

PETROGRAPHIC STUDY OF SELECTED MAMLUK-PERIOD POTTERY FROM KHIRBAT DIN'ILA

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Twenty-seven vessels dated to the Mamluk period from Khirbat Din'ila¹ were selected and sampled for petrographic examination (see Frankel and Getzov, this volume; see Stern, this volume).

The thin sections were prepared and examined under a polarizing microscope at magnifications between $\times 20$ and $\times 200$. The descriptions of the thin sections were prepared with the aid of charts and tables (Whitbread 1986:80; Orton, Tyers and Vince 1993:236–239). The samples were sorted into 'petrographic groups' based on the similar petrographic affinities of the vessels' clay and temper, regardless of archaeological variables such as typology, chronology or geographic location of the sample's archaeological findspot, the usual practice for petrographic studies (Goren 1995:290). By this means, comparison of the ceramic assemblage is based solely on the raw materials using independent technical criteria.²

The petrographic data were compared to the geologic settings in close proximity to the site (Sneh 2004) and the surrounding geographic area.

BACKGROUND

The raw materials for producing ceramic vessels are clay, which can be primary (underlying bedrock decomposition *in situ*) or secondary (sedimentary), and water, whose soluble salts may be incorporated in the clay. Non-plastics that may be naturally present in the clay groundmass or are added by the potter are termed 'temper' (Orton, Tyers and Vince 1993:113–117). The 'temper' can be either

natural, for example, sand or straw, or artificial, such as crushed rock or potsherds (so-called 'grog').

The following parameters were studied: the mineralogy and approximate amount of silt-sized material and the optical properties of the matrix; the mineralogy of non-plastic materials;³ volume in the sherds; grain size; shape; and sorting. Firing temperature was estimated according to the following mineral changes: Limestone and calcite begin to decompose at 700°–750°C and carbonate disappears, leaving voids, at 900°C (Rice 1987:97–98); hornblende turns to oxyhornblende (green to deep red) at 800°–850°C; clay turns to pottery at a temperature greater than 600°C; clay minerals start to change their optical properties at 650°–700°C; and at temperatures greater than 800°C clay turns isotropic and milky, a process termed vitrification. Full vitrification is reached at temperatures of approximately 1000°C (Porat 1986–1987:112; Rice 1987:80–110).

RESULTS

All the vessels examined were divided into four petrographic groups.

Group I.—This group is the most representative (22 samples out of the 27 examined), and includes unglazed and glazed storing, cooking and table wares (Table 1). All the examples have an isotropic ferruginous silty matrix containing silt-sized components that are sub-angular to rounded quartz (comprising c. 1–2% to 6–8% of the volume of the matrix) and rare minute ore nodules (opaque under the

Table 1. Inventory of Thin Sections of Group 1

Section	Locus/Wall	Basket	Vessel	Fig. No. ⁱ	Permit No.	Petrographic Subgroup
P3.5	W4	14/1	Bowl	7:7	A-3545	1.1
P4.2	58	645/2	Bowl	7:13	A-1313	1.1
P4.3		628	Bowl	7:15	A-1313	1.1
P5.1		626/1	Bowl	9:5	A-1313	1.1
P5.2		603/1	Bowl	10:2	A-1313	1.1
P5.3	10	102	Bowl	10:5	A-1313	1.1
P5.4	58	636/4	Deep bowl	10:6	A-1313	1.1 (Fig. 1)
P5.5	5	15/1	Deep bowl	10:7	A-3545	1.1
P1.1		628	Jug	4:6	A-1313	1.1
P6.3	55	627	Jar	11:5	A-1313	1.1
P1.3		616/1	Jug spout	4:10	A-1313	1.1
P6.4		118	Lamp	8	G-54/1986	1.1
P4.1	53	606	Bowl	7:10	A-1313	1.1
P3.4		612/1 (608)	Bowl	7:1	A-1313	1.2
P4.4	55	621/1	Bowl	9:3	A-1313	1.2
P2.4	52	527	Cooking bowl	6:7	A-1313	1.2
P2.3	58	641	Cooking bowl	6:1	A-1313	1.2 (Fig. 2)
P1.5		638/2	Jar	5:1	A-1313	1.2
P1.4	W4	14	Jug base	4:12	A-3545	1.2
P6.2	55	602	Jug handle	11:2	A-1313	1.2
P3.2		603	Cooking pot	6:11	A-1313	1.3
P3.3		(27)	Cooking pot from Oil Press A	6:12		1.3 (Fig. 3)

ⁱ For vessel figure numbers in this and the following tables, see Stern, this volume.

microscope). This group was divided into three subgroups according to the quantities of non-plastic inclusions and firing temperatures.

Subgroup 1.1 includes thirteen samples, mostly bowls (Table 1). Sand-sized materials in these samples comprise 0.5–5.0% of the volume of the potsherds, which means that they may have been present naturally within the clay, and are represented by rounded to sub-rounded quartz grains varying in size from 0.2 to 0.8 mm, sporadic chalk fragments (0.2–0.3 mm) and same-sized opaque rounded particles with occasional silt-sized quartz inside. Firing

temperature was estimated at 750°C or slightly greater because the clay minerals of the matrix partially preserved their optical properties and the carbonate material (chalk) is still present in the sections.

Subgroup 1.2 includes five specimens, two cooking pots, two bowls, two jugs and one jar (Table 1), in which sand-sized materials comprise 8–20% of the volume of the sherds. It is composed of rounded to sub-angular quartz grains varying in size from 0.2 to 0.7 mm, and rounded cavities of the same size, which could have remained after some carbonate

Table 2. Inventory of Thin Sections of Group 2

Section	Locus	Basket	Vessel	Fig. No.*	Permit No.
P1.2		638	Jug with strainer	4:11	A-1313
P2.2		604	Jar	5:5	A-1313
P2.1	40	401/1	Jar (Fig. 4)	5:3	A-1313

Table 3. Inventory of Thin Section of Group 3 (Fig. 5)

Section	Locus	Basket	Vessel	Fig. No.	Permit No.
P6.1	12	108/1	Two-handled jug	11:1	A-1313

material (for example, chalk balls or calcareous sand) decomposed while firing, or after quartz grains fell out while preparing the thin section. Some of the quartz grains have a ferruginous coating. There are in addition rare dark brown opaque nodules of some ore mineral, lumps of ferruginous shale and sandstone and/or siltstone with calcareous or ferruginous cement. The optical properties of the clay minerals of the matrix, which show stages of vitrification, indicate a firing temperature estimated at 800°C or more.

Subgroup 1.3 includes two cooking pots (Table 1), whose firing temperature is estimated at close to 800°C. The non-plastics present in the thin sections comprise about 20% of the volume of the sherds and some grains are relatively coarse (2–4 mm). In addition, other minerals and rocks particles were observed. Elongated and rounded dark brown opaque to brown ($0.2 \times 0.8 - 0.5 \times 2.0$ mm) particles of shale or pure clay are frequent, and sporadic rounded grains of basalt (0.2–1.5 mm) at different stages of vitrification. Some of the elongated inclusions are oriented parallel to the vessel surfaces, others are not. The poor orientation of the tempering material points to the low quality of the paste, which was not carefully mixed and/or thrown.

Group 2.— This group is represented by one jug and two jars (Table 2). These vessels were

allocated to this group based on the main feature they have in common, namely the presence of microfossils and their fragments within the thin section. They have a ferruginous carbonatic matrix containing foraminifers, complete and fragmentary, small amounts of silty quartz and brown nodules of pure clay. Sand-sized materials comprise 0.5–2.0% of the volume of the sherds and are represented by cryptocrystalline or milky carbonate grains, rounded fragments of foraminiferous chalk, rare quartz grains and opaque nodules of possibly pure clay, all 0.3–0.4 mm. Firing temperature is estimated at 750°C.

While the vessels belong to the same petrographic group, there are some differences between them. All the carbonate material in Jar Sample P2.2 is milky, which hints at a higher firing temperature (closer to 800°C). Jar Sample P2.1 contains more microfossils than do the others in this group.

Group 3.— This group is represented by one decorated, two-handled jug (Table 3), whose matrix is calcareous and rich in foraminifers, comprising about 25% of its volume. Minute opaque ore particles can be seen in the thin section. Sand-sized materials, comprising 2–4% of the volume of the sherd, are rounded particles of foraminiferous chalk (0.5–1.5 mm), rounded chalk particles and shell fragments with their lamellar inner structure still preserved. There are several fine (0.2–0.3 mm) quartz grains

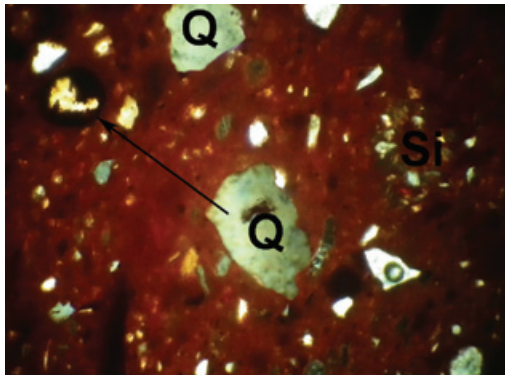


Fig. 1. Sample P5.4, deep bowl. Magnification $\times 50$, PPL. Q – quartz, arrow-marks – quartz grain with ferruginous coating, Si – siltstone.

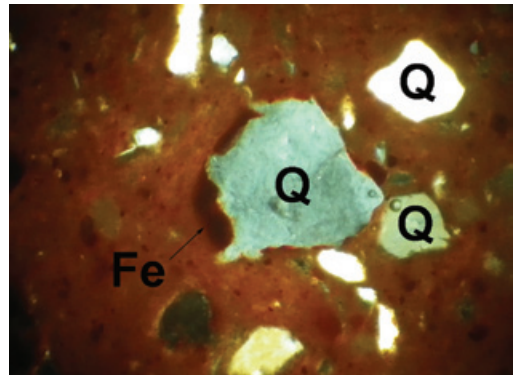


Fig. 2. Sample P2.3, cooking bowl. Magnification $\times 50$, PPL. Q – quartz, Fe – ferruginous coating on quartz grain.

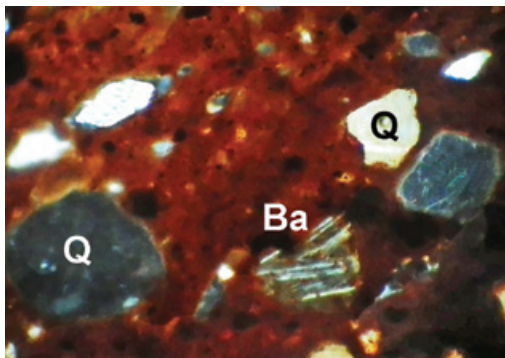


Fig. 3. Sample P3.3, cooking pot. Magnification $\times 50$, PPL. Q – quartz, Ba – basalt.

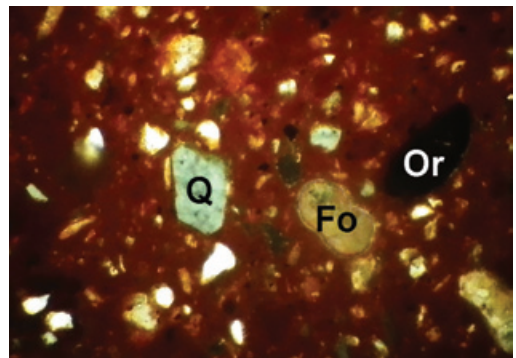


Fig. 4. Sample P2.1, jar. Magnification $\times 50$, PPL. Q – quartz, Fo – foraminifera, Or – ore mineral.

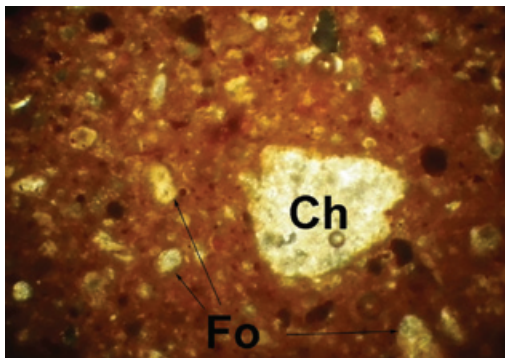


Fig. 5. Sample P6.1, jug. Magnification $\times 50$, PPL. Ch – chalk, Fo – foraminifera.

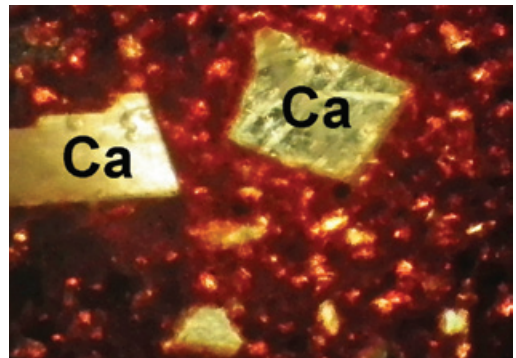


Fig. 6. Sample P3.1, cooking pot. Magnification $\times 50$, field PPL. Ca – crushed calcite.

Table 4. Inventory of Thin Section of Group 4 (Fig. 6)

Section	Locus	Basket	Vessel	Fig. No.	Reg. No.
P3.1		632/1	Cooking pot	6:16	A-1313

and a single inclusion of ferruginous limestone (4.5 mm) in the thin section. Firing temperature for this sample is estimated at between 700°C and 750°C because all the carbonate materials within the sherd saved their optical properties.

Group 4.— This group includes one unglazed cooking pot (Table 4), which has a ferruginous calcareous matrix with a reddish outer layer and a dark gray core (the inside of the sherd's cross section). The matrix contains minute particles of opaque ore mineral, silty quartz, and minerals derived from basalt (plagioclase, sporadic olivine and augite).

The sand-sized material is different from all the other types mentioned above, represented by angular calcite crystals split along their cleavage planes (0.1–0.3 to 1.2 mm), comprising about 7% of the volume of the sherd, sporadic rounded quartz grains (0.3–0.4 mm), shell fragments and rounded opaque nodules (1.5 mm). Despite the relatively small amount within the sherd, the sand-sized material should be termed 'temper', as there is no doubt that the crystalline calcite was crushed, sieved and then added to the paste. The presence of the calcite crystals indicates that the firing temperature reached no more than 700°C.

DISCUSSION

The raw material for the production of the vessels from Group 1 (Table 1) is probably *terra rossa* soil, which originates on top of carbonate rocks such as dolostone and hard limestone. *Terra rossa* frequently occurs on hills in the area of the southern Levantine Mediterranean, including the area in close vicinity to the excavated site,⁴ the Galilee in general, Mt. Carmel, the Judea–Samaria region

(Ravikovitch 1969; Wieder, Adan-Bayewitz and Asaro 1994:312–314; Goren and Halperin 2001:158; Wieder and Adan-Bayewitz 2002:395–397) and other regions. Thus, the provenance of the vessels belonging to Group 1 cannot be more precisely determined based on the matrix alone. On the other hand, sand-sized inclusions in the samples forming Group 1 can be indicative of provenance.⁵ The quartz sand with rounded grains and ferruginous coating, sandstone and siltstone, mentioned for the discussed samples, can be found only in the Lower Cretaceous formations, which are not characteristic of the area around the site (Sneh 2004). The Lower Cretaceous formations crop out in the Ḥananya Valley in Galilee, on the foothills of Mount Ḥermon, on the southern Lebanon Range (the area of Beirut) as well as in Transjordan, c. 50 km north of the Dead Sea, and in the Dead Sea region (Picard and Golani 1987).

Petrographic studies of a similar yellow-and-green gouged ware glazed bowl (see Stern, this volume: Fig. 10:5) excavated at Karak (Mason and Milwright 1998:181, Fig. 3.18) reveal a petrographic picture similar to that of the samples from Subgroup 1.1 and the same lithological raw materials may have been used in both cases.

The basalt grains present in samples from Subgroup 1.3 lead us to the area, where the materials deriving from the Lower Cretaceous formations meet those deriving from the basalt formations. The Ḥula Valley, where all the geological formations and soils can be easily found (Sneh and Weinberger 2003), matches the provenience for the vessels of Subgroup 1.3.

The foraminiferous rendzina soil, possibly mixed with *terra rossa*, may have served as

raw material for the Group 2 pottery (see Table 2). The rendzina soil originated on marl and biogenic chalk formations in the same areas mentioned for the *terra rossa* (Wieder, Adan-Bayewitz and Asaro 1994:312–314; Goren and Halperin 2001:158; Wieder and Adan-Bayewitz 2002:397–406). Lithological data on the region near Kh. Din'ila reveal that areas covered with this soil are situated about 2 km to the east (near Iqrit) and about 4 km to the south (Har Me'ona; Ravikovitch 1969) but in general, this soil is rather widespread throughout the region. The carbonatic sand-sized material present in the sections of Group 2 could be from the same geological source as that of the matrix and the quartz grains might be a result of the alluvial origin of the soil. Thus, based on petrography, it is difficult to determine the exact place of origin of these pottery samples within the Galilean hills.

The decorated two-handled jug attributed to Group 3 (Table 3) has a matrix composed of foraminiferous marl. The microfossils in the grains of foraminiferous chalk (non-plastic) present in the sherd are of the same geologic source as those within the matrix. The identifiable microfossils (mostly *Globorotalia* and *Subbotina*) are common in the Paleocene–Eocene ages (Blake and Goldschmidt 1947:326–327). Paleocene Taqiye Formation marl could have been used as raw material for the plastic component of the sample. Although the geologic formation is rather clear, the provenance of the vessel cannot be determined because Taqiye Formation marl is widespread along the southeastern Mediterranean (Bentor 1966:72–73); it crops out at four points in the Galilee—near Safed, Lavi, Aḥihud and Ya'ara—in close proximity to Kh. Din'ila (Sneh, Bartov and Rozenshaft 1998; Sneh 2000:3).

Basaltic Brown Mediterranean soils may have served as raw material for the cooking pot with crushed calcite 'temper', which represents Group 4 (see Table 4). The Basaltic Brown Mediterranean soils developed on basalts of different ages (Bentor 1966:45) and were frequently used for pottery production (Wieder,

Adan-Bayewitz and Asaro 1994:312; Wieder and Adan-Bayewitz 2002:406–410; Shapiro 2013). The basalt flows appear along the Jordan River in upper Galilee and in the eastern part of Lower Galilee (Sneh 2004), and the appearance of the basaltic soils among the examined examples well-correlates to this fact. I suggest that one of these areas could be the provenance of the vessels from Group 4. Crushed calcite was used for tempering the paste for cooking wares since the earliest periods of human history⁶ because calcite as temper increases the thermal-shock resistance of the vessels and reduces their porosity, and because of the similar expansion rates of calcite and clay (Arnold 1985:24). Crushed calcite became very common as tempering material for cooking pots from the Early Bronze to the Iron Ages (Glass et al. 1993:277–278), after which it was replaced by other tempers (Gopher, Sadeh and Goren 1992:13). Cooking-pot samples from the 2012 excavation at Ramla⁷ observed recently by the author reveal that this tradition reappears in the Mamluk period.

Calcite originates in calcite veins that are very common in the carbonate formations of Israel. The use of crushed calcite indicates that it was especially mined from veins in limestone to be crushed carefully and afterward added to the clay. This process, more time consuming than using wadi sand, is aimed at specific goals, such as tempering cooking wares.

CONCLUSIONS

All the soil types mentioned above are known for their use in pottery production throughout human history, as are the use of quartz sand or crushed calcite tempers. No innovations in pottery technology were brought to light by this study. Its significance lies in it being an addition to a yet earlier petrographic analysis of Mamluk-period pottery from Qazrin (Porat and Killebrew 1999). Further analyses of Mamluk-period pottery types will undoubtedly lead to a better understanding of pottery production during this period.

NOTES

¹ Permit Nos. A-1313, A-3545. I would like to thank Rafael Frankel, Nimrod Getzov and Edna J. Stern for allowing me to examine and publish this ceramic assemblage.

² However, there are always problems in classifying archaeological material into petrographic groups (see Glass et al. 1993:272); for example, defining the samples for the comparison and at the same time defining the degree of petrographic similarity and whether these definitions are enough for two examples to be classified within the same group.

³ In cases where they appear in large quantities, they are usually called temper (Rice 1987:72).

⁴ Khirbat Din'ila is located in the mountainous western part of Upper Galilee, where Cenomanian and Turonian dolostone and limestone are exposed.

⁵ These inclusions could be naturally present within the soil, especially in the case of Subgroup 1.1. For Subgroups 1.2 and 1.3, where sand-sized inclusions are present in quantities of between 10 to 20%, either they were left within the soil by a potter who did not carefully prepare the paste or they were purposely added to the paste as temper to improve its quality.

⁶ Tel Te'o: the Neolithic and Chalcolithic periods and the Early Bronze Age (Goren and Halperin 2001:157–159); Horbat Duvshan: the late Chalcolithic period (Shapiro 2013).

⁷ Ramla, Ha-Ezel Street, excavated by Ron Toueg in 2012 (Permit No. A-6297). The cooking pots from Ramla were of a different type and were handmade. I would like to thank the excavator for the opportunity to study the pottery from this excavation.

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