high proportion of quartz to prepare the pottery paste for cooking utensils. The addition of quartz improved the paste's properties, reduced porosity, provided appropriate plasticity, minimized shrinkage, and reduced thermal shock, enabling the vessels to withstand repeated heating and cooling during daily use. Additionally, the potter intentionally made these vessels with thin walls to allow greater heat transfer from the outside to the inside. Generally, cooking vessels were fired in an oxidizing environment at temperatures ranging from 950°C to 1050°C, as the potter recognized that such vessels required high firing temperatures to form heat-resistant minerals, selecting raw materials suited to the vessel's function. Wheel marks were evident on the bodies of these vessels, indicating they were made using a fast wheel. For jars and cooking pots, the potter used medium calcareous and medium iron-rich clay, adding less quartz compared to cooking vessels. They also used a higher proportion of lime, as these types of vessels were not exposed to heating during use. The paste of the jars contained small amounts of calcitic fragments, which naturally occurred with the clay. The potter increased the thickness of these vessels' bodies to suit their intended use for loading, display, transportation, and storage. The presence of quartz, which was intentionally added, suggests that these pieces were not locally made, with the closest possible source being the Jerash area, where sandstone is found to the south. Jars and cooking pots were fired in a reducing environment at temperatures between 800°C and 950°C. The storage jars and cooking pots featured relatively thick walls to suit their function, and the inconsistency in wall thickness and the presence of the potter's fingerprints indicated they were handmade. As for the tableware utensils, the potter used medium calcareous and medium iron-rich clay, similar to the jars, except for sample H99 from the plates and a cup sample, which were made from non-calcareous clay. This group contained high levels of potassium compared to the other two groups, indicating a different source for the clay used in their production. This group was divided into two categories based on the non-clay materials: the samples of jugs, the cup, and the yogurt sample H186 contained quartz grains with a bimodal distribution. Meanwhile, the plates and yogurt sample H176 contained a unimodal grain size distribution, suggesting that the quartz, being fine and either round or sub-rounded in shape, occurred naturally with the clay. These items were generally fired in an oxidizing environment, while sample H123 from the jugs and sample H176 from the yogurt were fired in a reducing environment, at temperatures between 950°C and 1050°C. Wheel marks were also visible on the bodies of these vessels, indicating they were made on a fast wheel. The quartz intentionally added by the potter to the paste of all the study samples is not found in the exposed rocks in the Al-Hasan area and its surroundings. This indicates that the studied pieces were not locally made. The closest possible source for the quartz, specifically sandstone, is the area south of Jerash.

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