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Mathilde Jean. Pottery production at Tell Arqa (Lebanon) during the 3rd millennium BC: preliminary results of petrographic analysis. *Levant: The Journal of the Council for British Research in the Levant*, 2020, 52 (1-2), pp.136-159. 10.1080/00758914.2018.1454239 . hal-03215208

HAL Id: hal-03215208

<https://hal.science/hal-03215208>

Submitted on 10 Dec 2021

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Pottery production at Tell Arqa (Lebanon) during the 3rd millennium BC: preliminary results of petrographic analysis

Mathilde Jean

Studying well-documented assemblages is key to enhancing our understanding of the long-term evolution of pottery production and distribution in Bronze Age Levant. As a contribution to this effort, this paper presents, for the first time, the results of petrographic analysis undertaken on the Early Bronze (EB) pottery assemblage from Tell Arqa (northern Lebanon). Macroscopic and thin-section analyses were performed on a large set of samples. Beyond the characterization of eight petrographic groups, the study discusses the provenance of the raw materials and, taking advantage of the precise stratigraphic and typo-chronological sequence, gives a detailed vision of temporal change in ceramic production. It highlights a disruption at the end of the EB II–Early Central Levant (ECL) 2 and then a continuous evolution towards the homogenization of production both petrographically and technically — until the end of the EBA. Finally, through comparison with other evidence, it is possible to contextualize the evidence from Tell Arqa within regional Levantine pottery traditions existing during the 3rd millennium BC.

Keywords ceramics, petrographic analysis, Early Bronze Age, northern Levant, Lebanon

Introduction

Pottery production constitutes an important research topic for the archaeology of the Early Bronze Age in the northern Levant. In western Syria and the Orontes valley, EB occupations have been identified since the early 20th century and typo-chronological sequences have been established on key sites, for example, Hama (Fugmann 1958), Tell Mardikh-Ebla (D’Andrea 2016; Mazzoni 1985; Vacca 2015), Tell Nebi Mend (Kennedy 2015). In contrast, in northern Lebanon, the EB culture was little known until recently and appears quite different. Byblos was one of the first sites excavated in the region, but the problematic means of excavation and recording has always made it difficult to reconstruct a reliable chrono-stratigraphy (Dunand 1950; Saghieh 1983). The Tell Arqa

project is of primary importance, as it has provided a continuous sequence for the EBA, based on ceramic evidence and radiocarbon dates — from transitional strata between Chalcolithic and EB II to the end of EB IV — and so constitutes a reference point for the archaeology of the central Levant (Thalmann 2006a; 2016). Recently, excavations in the area revealed a number of EB settlements that will expand our knowledge on this topic: for example, Tell Fadous (Genz 2010; 2014), Enfeh (Panayot-Haroun 2016) and Tell Koumba (Durham University project). The stratigraphic and typo-chronological sequence from Tell Arqa is, therefore, a key to understanding the EB culture in northern Lebanon and can provide a guideline for ongoing research projects.

The site of Tell Arqa is located in the Akkar plain in northern Lebanon. The excavation project focussing on the Bronze Age strata, led by J.-P. Thalmann, began in 1978 and ran until 2012: it revealed an uninterrupted archaeological sequence covering the whole 3rd millennium. The Tell Arqa EB sequence has

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been published by Thalmann (2006a; 2010; 2016) and constitutes a baseline for establishing the Early Central Levant periodization within the ARCANE chronology.¹ Moreover, the geographical location of the site, at the western end of the Homs-Tripoli gap, provides a connection between coastal Lebanon and inland Syria.

In ceramic analysis, besides typo-chronological sequences, technological and petrographic studies are an essential way of investigating ancient pottery, offering new insights in understanding the production context, the technical evolutions and the socio-economic and territorial development of populations. Such analyses have been undertaken on the ceramic assemblage from Arqa, whose precise chronological sequence made it possible to carry out a fine study and give accurate interpretations. Manufacturing processes were investigated by Roux (Roux 2013; Roux and Thalmann 2016). Petrographic analyses are in progress but have already yielded interesting preliminary results, presented hereafter.² The aims of this study are to characterize the main petrographic groups, to establish their relationship to the local geology, and then to use the chronological, morpho-functional and technological data to highlight the temporal development of ceramic production at the site.

The petrographic analysis of the pottery from Arqa is part of a set of studies that have multiplied in recent years on northern Levantine sites, especially since the 2000s. Among the studied ceramic assemblages are, in north-western Syria, those from the Amuq (Welton 2014), Tell Mardikh, Tell Tuqan (Falcone and Lazzarini 1998) and Tell Afis (Santarelli 2013); in the Orontes valley, Tell Archarneh (Boileau 2006) and Tell Mishrifeh (Iamoni 2012; 2014; Maritan *et al.* 2005); in southern coastal Syria, Tell Kazel (Boileau *et al.* 2010); and in Lebanon, Tell Fadous (Badreshany and Genz 2009), Sidon (Griffiths 2000; 2003; 2006) and the Beqaa valley (Badreshany 2013). These projects are an important basis for understanding the issues at a regional scale — however not all of these include EB samples.

This paper presents the first results of the petrographic study of the 3rd millennium assemblage from Tell Arqa. The ceramic raw materials have been characterized and assigned to several groups

(Table 2; Appendix 1); the results are then interpreted in the light of the morpho-functional, typological, chronological and technological data.

Geographical context

The site of Tell Arqa is located in the south of the Akkar plain — northern Lebanon — on the northern Levantine coast (Fig. 1). At the opening of the Homs gap, the site is in a strategic position between the Mediterranean and inner Syria, between the Syrian coast and Lebanon and, beyond, to the southern Levant. The Akkar plain is one of the most extensive units of land on the east Mediterranean coast, measuring around 30 km east–west and covering 450 km²; elsewhere the coastal plain is much narrower. This large extent of arable land offers great potential for agriculture, which provided the basis for the economic and demographic development of the Akkar plain during the Early Bronze Age, especially EB IV–ECL 5/6 (Thalmann 2006a: 210–23; 2007: 220–21).

Tell Arqa lies 22 km north of the modern city of Tripoli, 12 km south of the Nahr el-Kebir — the current Syrian–Lebanese border — and 6 km east from the coast. The site is located in the north-western foothills of Mount Lebanon, on the north bank of the Nahr Arqa, a small watercourse flowing from Mount Lebanon to the Mediterranean Sea. The tell is around 30 m high and 4.5 ha in extent at the top. It is one of three major sites on the Akkar plain, along with Tell Kazel and Tell Jamous (Thalmann 2007: 220–21). Tell Arqa should, therefore, be considered an important Bronze Age site in the central Levant, and one sitting in a favourable geographical location, at the junction of major routes.

Geological context

The geological environment of Tell Arqa is diverse, but is dominated by calcareous and basaltic outcrops along with recent deposits (Fig. 2).

The geography of the Levant is affected by an important tectonic event that shaped the landscape, the Levant Rift System or Dead Sea Transform Fault System. Two orientation changes of the major fault, occurring south and north of the Lebanese mountains, caused volcanic activity and the eruption of basaltic flows during the Pliocene (5.3–2.5 Ma; Mart *et al.* 2005; Sanlaville 2000: 19–20). It corresponds to the volcanic formations of the Golan plateau and the alkali basalt outcrops in the Akkar plain (Nassar 1999: 18; Sanlaville 2000: 90–91). The basalts analyzed from the Akkar plain are phyrlic in texture and may be highly weathered on the outcrop periphery. They usually contain 15 to 25 vol.% olivine, 30 to 40%

¹Corresponding to the Early Bronze Age in conventional chronology. The ARCANE project has revised the entire periodization of the 3rd millennium BC in the Near East; the chronological table is available on the website of the ARCANE project (http://www.arcane.uni-tuebingen.de/EA-EM-EL_phasing_v5-4-6.pdf).

²The petrographic study of the EB pottery from Tell Arqa is part of an ongoing PhD thesis. The petrographic groups are well defined and the results presented in this paper may be considered reliable. If some refinements occur in future work, they should be limited.



Figure 1. Geographical location of Tell Arqa (background map: M. Sauvage).

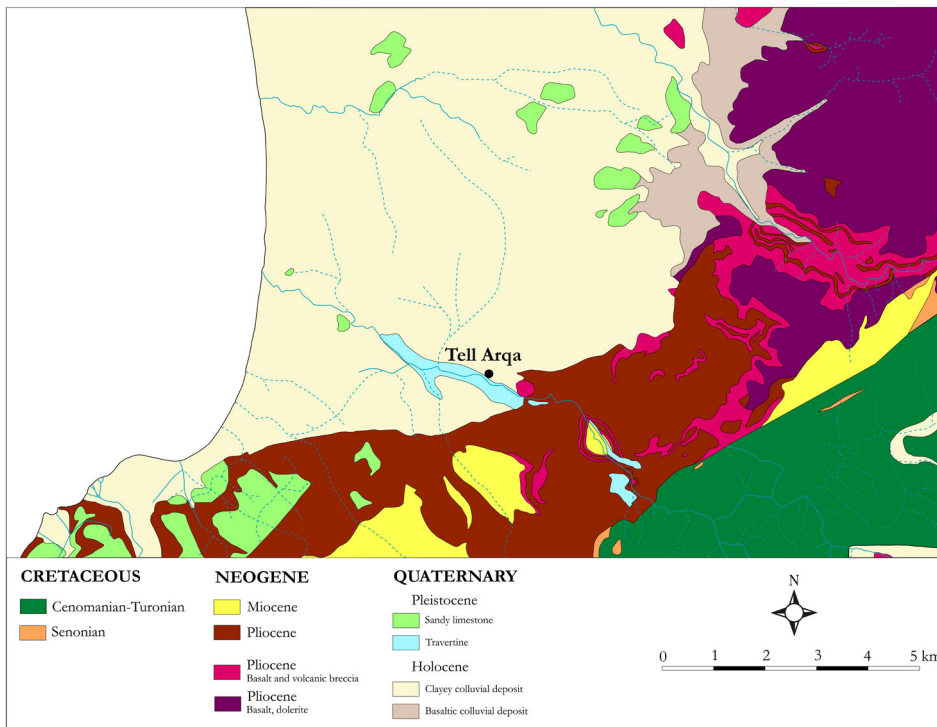


Figure 2. Geological map of Tell Arqa and the Akkar plain (from Guerre 1975).

clinopyroxene, 40 to 50% plagioclase feldspar and c. 5% opaque oxides (Abdel-Rahman and Nassar 2004).

Regarding sedimentary deposits, the coastal zone and the major part of the Akkar plain consist of

Quaternary deposits — Holocene colluvial sediments, along with Pleistocene marine calcareous sandstone and travertine along the Nahr Arqa (Guerre 1975; Walley 1997: 95). The Mount Lebanon foothills are

made of older Neogene and Cretaceous sedimentary formations. The Neogene strata (23.3–2.5 Ma) include Miocene lacustrine and fluvial marl, conglomerate and red clays, and Pliocene marl and limestone. Higher on the mountain, the Upper Cretaceous carbonate platform deposits include Cenomanian-Turonian and Senonian formations (99.6–65.5 Ma; Guerre 1975). The Cenomanian deposits are composed of fine-grained micritic limestone and dolostone, with marl and chert nodules occurring. The Turonian formation is made of marly chalk, marly limestone and microcrystalline limestone with foraminifera. Chert and marl may also be encountered. Finally, the Senonian outcrops correspond to the Chekka formation: chalk, chalky limestone — containing mainly foraminifera and ostracods — and marl with phosphate and chert nodules (Abdel-Rahman and Nader 2002: 75, table 1; Walley 1997: 91–93). It should be noted that these sedimentary rocks contain a wide karst system which constitutes the main water supply in the region (Abdel-Rahman and Nader 2002: 70).

The geological background of the area surrounding Tell Arqa encompasses highly diversified formations, including basaltic outcrops and varied sedimentary rocks dating back from the Upper Cretaceous to the Holocene.

The archaeological sequence of Tell Arqa

The excavated strata at Tell Arqa form a long sequence of occupation, from the end of the Chalcolithic to the Mamluk period. The excavations directed by J.-P. Thalmann focused on the extensive Bronze Age deposits, 16 m thick, and, in particular, on the 3rd millennium occupation which was especially substantial (Thalmann 2006a; 2010; 2016). The excavation field, on the western edge of the tell, revealed five main strata corresponding to the EB settlement, numbered

20 to 15, and clustered in four chronological phases, from T to P (Table 1). This occupation covers the whole 3rd millennium, from 3100 BC — beginning of phase T, corresponding to EB II–ECL 2 — to 2000 ± 50 BC — end of phase P, EB IV–ECL 5/6. Two instances of destruction by fire marked the history of the tell and provided radiocarbon dates from several archaeological contexts, which established the absolute chronology of occupation (see Cichocki 2007 for the EB IV radiocarbon dates; samples from older strata are yet to be published). The conflagrations occurred at the end of phase S (EB II/III–ECL 3), *c.* 2700/2650 BC (stratum 18A) and during phase P (strata 16A–B, end of EB IVA–ECL 5), *c.* 2250 ± 50 BC. Domestic installations such as houses were uncovered, positioned on the two sides of a small curved street, following the edge of the tell (for detailed analysis of the architectural remains see Thalmann 2006a; 2006b; 2010; 2016). All the archaeological remains, including the pottery analyzed in this paper, come from domestic contexts. Moreover, the precision of the chronological data helps us to understand the temporal evolution of potters' raw material choices.

EB pottery assemblage

The EB pottery from Tell Arqa forms a homogeneous assemblage consistent with the ongoing stratigraphic sequence; it constitutes a good reference for the 3rd millennium in the northern Levant. Detailed typological and technological studies have already been published (Roux 2013; Roux and Thalmann 2016; Thalmann 2006a; 2016). These provide important baseline data, and, when combined with the petrographic study, allow an extension of our interpretations regarding ceramic production and EB Levantine societies.

Table 1. Chronological sequence of the 3rd millennium occupation at Tell Arqa.

Phase	Stratum	Date	ARCANE Chronology	Conventional Chronology
T	20	3100 BC	ECL 2	EB II
	19	2900 calBC		
S	18	2800 BC	ECL 3	EB II/III
		2700/2650 calBC		
R	17	2450 ± 50 calBC	ECL 4	EB III
P	16		ECL 5	EB IV A
	15	2250 ± 50 calBC	ECL 6	EB IV B
		2000 ± 50 calBC		

Typo-chronological data: morphology and function

The evolution of pottery shapes from phase T (EB II–ECL 2) to phase P (EB IV–ECL 5/6) is characterized by a continuing diversification of morphological types through time (Thalmann 2006a: 109–31, pls 46–79; 2010: 89, 92–93, figs 7, 11; 2013: 265–69, figs 12–14; 2016: 34–71, pls 1–27). The typological classification is based on four functional categories: service, transfer, storage and cooking vessels (as defined by J.-P. Thalmann; see Roux and Thalmann 2016: 103–11).

Within these categories, the shapes and surface treatments evolve over the chronological phases (Thalmann 2016: fig. 36).

Serving vessels include platters, bowls, goblets and jugs (Fig. 3). During phase T large, burnished, carinated platters are widespread, as at other Levantine sites, probably revealing common eating habits (Thalmann 2016: 34). They disappear by the middle of phase S, with no replacement open form appearing, thus changing the overall shape repertoire. In fact, the

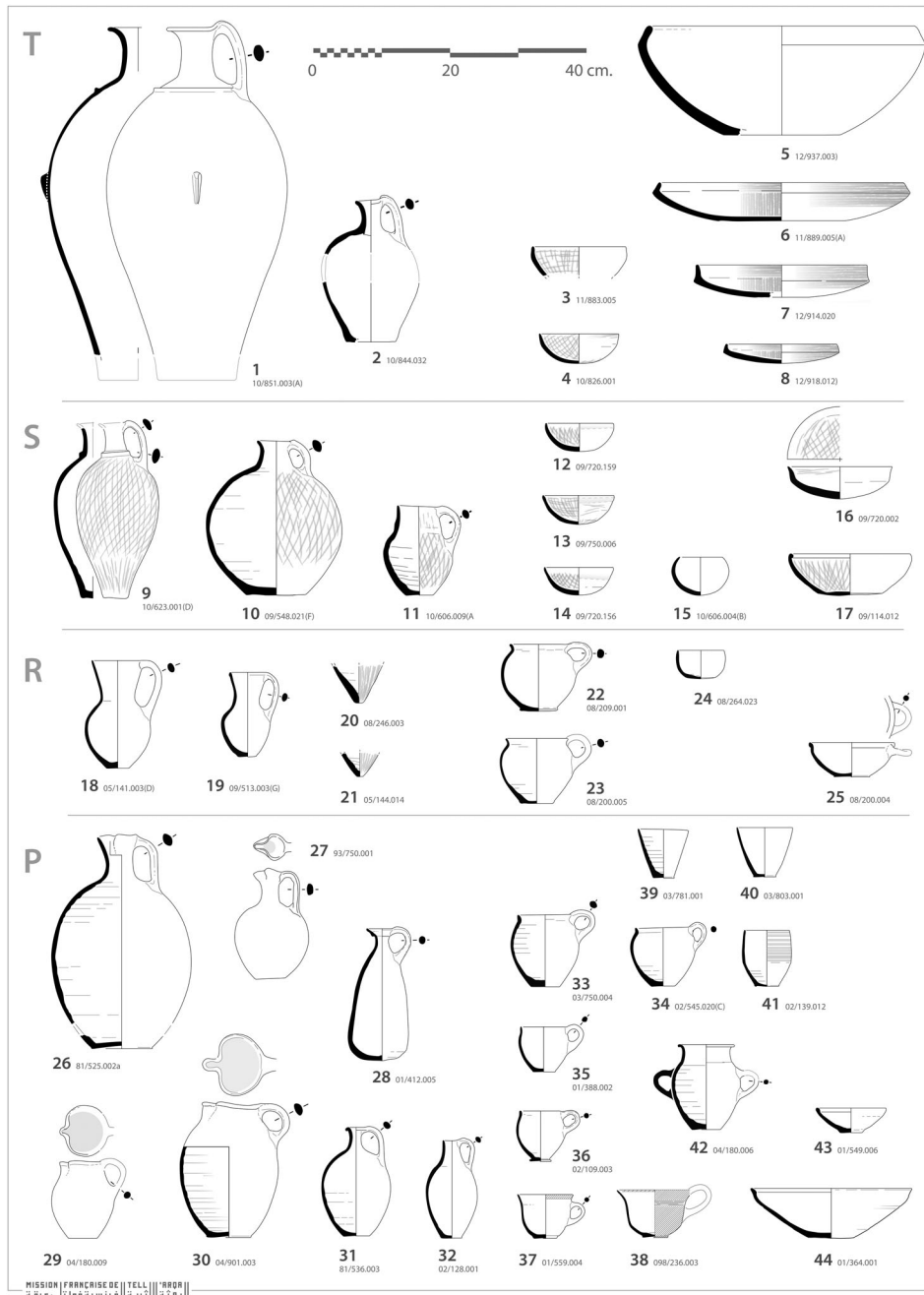


Figure 3. Evolution of serving vessel forms from phases T to P. The evolution of forms is correlated with the evolution of surface treatments: vertical and pattern burnishing during phase T; pattern burnishing only during phase S; vertical burnishing only during phases R and P (Roux and Thalmann 2016: fig. 4).

hemispherical bowls that appear during phase S suggest the introduction of individual drinking practices, thus pointing to a change in consumption practices. In addition, single-handled pots appear during phase S; these decrease in size to become the one-handled cups that are very common during phases R and P. The absence of any shape that could have functioned as a platter after the middle of phase S (stratum 18B–C) raises questions about the existence of containers of perishable materials and ways of consuming food (Thalmann 2016: 50). In contrast, jugs are rare at the beginning of the 3rd millennium, but become increasingly common and show greater diversity of shape over time. Serving vessels were usually pattern burnished during phases T and S, and vertically burnished during phases R and P.

The category ‘transfer’ is introduced as an intermediate class between service and storage vessels (Roux and Thalmann 2016: 108). The capacity of transfer vessels varies from 5 and 15 litres: large jugs — that may have served as water containers, pots and small jars fall into this category. They were presumably used for short-term storage or transfer of goods, rather than for the direct consumption of food or drink or long-term storage. As with the serving vessels, the transfer containers were pattern burnished during phases T and S and vertical burnished during phases R and P.

Storage vessels are mostly large storage jars, the larger examples of which are called pithoi (Thalmann 2006a: 107–08, fig. 38; 2016) (Fig. 4). Examples from the earliest periods are usually slender in shape with a moderately long neck, while the jars from phase P exhibit squatter shapes and shorter necks. The two main temporal trends in the evolution of storage vessel forms during the EB are, an increase bulk and a change in surface treatment. Jars were vertically burnished during phase T, but after that the only surface treatment given to jars was combing. The storage jars from phase S were pattern combed until the end of phase R, whereas horizontal combing develops during phase R and became the only surface treatment documented on storage vessels during phase P.

Finally, culinary pottery includes mainly cooking pots and, at the end of the sequence, some baking trays (Roux and Thalmann 2016:104–05, fig. 2; Fig. 5). Cooking pot shapes do not show any great evolution from phases T to P, except on the rim. The ovoid shape present from phase T (ECL 2) is replaced by a globular shape during phases S and R, while the ovoid shape became predominant again during phase P. The neck is usually short, and everted to straight. The cooking pots are frequently undecorated, even though some examples may display impressions,

combing or marks. A wide range of sizes are encountered, perhaps evidence for different functions.

To sum up, the typological study highlighted a break in the vessel shapes between phases T and S — probably corresponding to a shift in eating habits — and then the evolution and diversification of ceramic forms from phases S to P. The typological evidence will be compared to the results from the petrographic analysis to investigate their relationship. In addition, the four functional categories of vessel (serving, transfer, storage and cooking) were each associated with a different set of constraints, and it is likely that, in order to address these, the potters made specific choices during pottery manufacture (Gosselain and Livingstone Smith 2005; Lemonnier 1993). Correlations between function and the selection and treatment of raw materials are evidenced at Arqa and are examined below.

Technological data: manufacturing processes

The technological investigation was carried out by V. Roux (Roux 2013; Roux and Thalmann 2016) and led, based on the presence or absence of a slip, to the definition of two main categories of pottery in the Arqa assemblage.

The first and main category, without slip, is subdivided into three *chaînes opératoires*: ARQ-1, ARQ-2 and ARQ-3-RKE, which are distinguished by the surface treatments and the use of Rotary Kinetic Energy (RKE) (for a definition of RKE, see Roux and Courty 1995). The first manufacturing steps are shared: the bases are made of a spiral coil placed on a thin disc of clay. A peripheral coil is added and another coil makes the junction with the walls, which are then built by pinching coils. The rim is fashioned by turning out the last coil. The main differences are the surface treatments: the ARQ-1 process was completed by burnishing the outer surface of the vessel when leather hard; ARQ-2 vessels were combed. The ARQ-3-RKE ceramics were shaped on a rotation device, i.e. with the help of RKE. The significant evolution in manufacturing techniques during the EB is the gradual increase, throughout the 3rd millennium, in the use of RKE in the manufacturing process. During phase P, the entire production was made using RKE — to different extents — and the *chaînes opératoires* are named ARQ-1-RKE, ARQ-2-RKE and ARQ-3-RKE (Roux and Thalmann 2016: 113–22).

The manufacturing processes and the functional categories were correlated. During phase T, storage, transfer and serving vessels were made using ARQ-1, while ARQ-2 and ARQ-3-RKE were little

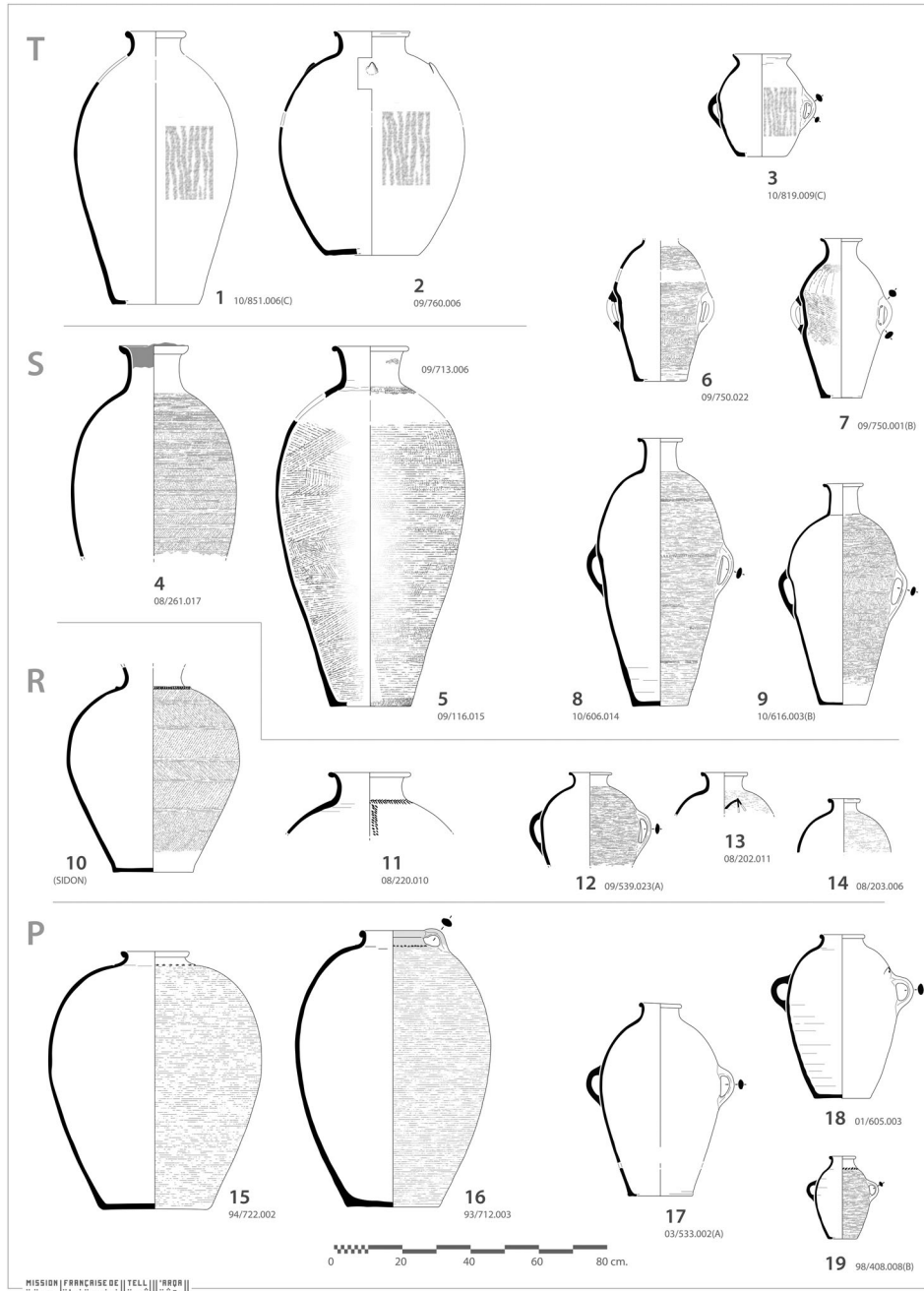


Figure 4. Evolution of storage vessel forms from phases T to P. The evolution of forms is correlated with the evolution of surface treatments: vertical burnishing during phase T; pattern combing during phase S; horizontal and pattern combing during phase R; horizontal combing only during phase P (Roux and Thalmann 2016: fig. 3).

represented. During the succeeding phases, each *chaîne opératoire* corresponds to a functional category: ARQ-1(-RKE) corresponds to transfer and serving vessels, ARQ-2(-RKE) to storage vessels and ARQ-3-RKE to small vessels such as bowls and goblets (Roux and Thalmann 2016: 124).

The second category of manufacturing processes — with slip — corresponds to cooking pots. The walls were made of pinched coils and the rim formed by turning outside or inside the last coil, depending on

the chronological phase. The characteristic feature is the rounded base, which is formed by scraping, and the thin slip covering the surface (Roux and Thalmann 2016:122–24).

The technological study evidenced the homogeneity and strong continuity in manufacturing processes. The main steps can be observed throughout the EBA and the use of RKE spreads progressively, to peak during phase P. According to V. Roux’s interpretation, this technological evolution appears to take place without

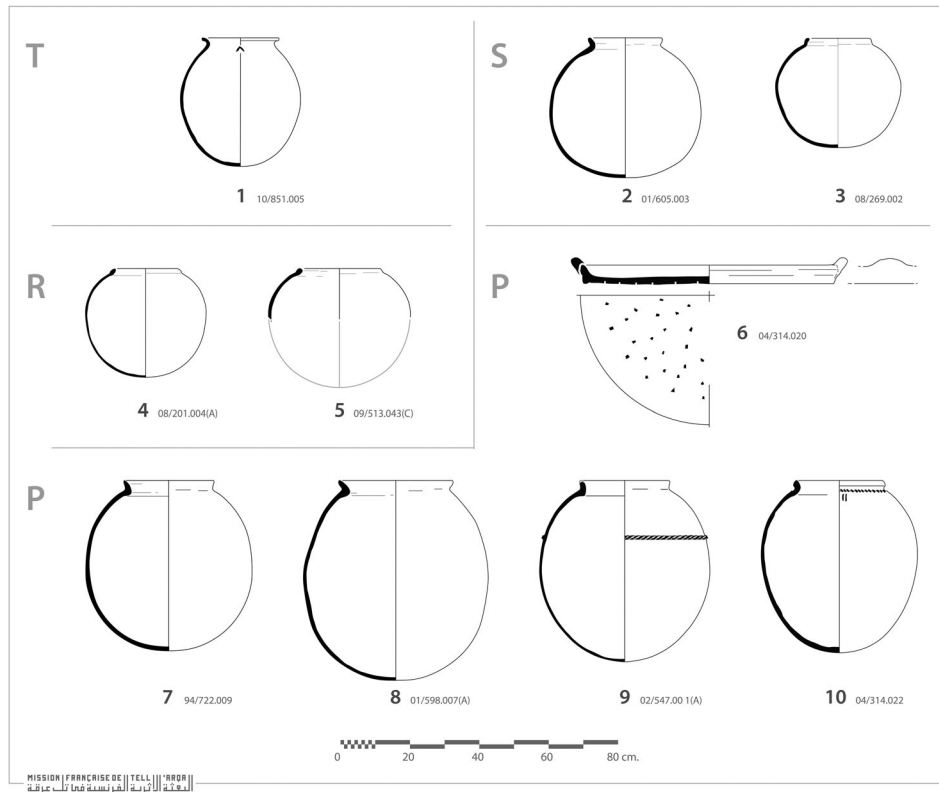


Figure 5. Evolution of cooking vessel forms (Roux and Thalmann 2016: fig. 2).

a break — though typochronological and petrographic studies indicate a break in pottery shapes between phases T and S — and reveals a homogeneous production background and a sociologically stable group of potters. Moreover, the use of RKE in ceramic production necessitates the acquisition of complex skills that are likely to indicate the involvement of specialized potters from the beginning of the 3rd millennium on (Roux and Thalmann 2016: 125). Here again, these conclusions have to be combined with the results of the petrographic analysis to highlight the wider trends in the evolution of ceramic production at the site.

Methodology and sampling of the petrographic study

To take advantage of the abundance and quality of the pottery data from Tell Arqa, the petrographic study had to investigate as many samples as possible. The methodology involved a two-stage analysis: an initial macroscopic observation was undertaken on hundreds of samples; followed by the examination of thin sections on a smaller number of representative samples. The macroscopic and microscopic analyses are thus complementary (e.g. Shepard 1956: 157) and their combination made it possible to understand raw material choices in ceramic production at Arqa during the EB.

The macroscopic analysis was performed using both the naked eye and a stereo-microscope, and was undertaken on a set of 1359 samples of known shape and archaeological context covering the whole 3rd millennium sequence. A second set of 2447 samples of known archaeological context, but for which the typology was unknown, was examined to control for any bias that the typological selection may have introduced into overall proportions of each group — i.e. the potential over-representation of uncommon types and thus the related petrographic groups. The analysis led to the formation of eight macroscopic groups. The observations undertaken on each sample included the description of the matrix colours (inner and external surfaces, sub-surfaces and core), the overall percentage and sorting of non-plastics, and the description of the frequency, shape and size of voids and non-plastics. The extended macroscopic analysis sought to give a precise overview of the ceramic raw materials, to define groups and to observe their distribution over time, while offering a dataset that was large enough to support quantitative analyses.³

The second stage of the analysis, the microscopic study, was carried out on thin sections using a

³More information on the macroscopic study and the quantitative analysis of the results will appear in Jean (forthcoming).

polarizing microscope.⁴ 71 samples of known shape were selected from the samples used in the macroscopic study⁵ to represent the different macroscopic groups, the diversity of shapes and functional categories and the chronological phases (Fig. 6, Table 3).⁶ The observation of each sample included matrix colours — PPL and XPL — and optic activity, overall percentage and sorting of non-plastics, description of voids and of non-plastics⁷ — mineralogical nature, frequency, shape, size.⁸ The microscopic analysis was designed to provide more accurate data on the mineralogical composition, selection and treatment of the raw materials. From these observations, a microscopic classification of the thin sections was established. This was observed to correlate very well with the results of the macroscopic analyses, rendering the petrographic groups reliable.

Each stage of analysis involved photographic documentation and allowed the creation of a set of reference images (Figs 7–15). From these observations, the samples were classified into eight petrographic groups which are discussed below. Comparing and combining the macroscopic and microscopic data made it possible to gain a broad overview of the raw materials: a large dataset of hundreds/thousands of samples and a precise mineralogical identification.

Description of the petrographic groups

The mineralogical nature of the non-plastics has been identified (Fig. 7); a number of them are represented in several petrographic groups, in differing proportions and grain sizes. Distinctions between the groups are based on the presence, or absence, of different types of non-plastic inclusions, their association, and their relative proportions and grain sizes in the clay. As a result, eight petrographic groups were defined and numbered from 1 to 8. The 71 samples observed in thin section are distributed between these groups, the main characteristics of which are summarized below and in Table 2. A more precise petrographic

description of each group and a list of the samples are provided in Appendix 1 and Table 3.

Group 1 (8 samples)

The discriminating feature is the presence of coarse angular to rhombohedral calcite grains in various proportions, along with micritic and bioclastic limestone (Fig. 8).

Group 2 (6 samples)

The characteristic feature of group 2 is the presence of frequent sandy quartz grains, sub-rounded, microfractured and of irregular shape, along with rounded micritic or bioclastic limestone (Fig. 9).

Group 3 (42 samples)

In group 3, the non-plastic inclusions are dominated by micritic to bioclastic limestone, isolated bioclasts and iron-rich argillaceous clasts, angular to rounded and red to black in colour, their frequency is the key identifier of the group (Fig. 10).

Group 4 (2 samples)

The discriminating feature of group 4 is the abundance of sandy quartz grains that are of irregular shape and frequently microfractured, and which give a grainy texture to the vessel surfaces (Fig. 11).

Group 5 (7 samples)

The specific feature of group 5 is the frequency of argillaceous rock fragments (ARFs, as defined by Whitbread 1986), which are elongated, rounded, tabular inclusions that may also be called 'shales' (e.g. Badreshany and Genz 2009; Greenberg and Porat 1996). In this group, ARFs are the predominant inclusions and they usually take the same colour as the surrounding clay matrix (Fig. 12).

Group 6 (2 samples)

The characteristic feature of group 6 is that ARFs are present in relatively low proportions, and are mixed with more frequent sandy quartz and limestone, usually rounded (Fig. 13). It is important to stress that ARFs are only attested in samples from groups 5 and 6.

Group 7

Only one sample among the set of thin sections belongs to group 7.⁹ The discriminating feature of the group is the presence of frequent basaltic

⁴The observation of thin sections under a polarizing microscope was performed at the Service d'Imagerie et de Microscopie Optique (SIMO), Maison d'Archéologie et d'Ethnologie-René Ginouvès, Nanterre (France), using a Nikon Eclipse E600 POL.

⁵As this work is part of a PhD thesis in progress, the number of thin sections is likely to increase in future.

⁶A set of *unica* was also sampled. As they are rare and not representative of the whole EB assemblage, they are not discussed in this paper.

⁷The methodology and criteria used for describing the thin sections in this study are commonly accepted and may be found in several references (e.g. Braekmans and Degryse 2017: 235–36; Orton *et al.* 1993: 158–60; Quinn 2013: 81–93; Rice 1987: 376–80).

⁸The comparison charts chosen for the visual estimation of the frequency, sorting and shape of non-plastics are those suggested by Orton *et al.* (1993: 238–39). Grain size is indicated according to the Wentworth (1922) grain size classification.

⁹The scarcity of samples from group 7 is probably due to its late appearance, in low proportions, at the end of phase P. It becomes common during the succeeding chronological phase N (MB I). Sample 187 is from phase N but corresponds to the emerging group 7 from the end of phase P, as indicated by its very similar characteristics in macroscopy.

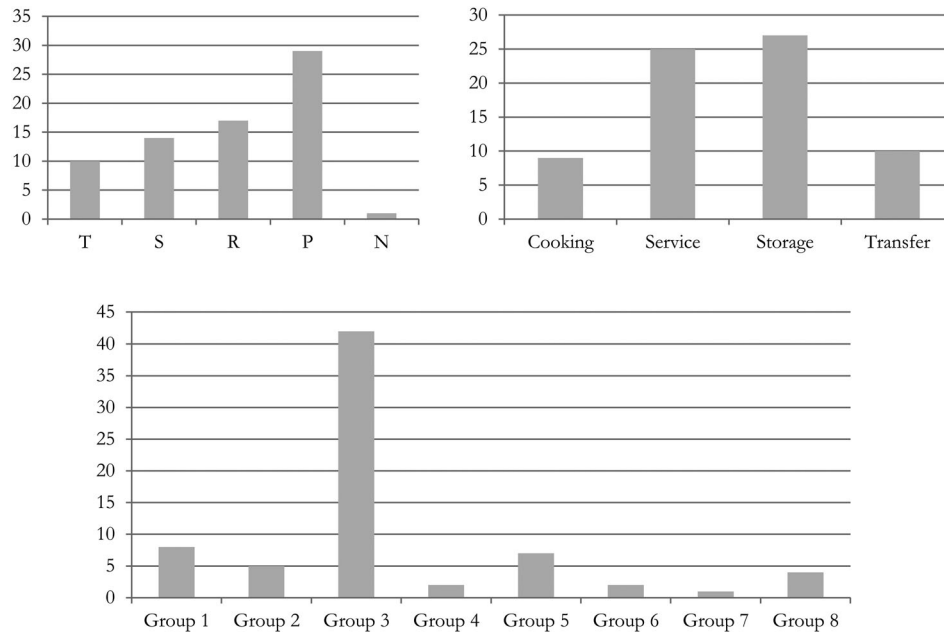


Figure 6. Representation of sherds sampled by thin section across chronological phases, functional categories and macroscopic groups (n = 71). Group 3 shows a marked predominance, especially during phase P although instances were sampled for all phases and functional categories. One sample from phase N (MB I) was selected to represent group 7, which appears at the end of phase P and become more common during phase N.

inclusions; these are very uncommon in samples from the other groups (Fig. 14).

Group 8 (4 samples)

The characteristic feature of group 8 is the high frequency of siliceous inclusions — both quartz and chert, mostly angular — associated with specific colours of the matrix, light red to pink and greenish beige, that are very different from the usual colours of the ceramics from Arqa (Fig. 15).

These eight groups are well defined and sufficiently different to be reliable. In order to understand their actual meaning, in technical, functional or chronological terms, a consideration of the distribution of the groups across the assemblage is required; doing so highlights new features of ceramic production in Tell Arqa during the 3rd millennium.

Discussion

Provenance: local or imported?

Petrographic analysis allowed a precise mineralogical characterization of the ceramic raw materials, which can be compared to the surrounding geological environment to determine their origin. It is often assumed that potters select their raw materials — both clay and temper — from a restricted area around the production site. Based on ethnographic observation, Arnold (2006) proposed a ‘threshold model’ to formalize this assumption, concluding

that the distance from the site to the raw material sources was less than 7 km in more than 90% of his examples. Following this model, raw materials available within 7 km of Arqa are considered to be local, and as all the non-plastic inclusions are consistent with the local geology described above (Fig. 2), it seems likely that the greater part of the ceramic raw materials used at EBA Arqa came from local outcrops.¹⁰

The only part of the assemblage that could be exogenous is group 8, the colours of the matrix being lighter than is normal in the Arqa assemblage — from beige-rose to greenish grey — and the predominantly siliceous nature of the inclusions. The shapes of the group 8 samples are also unusual on the site, corresponding to medium jars of type P5 that have been compared by Thalmann (2006a: 116) with vessels from inner Syria. In light of both their typological and petrographic features, these vessels were probably imported to Tell Arqa during phases R and P (EB III/IV or ECL4–6) and may well come from the Homs area.

At this point of the study, it seems that by far the bulk of the ceramic raw materials were available in the immediate vicinity of the site, with the exception of that for group 8, a fabric which also

¹⁰Geological samples — both rocks and clays — from the area around Arqa have been collected and are expected to provide further information on the provenance of raw materials.

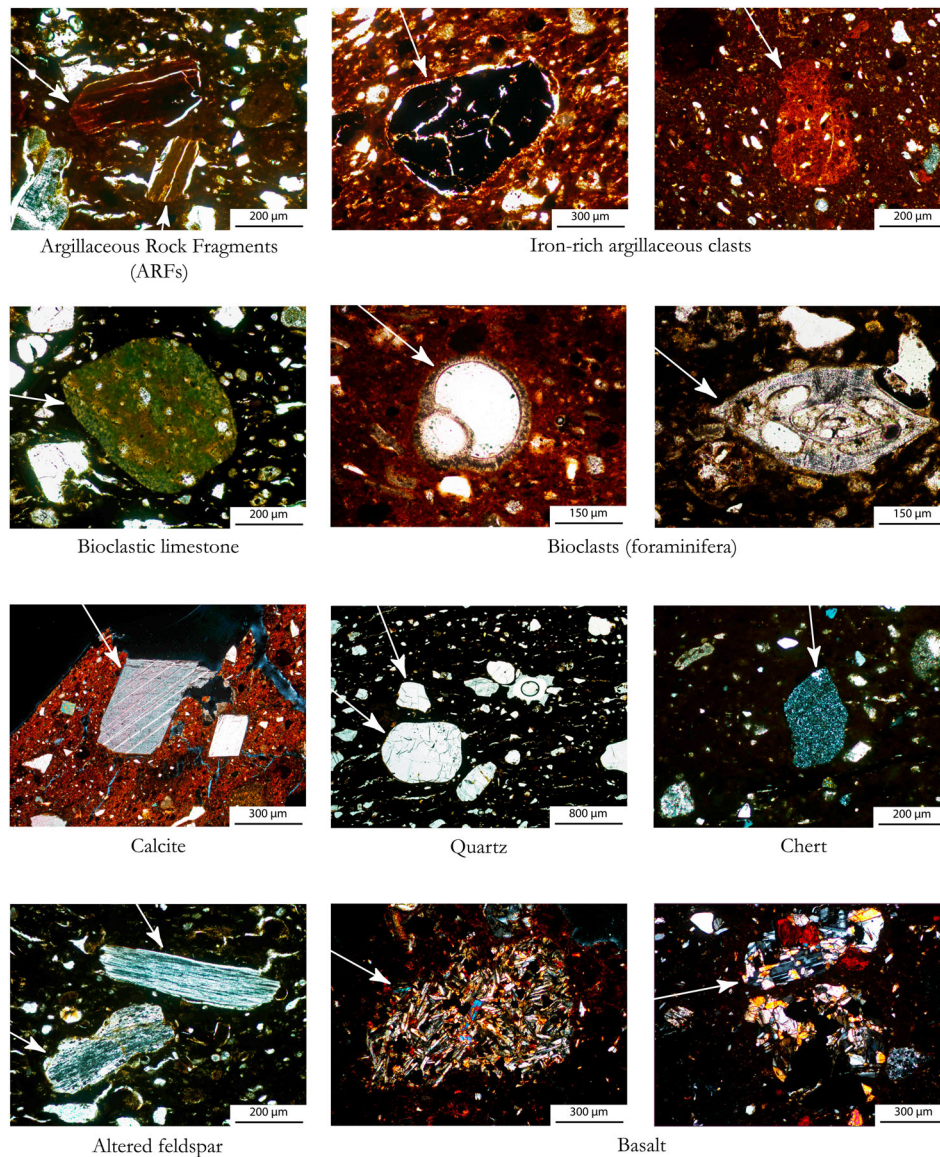


Figure 7. Illustration of the different types of inclusions observed in the thin sections.

corresponds to a specific vessel shape. These samples could well represent imports from inland Syria, underlining the intermediate location of Tell Arqa between the Orontes Valley and the Mediterranean coast, at the western end of the Homs-Tripoli gap.

Raw materials and functional choices

Regarding the potters' technical choices, the question of tempering is usually difficult to answer (Quinn 2013: 156–71). At Tell Arqa, group 1 is the only example of intentional tempering using crushed calcite. This material is recognizable by its marked angularity and rhombohedral shape (although calcite is an easily alterable mineral), its frequency and poor sorting (Quinn 2013: 165). In the other cases, the evidence is not sufficiently clear to determine whether

the non-plastics were deliberately added into the clay, or not.

The vessels from group 1 are exclusively dedicated to cooking, through the entire 3rd millennium. Tempering clays with calcite for cooking purposes is a frequent phenomenon in the EB northern Levant, and it has been identified at several sites: e.g. Tell Fadous (Badreshany and Genz 2009), Sidon (Griffiths 2006) and Ras Shamra.¹¹ Its continued use is probably due to a mechanical requirement for vessels designed to be subjected to shocks, as its presence increases toughness (Müller *et al.* 2010: 2465); it could also be a part of the ceramic tradition of the EB Levant.

¹¹Personal observation, Département des Antiquités Orientales, Musée du Louvre (Paris). Calcite has also been observed in non-Levantine ceramics (e.g. Fabbri *et al.* 2014: 1903).

Group 1

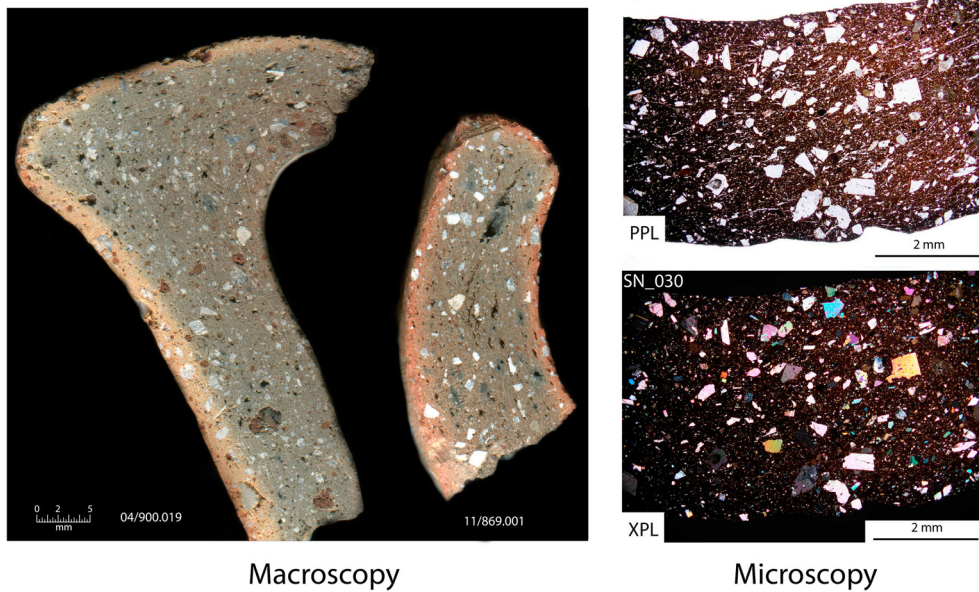


Figure 8. Group 1 samples in macroscopy and in thin section (PPL and XPL).

Group 2

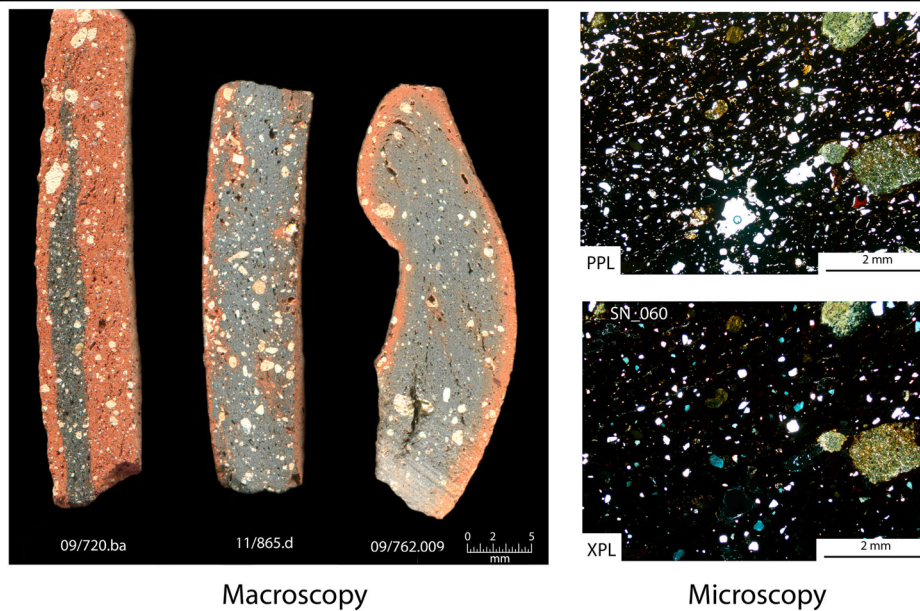


Figure 9. Group 2 samples in macroscopy and in thin section (PPL and XPL).

Petrography, chronology and function

Correlations between function, chronology and petrographic groups can be observed¹² (Fig. 16). Firstly, it is

¹²The set of 71 thin sections is not sufficient to provide a reliable quantitative analysis. However, these results are supported by those of the macroscopic analysis undertaken on an important set of samples (Jean forthcoming). The trends evidenced here may thus be considered as representative of the evolution of the assemblage.

very clear that cooking pots are made of specific raw materials: group 1 is the predominant choice for cooking vessels during the entire 3rd millennium, revealing both a continuity of tradition in ceramic production and a functional choice of raw materials (i.e. calcite tempering).

Group 2 appears at the beginning of phase S and is present until phase R; it is mainly used for storage

Group 3

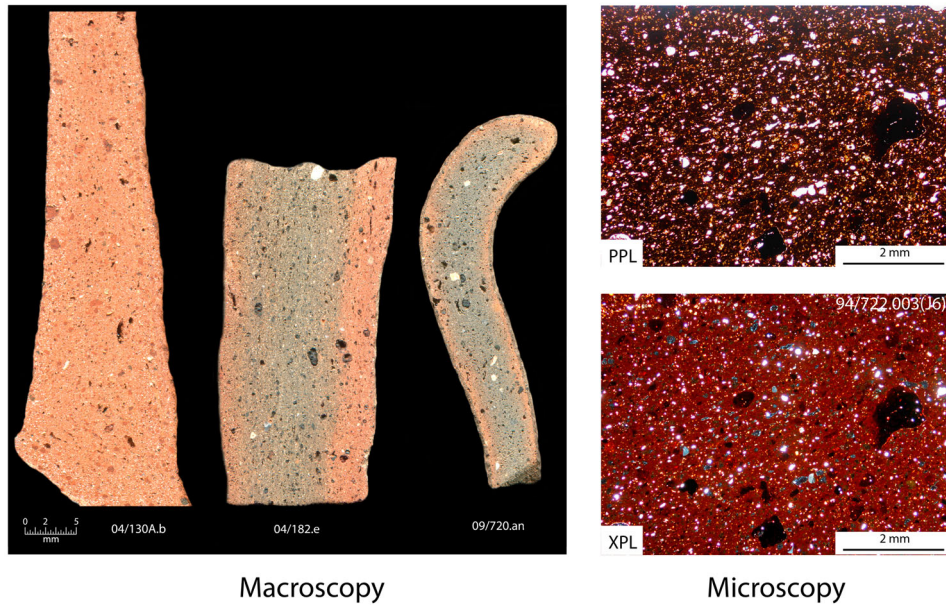


Figure 10. Group 3 samples in macroscopy and in thin section (PPL and XPL).

Group 4

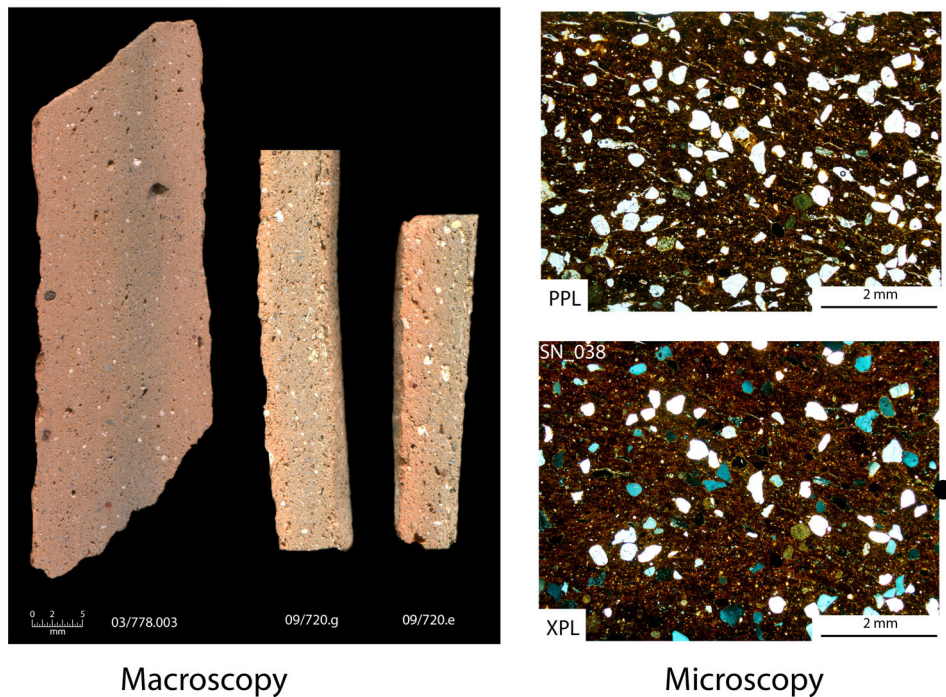


Figure 11. Group 4 samples in macroscopy and in thin section (PPL and XPL).

vessels. It is therefore possible, that its coarse composition rendered it more suitable for the production of large vessels.

On the other hand, group 3 does not denote any particular functional association but seems, rather, to

have served as a multi-purpose fabric, used to produce both serving, storage and transfer vessels. Its chronological distribution is telling, however, as it appears during phase S, and extends through the assemblage to become, by far, the predominant

Group 5

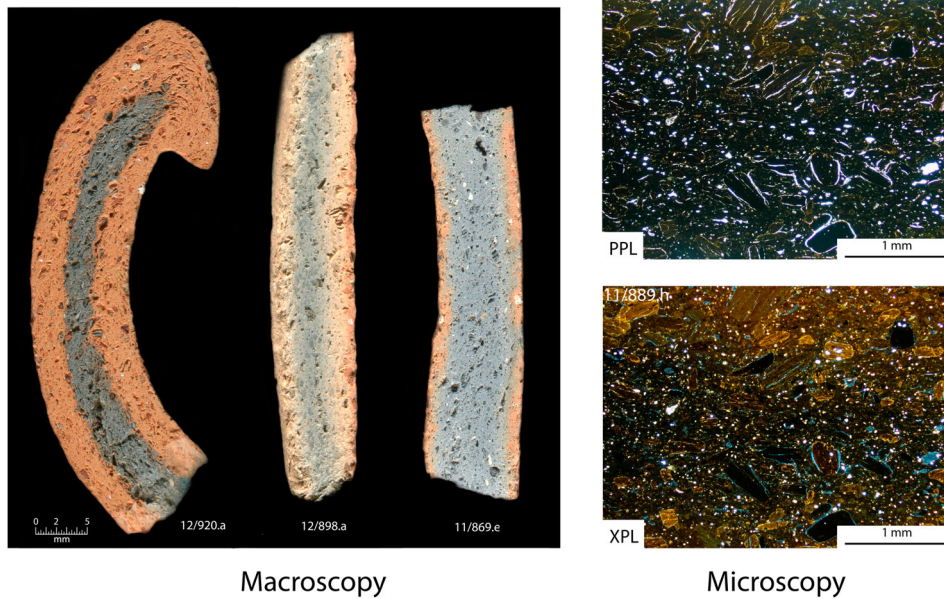


Figure 12. Group 5 samples in macroscopy and in thin section (PPL and XPL).

Group 6

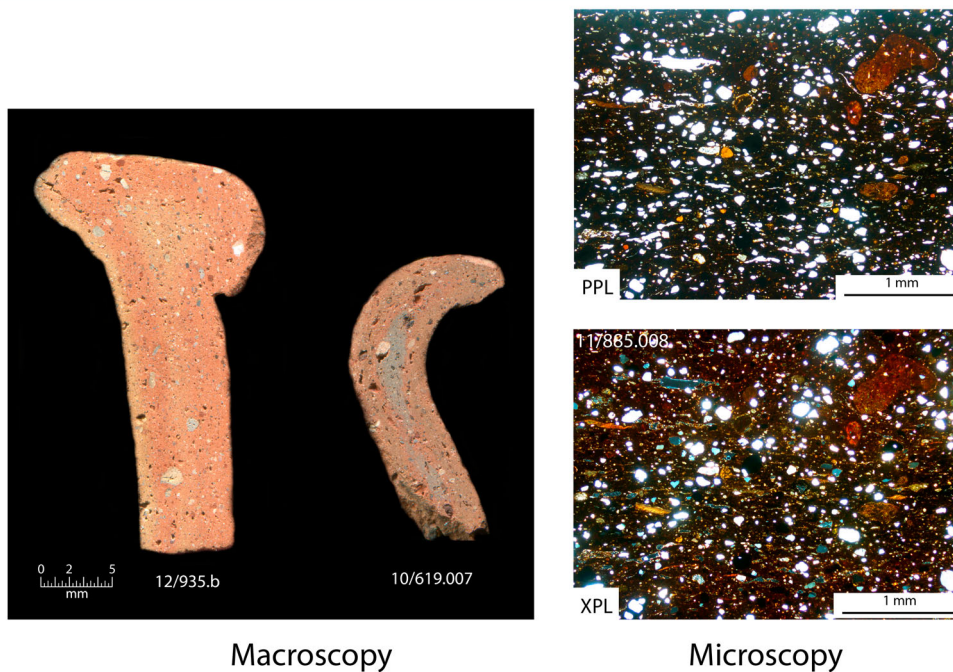


Figure 13. Group 6 samples in macroscopy and in thin section (PPL and XPL).

group of ceramic raw materials during phase P, where it represents more than 80% of the assemblage.¹³ The growing reliance upon group 3 over time is also associated with the diffusion of the use of RKE in the

manufacturing process (Roux and Thalmann 2016: 124) and a diversification of vessel shapes (Thalmann 2006a), and is therefore part of a more general evolution within ceramic production.

Groups 5 and 6 do not correspond to any functional category, but are, however, found only at a particular point in time, being specific to phase T, after which

¹³For quantitative analysis based on macroscopic observations, see Jean (forthcoming).

Group 7

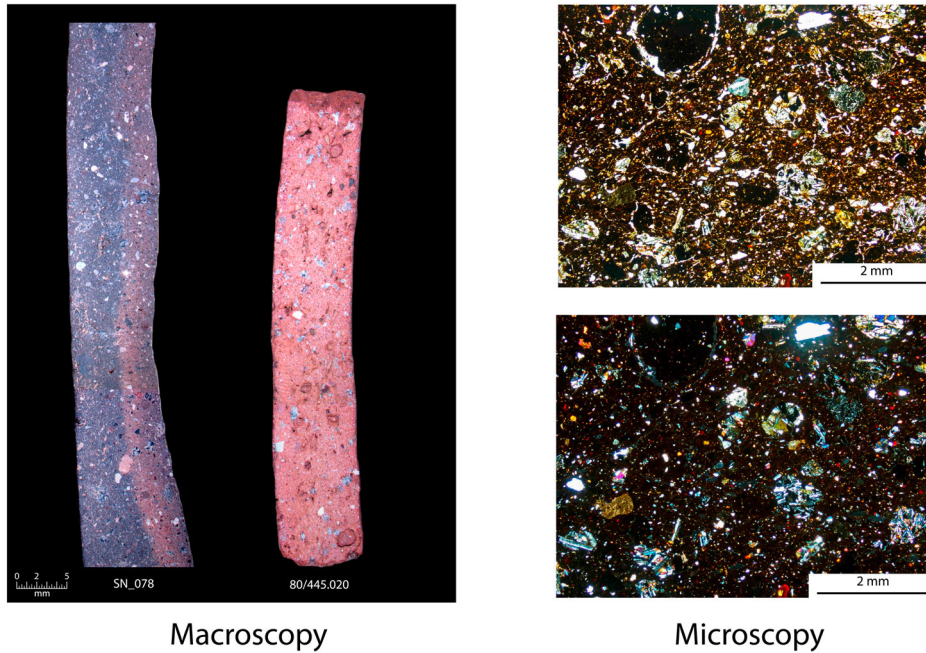


Figure 14. Group 7 samples in macroscopy and in thin section (PPL and XPL).

Group 8

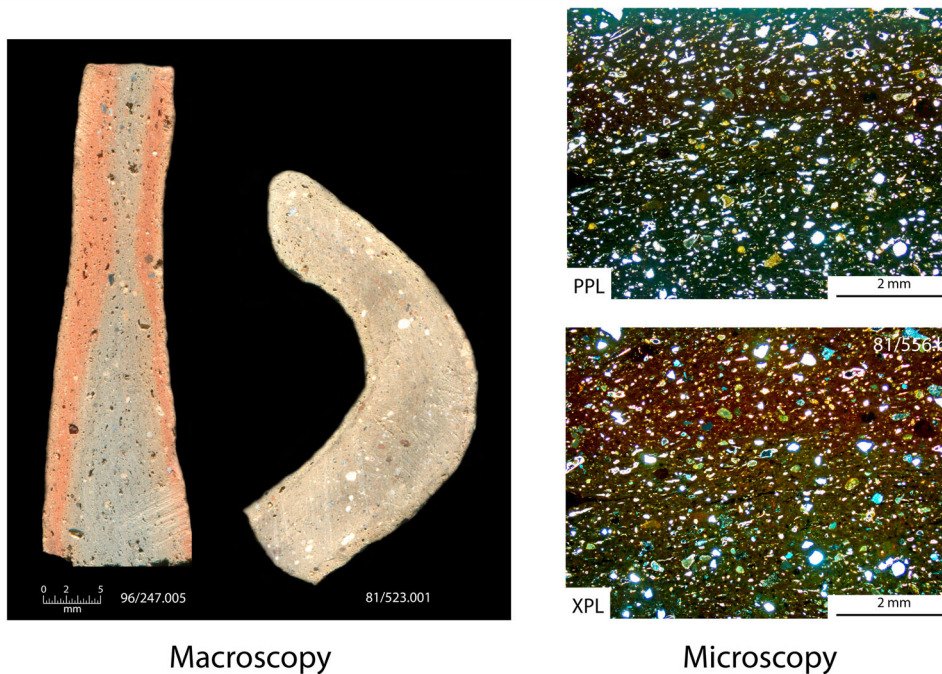


Figure 15. Group 8 samples in macroscopy and in thin section (PPL and XPL).

they disappear rapidly. This change, at the end of ECL 2, also corresponds to a contemporary shift in vessel shapes: thus an adjustment to the shape repertoire, apparently linked to changes in food consumption, is

correlated with a more substantial modification of processes of ceramic production.

The other petrographic groups are less well represented in the assemblage. Group 4 is present from

Table 2. Synthesis of the main characteristics of the eight petrographic groups defined in the EB pottery assemblage from Tell Arqa.

	Group 1	Group 2	Group 3	Group 4
Main feature	Angular to rhombic calcite	Coarse rounded quartz and limestone	Iron-rich clasts and limestone	Abundant sandy quartz grains
Percentage of inclusions	30–35%	ca. 30%	20–30%	20–25%
Sorting	Poor to very poor	Fair to very poor	Fair to poor	Poor
	Group 5	Group 6	Group 7	Group 8
Main feature	Abundance of ARFs	ARFs and sandy quartz and limestone	Abundant basaltic inclusions	Siliceous inclusions (quartz, chert)
Percentage of inclusions	20–30%	ca. 30%	30–35%	ca. 20%
Sorting	Poor to very poor	Fair to poor	Poor to very poor	Fair to poor

phases S to P, but in low proportions. Group 7 only appears in a few cases at the end of phase P — and is then characteristic of cooking pots from phase N (MBA). Finally, group 8 is present only during phases R and P and corresponds to some serving vessels and storage jars (jars type P5; see above and Thalmann 2006a: 116, 124).

The use of the chronological, functional and typological data thus make it possible to observe the distribution of the petrographic groups and to compare the results of the different studies, in order to highlight correlations that could be meaningful for understanding the evolution of ceramic production and use.

Pottery technology: how specialized is the production?

The technological study of the assemblage demonstrated continuity in manufacturing processes throughout the 3rd millennium, the main evolution being greater frequency in the use of the wheel (RKE) over time, a development that culminated during phase P (EB IV–ECL 5/6; Roux and Thalmann 2016: 124). The evident technical stability has been interpreted as an indication of sociological homogeneity and continuity over time, while the use of complex skills such as RKE points to the presence of a group of specialized potters from the earliest EB phases at Arqa (Roux and Thalmann 2016: 125).

The results of the petrographic study are consistent with the existence of specialist potters. During each period a limited number of petrographic groups is represented: this may well correspond to a limited number of specialist potters rather than to domestic

production. Moreover, each group is internally homogenous rather than to domestic production, which argues for control over the selection and treatment of the raw materials.

In contrast, the chronological distribution of the petrographic groups reveals a break at the end of phase T (ECL 2), as confirmed by the typological study. Such a break was not observed in the technological investigation, which argues for a marked degree of continuity over time. This phenomenon, while not yet well understood, is probably an important clue regarding the reconstitution of the socio-economic history of the site. If, according to Roux's conclusions, the group of potters was socially homogenous, why did they drastically change the clays and shapes of the vessels they made at this particular point in time? Could it be a cultural shift, quite separate from any social transformation, or is this evidence for some wider disruption — perhaps far more significant than pottery production alone — of political, economic or territorial importance? If so, this issue may have to be viewed at a wider scale and here again, the comparison of the different datasets raises deeper questions and more complex interpretations.

A regional pottery tradition

In comparing these results to evidence from elsewhere in the Levant, we can detect regional similarities in the selection of raw materials that may indicate a shared ceramic tradition in the EB of the northern Levant. The frequent employment of calcite-tempered clays (group 1) for the manufacture of cooking pots has been discussed above and seems to constitute a regional phenomenon — one that was at least partly related to functional concerns.

In addition, a number of EB sites in northern Lebanon have produced evidence for petrofabrics similar to those of group 2 (coarse limestone and quartz) and from the same time period — EB III–ECL 3/4: in particular, Tell Fadous (Badreshany and Genz 2009), Enfeh and at Ardeh (personal observations). It seems, therefore, that during the EB III, potters working at different sites were selecting and using very similar raw materials. This could, of course, be due to the similarity between geological outcrops around these sites, although it may also reflect a shared potting tradition in the area — or, perhaps, a combination of those factors; it could also be for reasons that are not yet determined.

Another regional issue is the presence of ARFs — also named 'shales' — in clays. At Arqa, they were observed in groups 5 and 6, and are also identified in

Table 3. List of sherds investigated by thin-section including: chronological phase, typology and petrographic group. 'Type code' corresponds to the morphological classification presented in Thalmann 2006a (p. 107 et seq.).

Sample Number	Arqa Number	Chronological phase	Functional category	Type	Type code	Petrographic group
2	11/885.e	T	Storage	Jar	R	5
3	11/885.f	T	Storage	Jar	R	5
5	11/885.008	T	Storage	Jar	R	6
9	11/887.d	T	Cooking	Cooking pot	M	1
15	11/889.g	T	Storage	Jar	R	6
16	11/889.h	T	Service	Carinated platter	C	5
17	11/889.i	T	Service	Carinated platter	C	5
21	11/890.c	T	Storage	Jar	R	5
25	SN_069	T	Service	Carinated platter	C	5
27	SN_071	T	Service	Carinated platter	C	5
32	SN_013	S	Transfer	Handled pot	N	3
33	SN_014	S	Transfer	Handled pot	N	3
36	SN_017	S	Cooking	Cooking pot	M	1
37	SN_018	S	Storage	Jar	R	2
40	SN_021	S	Service	Jug	K	3
42	SN_023	S	Transfer	Jar	P	3
49	SN_030	S	Cooking	Cooking pot	M	1
50	SN_031	S	Service	Jug	K	3
52	SN_033	S	Transfer	Pot	N	3
53	SN_034	S	Service	Goblet	G	3
54	SN_035	S	Storage	Jar	R	2
56	SN_037	S	Storage	Jar	R	2
57	SN_038	S	Storage	Jar	R	4
58	SN_039	S	Storage	Jar	R	3
59	09/532.a	R	Storage	Jar	R4	2
60	08/253.a	R	Storage	Jar	R4	2
61	09/513.024	R	Transfer	Jar	P	3
62	09/145.a	R	Transfer	Jar	P	3
73	09/102.a	R	Cooking	Cooking pot	M1	1
74	09/103.a	R	Cooking	Cooking pot	M1	1
75	09/513.013	R	Service	Goblet	G4	3
80	08/243.015	R	Service	Goblet	G4	3
81	09/536.016	R	Service	Jug	K	3
89	09/515.a	R	Storage	Jar	R4	3
93	01/371.105	P	Service	Jug	K1	3
95	SN_041	P	Service	Goblet	G5	3
96	SN_042	P	Service	Goblet	G5	3
100	SN_046	P	Transfer	Jar	P3/4	3
102	SN_048	P	Transfer	Jar	P3/4	3
103	SN_049	P	Service	Goblet	G1	3
104	01/549.a	P	Service	Goblet	G5.c	3
105	SN_050	P	Cooking	Cooking pot	M2	1
108	SN_052	P	Transfer	Jar	P1	3
112	SN_055	P	Cooking	Cooking pot	M2	1
115	SN_058	P	Service	Jug	K3	3
122	SN_065	P	Service	Goblet	G5	3
160	81/532	P	Service	Goblet	G2	3
162	81/532.039	P	Storage	Jar	R	3
168	81/521	P	Storage	Jar	R	3
169	81/561.001	P	Service	Jug	K2.b	4
171	81/532	P	Storage	Jar	R	3
172	93/708.007(A)	P	Storage	Jar	R2.b	3
175	81/556.005	R	Service	Goblet	G2.a	3
176	81/546.011	R	Storage	Jar	P5	8
179	81/532.029	P	Storage	Jar	P5	8
180	81/559.007	P	Service	Goblet	G2.a	8
181	80/447.001	P	Service	Bowl	E2	3
182	97/106.004	R	Storage	Jar	R	3
184	81/556	R	Storage	Jar	P5	8
187	80/445.020	N	Cooking	Cooking pot	M2.b	7
191	81/532	P	Service	Jug	K	3
192	81/524	P	Service	Jug	K	3
197	94/722.003	P	Storage	Jar	R2.b	3
200	81/544.001	R	Service	Jug	K1.d	3
202	94/722.007	P	Storage	Jar	R1.a	3

Continued

Table 3. Continued

Sample Number	Arqa Number	Chronological phase	Functional category	Type	Type code	Petrographic group
204	81/532	P	Storage	Jar	R	3
214	81/539.009	P	Storage	Jar	R	3
217	81/536.007	P	Cooking	Cooking pot	M2.b	1
220	98/378.055	R	Transfer	Pot	N	3
221	96/258	P	Storage	Jar	R	3
224	97/104.004	R	Storage	Jar	R4	3

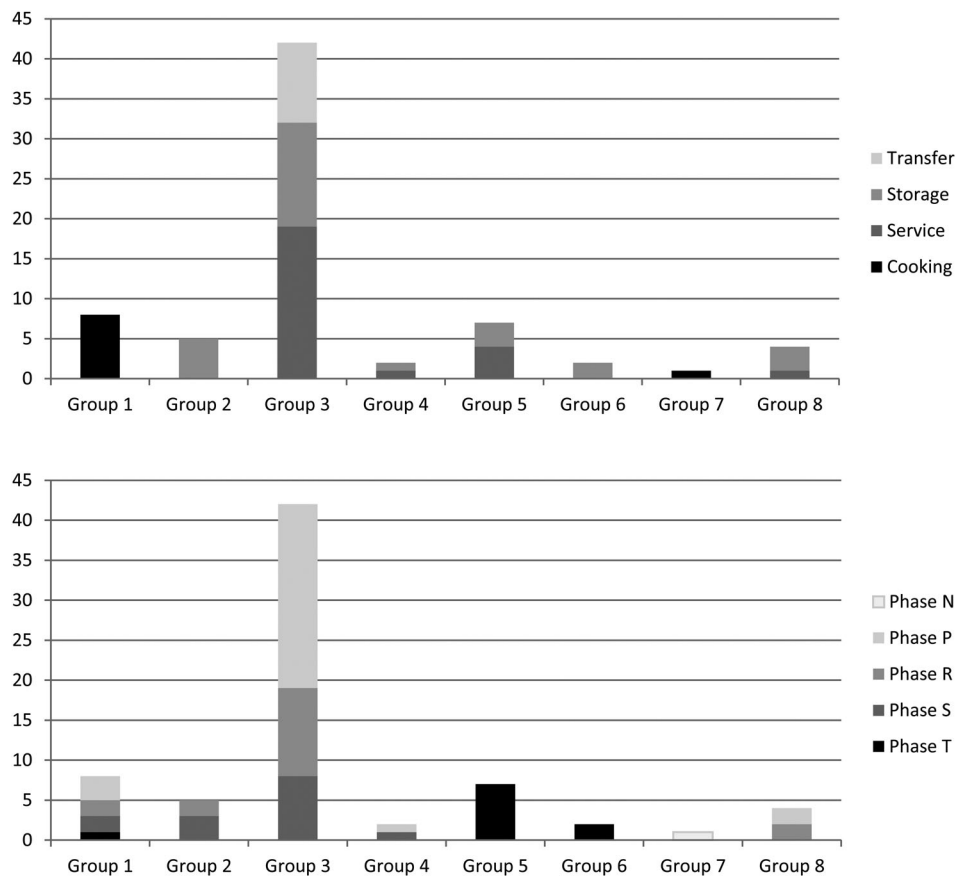


Figure 16. Repartition of the samples into the petrographic groups, functional categories and chronological phases.

vessels from Sidon (Griffiths 2006), Tell Fadous (Badreshany and Genz 2009), the Beqaa Valley (Badreshany 2013) and, further south, in so-called ‘Metallic Ware’ from the southern Levant (Greenberg and Porat 1996). This petrofabric is also present at Tell Acharneh, where it appears as sherds from vessels bearing combed decoration, and was probably imported from southern regions (Boileau 2006). While their exact provenance and exploitation are not yet clearly understood, the ARFs/shale-bearing clays are typical to the EB in the Levant and are believed to come from the Lower Cretaceous formations that outcrop in Lebanon and Galilee

(Dubertret 1955; Greenberg and Porat 1996: 16–17) — a view consistent with the presence of imports at Acharneh.

Therefore, by comparing the petrographic study undertaken on examples from Arqa, with evidence from other assemblages, it is possible to document a number of similar behaviours in ceramic production at a regional scale. The widespread selection of very similar raw materials could result from a number of factors: a specific cultural and technical tradition; the similarity of the geological outcrops across the region; and/or a specific mode of organizing ceramic production that existed at that particular point in time.

Conclusion

The results of the petrographic analysis of the EB pottery from Arqa shed light on a number of interesting features associated with local and regional ceramic production at that time. The first issue concerns provenance; the great majority of raw materials were available locally, i.e. at a limited distance from the site (Arnold 2006). However, one petrographic group is probably non-local, both because of the petrographic characteristics of the fabrics and the otherwise unusual typology of the vessels concerned (group 8; Thalmann 2006a:116).

One clear example of choice related to function has been evidenced; the use of crushed calcite as a temper for cooking vessels, probably to improve vessel toughness (Müller *et al.* 2010). However, relating the functional categories to the petrographic groups helped to highlight some indirect correlations — such as that between group 2 and storage vessels. On the other hand, groups 3, 4, 5 and 6 were ‘polyvalent’, i.e. were used for the production of a wide range of vessel forms.

Taking a synchronic perspective, the results reveal a relationship between petrographic groups and chronological phases. The most significant break occurs between phase T (ECL 2) and phase S (ECL 3), when the entire range of raw materials changed — in association with a radical shift in the shape repertoire. However, while the bulk of ceramic production at Arqa showed marked change at this point in time, the production of cooking vessels indicates strong continuity in shapes and petrofabrics — with crushed calcite continuing in use. Finally, from phase S onwards, a long evolution is observed, with one petrographic group (group 3) progressively coming to dominate the production of almost all non-cooking vessels, while the use of wheel-coiling (with RKE) grew in sufficiently frequency to become systematic (Roux and Thalmann 2016) and the shape repertoire became further diversified (Thalmann 2006a; 2016). This phenomenon is gradual from phases S to P and culminates at the end of the 3rd millennium. It may indicate a growing homogenization of ceramic production processes in the second half of the 3rd millennium, probably associated with developments in the organization of production.

With regard to the organization of the producers, the limited number of petrographic groups in use during each phase along with their internal consistency, would appear to indicate a fairly standardized and specialized mode of production — although not

necessarily full-time specialists. This is consistent with the results from the technological analysis, which concluded that the complex skills of the potters reveal a group of specialists that is likely to have been socially homogenous throughout the 3rd millennium (Roux and Thalmann 2016).

Finally, the petrographic study made it possible to compare the pottery from Tell Arqa with evidence from contemporary assemblages and thus place it within a wider regional ceramic framework.

Acknowledgements

This research was made possible thanks to the General Directorate of Antiquities of Lebanon, who provided all necessary facilities. The French Archaeological Mission of Tell Arqa, along with the VEPMO and HAROC laboratories (CNRS, UMR 7041 ArScAn) are happily acknowledged for their financial support. I am deeply indebted to Jean-Paul Thalmann, whose wide knowledge, reflections and trust were essential to this work. I am also grateful to the supervisors of my PhD, Professor Pascal Butterlin (Université Paris 1) and Dr Sophie Méry (CNRS), who read drafts of this paper. Finally, many thanks to Professor Graham Philip and Dr Kamal Badreshany for organizing the workshop and welcoming me to Durham to discuss ceramic petrography.

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Appendix 1

Description of the petrographic groups

Eight petrographic groups were defined and are precisely described in thin section hereafter.¹⁴ The clay

¹⁴The comparison charts chosen for the visual estimation of the frequency, sorting and shape of non-plastics are those suggested by Orton et al. (1993: 238–39). Grain size is indicated according to the Wentworth grain size classification (1922).

matrices are usually iron-rich, red to brown (5YR 5/6¹⁵ and nearby colours) when oxidized, and turn to grey-black (5YR 2/1 to N2) when fired in reducing conditions. The only exception are the samples from group 8, which exhibit a lighter colour, ranging from pink to beige and light grey (10YR 7/3 to 5YR 7/4). The groups are primarily distinguished by the relative proportions and grain sizes of the non-plastic inclusions (Fig. 7). Secondary calcite crystallization may occur in various proportions.

Group 1 (n=8; Fig. 8)

The matrix is optically slightly active to active and exhibits red-brown to light or dark brown colours. Matrices of samples 36 and 73 show a speckled aspect quite different from the other samples. Voids are few (*c.* 5%) and elongated, although rarely of vesicular shape.

The overall frequency of non-plastics is 30 to 35%, sorting is poor to very poor and the maximal grain size is very coarse sand to granule. The silty inclusions are micritic limestone, bioclastic inclusions, quartz grains, calcite and very few magmatic minerals. Micritic limestone inclusions are usually well rounded and frequent. Bioclasts are frequent — mainly foraminifera. Quartz grains are angular to sub-angular and moderately frequent. Calcite is angular to rhombic and moderately frequent, while magmatic minerals are very few and were identified as olivine altered to iddingsite and pyroxene.

The sandy inclusions include calcite, micritic and bioclastic limestone, bioclasts, quartz, some chert and rare altered feldspar. Calcite is frequent, angular to rhombic, mainly monocrystalline but polycrystalline grains may occur. The micritic and bioclastic limestone grains are well rounded and frequent, while bioclastic inclusions are moderately frequent and mainly correspond to complete or fractured foraminifera. Quartz grains are moderately frequent, of rounded to sub-angular shape and may display fluid inclusions or micro-fractures. Chert inclusions are rare and sub-rounded and feldspar is rare, usually altered and subhedral. Iron-rich argillaceous clasts are present in every grain size class, and are moderately frequent to frequent. A continuum in colours and shapes is observed in the argillaceous clasts, from red-orange to very dark red colours, from rounded to angular irregular shape. They are frequently fractured and may be surrounded by a shrinkage void, especially when of angular shape. The argillaceous clasts may contain angular silty quartz grains similar to those

observed in the matrix, but do not show any internal structure. They are probably naturally present in the clay. On the contrary, the presence of angular to rhombic calcite is likely to reveal the addition of crushed calcite as a temper in these samples (see Discussion).

Sample 217 is slightly different as it contains angular to rhombic calcite, as well as fluvial sand, probably coming from Nahr Arqa.¹⁶ This sand includes well-rounded grains of micritic limestone, quartz, argillaceous clasts and basalt. As the matrix and other sandy and silty inclusions look like the other samples from group 1, it seems likely that fluvial sand and crushed calcite have been deliberately added to the clay of sample 217.

Group 2 (n=6; Fig. 9)

The matrix is generally sub-isotropic (samples 37, 50, 56, 59, 60) but slightly active in sample 57. It exhibits orange-red to dark red colours when oxidized, and very dark grey to black colours with greenish patches when fired in reducing conditions. Some of the samples (54, 56, 59, 60) attest to highly reducing firing conditions and the sharp delimitation between oxidized and reduced areas reveals sudden changes of firing conditions. Voids are few, representing 5 to 8% of the surface of the thin sections. Shrinkage voids are elongated, parallel to the surfaces and also occur around some argillaceous clasts. Some voids may reveal the presence of a vegetal temper that burnt during firing.

The overall frequency of non-plastics is *c.* 30%, sorting is fair to very poor, the maximal grain size is very coarse sand and the non-plastics do not exhibit any preferential orientation. The silty inclusions include very angular and frequent quartz grains; rounded micritic limestone, moderately frequent; frequent isolated bioclasts (complete or fractured, often re-crystallized) and moderately frequent argillaceous clasts, rounded and of very dark red colour.

The sandy inclusions are dominated by frequent sub-rounded and micro-fractured quartz grains of irregular shape, often containing fluid inclusions. Isolated bioclasts (mainly foraminifera, complete or fractured) are frequent and often re-crystallized. Micritic and bioclastic limestone, rounded to sub-angular, is moderately frequent. Argillaceous clasts are orange-red to dark red, rounded to angular and may contain silty angular quartz grains. Chert is rare, of sub-angular shape, and altered feldspar is rare and subhedral. A grain size continuum is observed between the silty

¹⁵The colours are indicated according to the Munsell colour chart.

¹⁶As indicated by comparing the ceramic sample with a geological sample of sand from Nahr Arqa in thin-section.

and sandy quartz grains, and silty quartz grains are observed into the argillaceous clasts, suggesting that quartz grains and argillaceous clasts could be naturally present in the clay.

Group 3 (n=42; Fig. 10)

The matrix is isotropic to slightly active. When oxidized, the matrix is red-orange to red-brown or very dark red and may display brown-greenish patches. When reduced, the matrix is of grey-brown to very dark brown, almost black colours. Voids represent c. 10% of the surface of the thin section and are mainly shrinkage voids of elongated or vesicular shape. In some samples, voids of sub-rectangular shape may reveal vegetal inclusions, burnt during firing (samples 80, 160, 162, 204, 214).

The overall frequency of aplastic inclusions is 20 to 30%, sorting is fair to poor and the maximal grain size is very coarse sand to granule. In the silty grain size, bioclasts (complete or fractured) are frequent to few, rounded micritic limestone is moderately frequent and angular quartz is few to moderately frequent. Iron-rich argillaceous clasts are angular to rounded and few to moderately frequent. Feldspar is usually anhedral and few to rare.

The sandy inclusions are dominated by bioclasts, micritic to bioclastic limestone and iron-rich argillaceous clasts. Bioclasts, complete or fractured, are very frequent and often re-crystallized. They correspond mainly to foraminifera and some echinoid radioles. Micritic to bioclastic limestone is very frequent to moderately frequent, sub-angular to rounded. The limestone grains may contain some opaque oxides, and often suffered during firing. Iron-rich argillaceous clasts are light red to very dark red, almost black. They are frequent, angular to rounded, with sharp to unclear boundaries and exhibit a high relief in thin section. The argillaceous clasts may contain silty to sandy quartz grains or feldspar, are often fractured and may be surrounded by shrinkage voids. Quartz grains are moderately frequent to few, angular to rounded, often fractured and may contain fluid inclusions. Feldspar is rare to few and of subhedral to anhedral shape. Finally, sub-angular chert is rare to absent and isolated rounded basalt inclusions occur in samples 104 and 192. Into this set of inclusions, no intentional addition of temper had been evidenced and the non-plastics are probably naturally present in the clay.

Group 4 (n=2; Fig. 11)

The matrix is slightly active and orange-brown to brown. Voids are few (c. 5%), and are primarily

shrinkage voids. Some voids are of vesicular shape, while rare rounded voids may be caused by bioclast de-carbonation during firing.

The overall frequency of non-plastic inclusions is 20 to 25%, sorting is poor and the maximal grain size of non-plastics is very coarse sand. The silty fraction includes frequent bioclasts, often re-crystallized, which are mainly complete or fragmented foraminifera. Micritic to sparitic limestone is moderately frequent and rounded. Iron-rich argillaceous clasts are also moderately frequent and rounded, while quartz and calcite grains appear angular and few.

The sand grain size fraction is dominated by frequent quartz grains, which may be rounded to angular, but primarily sub-rounded. They exhibit irregular shapes, frequent micro-fractures and fluid inclusions. Complete or fractured bioclasts (mainly foraminifera, often re-crystallized) occur frequently. Iron-rich argillaceous clasts are moderately frequent, from very dark red to almost black, with sharp to unclear boundaries and may contain silty to sandy quartz grains. Sub-rounded to rounded micritic limestone grains are few, as altered feldspar which adopt subhedral to anhedral shapes. Finally, sub-rounded to sub-angular chert inclusions and anhedral idding-site grains occur scarcely. Here again, no clear indication of tempering has been evidenced. The optical activity of the matrix associated with scarce evidences of carbonate decarbonation is likely to indicate a relatively low firing rate.

Group 5 (n=7; Fig. 12)

The matrix is optically active to isotropic (active in sample 17; slightly active in samples 16, 21 and 25; sub-isotropic in sample 3; isotropic in samples 2 and 27). When oxidized, the matrix is of yellowish orange to red-orange and red-brown colours. In reduced areas, the colours vary from yellowish brown-grey to dark brown-grey, almost black. Voids represent 5 to 10% of the surface of the thin sections and are usually shrinkage voids.

The overall frequency of non-plastics is c. 20 to 30%, sorting is poor to very poor and the maximal grain size of inclusions is very coarse sand to granule. In the silty fraction, angular quartz grains are moderately frequent, as iron-rich argillaceous clasts, of red to very dark red colour, rounded to angular. Bioclastic inclusions are moderately frequent, often decarbonated and re-crystallized and primarily correspond to foraminifera. Rounded micritic limestone is few to moderately frequent. Few anhedral, altered feldspar occurs along with rare anhedral pyroxene.

The sandy inclusions are dominated by frequent to very frequent ARFs — Argillaceous Rock Fragments (Whitbread 1986), also named ‘shales’. They are elongated inclusions, sub-angular to rounded, thin bedded and usually fractured in the direction of elongation. They are constituted of clay phyllites oriented in the direction of elongation, and may contain silty angular quartz grains and opaque oxides. Extinction is straight and they adopt the same colours as the surrounding matrix, sometimes slightly lighter or darker. The ARFs mainly differ from the iron-rich argillaceous clasts because of their sub-rounded elongate shape and their thin internal bedding. Rounded grains of micritic to sparitic limestone are few to moderately frequent. Sample 3 also contains bioclastic limestone and few isolated angular calcite. Iron-rich argillaceous clasts of orange-red to dark red colours, with sharp to unclear boundaries, are moderately frequent and may contain the same silty inclusions as the matrix. Bioclasts are few to moderately frequent, complete or fractured, and usually suffered decarbonation during firing, and re-crystallization. Few quartz grains are observed, angular to rounded, mainly sub-rounded, often micro-fractured and containing fluid inclusions. Altered feldspar is few and subhedral to anhedral, and sub-rounded to angular chert inclusions are rare. The frequency of ARFs is very characteristic of group 5.

Group 6 (n=2; Fig. 13)

The matrix is optically slightly active to sub-isotropic. When oxidized, the matrix colours are red-orange to dark red and, when moderately reduced, orange-brown to brown. The two samples from this group were not highly reduced. Voids represent 5 to 10% of the surface of the thin sections. These are primarily elongated shrinkage voids, but some rounded voids occur that may indicate the decarbonation of bioclasts during firing. Few large voids of irregular shape may reveal vegetal inclusions which burnt during firing.

The overall frequency of non-plastics is 30%, sorting is fair to poor and very coarse sand is the maximal grain size. Among the silty inclusions are frequent to moderately frequent angular quartz grains, and frequent rounded micritic limestone. Isolated bioclasts are moderately frequent, mainly corresponding to foraminifera (complete or part of). Iron-rich argillaceous clasts are dark red to black, rounded to angular and moderately frequent. Rare anhedral iddingsite grains may be found.

In the sand grain size, the dominating inclusions are also quartz and limestone. Quartz grains are frequent,

rounded to angular but mainly sub-rounded, of irregular shape and micro-fractured. Limestone is micritic to bioclastic, frequent and rounded. Argillaceous clasts are also frequent, rounded to angular and of orange to dark red colour. They may contain silty angular quartz grains or, scarcely, micrite or bioclasts. ARFs are few to moderately frequent. They are of elongated shape, low sphericity and regularly exhibit fractures in the direction of elongation. Finally, rounded chert and altered subhedral feldspar are rare, while iddingsite is very rare and sub-rounded. The presence of ARFs along with other inclusions (quartz, limestone) is typical of this group.

Group 7 (n=1; Fig. 14)

The matrix is active to slightly active and of orange-red to brown colour. Voids are few (c. 5%) and are primarily shrinkage voids, along with some vesicular voids.

The aplastic inclusions represent 30 to 35% of the surface of the thin section. Sorting is very poor and the maximal grain size is very coarse sand. The silty inclusions are quartz, iron-rich argillaceous clasts and basaltic inclusions. Angular quartz grains are frequent, and angular to rounded iron-rich argillaceous clasts are moderately frequent. Euhedral to subhedral plagioclase feldspar, anhedral clinopyroxene and iddingsite are moderately frequent. Olivine is usually almost completely altered into iddingsite, but few anhedral silty inclusions of non-altered olivine are present.

The sandy fraction is dominated by frequent to very frequent basalt grains, rounded to sub-rounded, which include plagioclase feldspar, clinopyroxene, olivine often altered into iddingsite and some opaque oxides in various proportions. Basalt inclusions display different types and rates of crystallization. Isolated magmatic minerals are also present. Isolated plagioclase feldspar is frequent, euhedral to subhedral, along with frequent iddingsite grains, which are euhedral to anhedral. Non-altered or partially altered olivine crystals are few, also euhedral to anhedral, depending on the conditions of crystallization. Isolated clinopyroxene is usually anhedral and moderately frequent, while opaque oxides are black, angular to rounded and with sharp boundaries. Along with these magmatic inclusions are moderately frequent argillaceous clasts, sub-angular to rounded, with sharp to unclear boundaries and of brown to very dark red colours. They may include the same silty and sandy inclusions as those present in the matrix (primarily quartz and isolated basaltic minerals). Sandy quartz grains are few, rounded to angular (mainly sub-rounded) and may often exhibit micro-

fractures and fluid inclusions. Micritic to sparitic limestone grains are few, rounded to sub-rounded. No bioclastic inclusion has been identified. Lastly, rare sub-rounded chert may be encountered.

Group 7 sample, containing very frequent basaltic inclusions, differs from the majority of the studied samples which exhibit primarily sedimentary inclusions. It presumably comes from different outcrops.

Group 8 (n=4; Fig. 15)

The clay matrix is sub-isotropic to isotropic. The matrix is light red with brown greenish patches in oxidized areas, while greenish brown-beige to very greenish grey when reduced. Voids represent 5 to 10% of the surface of the thin section. Shrinkage voids are elongated. Few rounded voids may indicate decarbonated limestone grains or bioclasts which suffered during firing.

The overall frequency of non-plastic inclusions is *c.* 20%. Sorting is fair to poor and the maximal grain size of non-plastics is very coarse sand. In the silt grain size, angular quartz grains and rounded micritic limestone are moderately frequent. Argillaceous

clasts, rounded to angular, are moderately frequent to frequent. Few rounded chert inclusions may be observed.

Among the sandy inclusions are quartz, chert, argillaceous clasts and micritic limestone. Quartz grains are moderately frequent to frequent, rounded to angular (mainly sub-rounded) and often display irregular shape and micro-fractures. Chert inclusions are sub-angular to rounded, moderately frequent and mainly micro-crystalline. The argillaceous clasts may contain silty or sandy quartz grains. Their shape is mainly rounded but extends to angular. They are moderately frequent to frequent. Finally, micritic limestone inclusions are few to moderately frequent and occur in rounded to sub-rounded shapes. The light colours and the composition of the matrix along with the frequency of siliceous inclusions (especially chert, which is uncommon in the other groups) contrast with the other samples examined here. These differences of clay and inclusions may indicate a different provenance of raw materials, which still is to define precisely.