Analytical investigations of cooking pottery from Tell Beydar (NE-Syria)

T. Broekmans [a], A. Adriaens [b,*], E. Pantos [c]

[a] *Department of Chemistry, University of Antwerp, Universiteitsplein 1, B-2610 Antwerp, Belgium*
[b] *Department of Analytical Chemistry, Ghent University, Krijgslaan 281-S12, B-9000 Ghent, Belgium*
[c] *CCLRC, Synchrotron Radiation Department, Daresbury Laboratory, Warrington WA4 4AD, UK*

Abstract

Within the framework of a technological and socio-economical study of pottery production in Tell Beydar (NE-Syria) during the third millennium BC, the chemical composition and mineralogy of cooking pottery from that site has been studied using polarizing microscopy, scanning electron microscopy with energy dispersive X-ray detection (SEM-EDX) and X-ray diffraction by means of synchrotron radiation (SR-XRD). The obtained data were used to make inferences concerning the pottery's technology, such as clay preparation and firing techniques.
© 2004 Elsevier B.V. All rights reserved.

1. Introduction

Ceramics are amongst the artifacts that are most frequently unearthed by the archaeologist. These utilitarian goods are generally found in a fragmentary state, but frequently also complete pots are exposed. Such an assemblage of pottery is composed of different types of vessels, characterized by different fabrics, forming techniques, shapes, decorations, functions, etc. One of these types of ceramics, which is found in most cultures and in most eras, is what archaeologists label as

cooking pots or *cooking ware*. Due to their specific function, they have to fulfil certain conditions and therefore they are believed to be easily recognizable. Cooking pots are likely to have rounded shapes to avoid thermal damage and for greater exposure to heat. They also have relatively thin walls for better heat conduction and reduction of the thermal gradient between the surfaces. Moreover, cooking pots are usually coarse textured, porous, and tempered with material having low thermal expansion coefficients, all this to reduce thermal stresses [1].

In an attempt to assess to which extent third millennium BC cooking pots from Upper Mesopotamia correspond to this image of the 'typical' or 'ideal' cooking pot, cooking pottery from Tell Beydar (NE-Syria) has been investigated using a

---

* Corresponding author. Tel.: +32-9-264-4826; fax: +32-9-264-4960.
E-mail address: annemie.adriaens@ugent.be (A. Adriaens).

range of analytical techniques. In order to understand the pottery's mineralogy, thin sections of 41 cooking ware samples have been investigated using polarizing microscopy; 18 of them were also analyzed by X-ray diffraction using synchrotron radiation (SR-XRD). To obtain an idea of the alleged local character of the pottery, the latter technique was also used to study the mineralogy of 4 local clay samples, 5 clay seal impressions, and an object in unbaked clay. While we cannot know if the local clay samples represent clay beds that were exploited in antiquity, we can be sure that the seal impressions and the clay object represent resources that were used 4500 years ago, be it not necessary for pottery production. Finally, 11 cooking ware samples and 8 basalt samples (the latter being surface finds that were taken from basalt outcrops near the site) were investigated using a scanning electron microscope with an energy dispersive X-ray detector attached to it (SEM-EDX).

2. Experimental

XRD is one of the most direct techniques for the identification of the mineral composition of ceramics as it can be used to analyze both inclusions and matrix. Its main disadvantage is that data collection can be quite time-consuming, each data set requiring several hours. It is mainly for this reason that XRD analysis is usually applied only to a limited set of samples. The data collection time can be reduced by orders of magnitude, using synchrotron X-rays and a fast area detector. An additional advantage of 2D data recording is that an easy distinction can be made between fine-particle phases, such as hercynite in pottery produced under reducing conditions, and overlapping reflections of coarser material such as quartz. In this study 2D diffraction patterns were acquired using a CCD detector at station 9.6 of the synchrotron radiation source at Daresbury Laboratory (UK). Powdered ceramics were loaded in 0.5 mm quartz capillaries. The beam footprint was 200–250 μm and the exposure times 3–4 min in single bunch mode. The data were polar transformed and azimuth integrated using the using the

ESRF program FIT2D [2]. Macros permit batch processing of several datasets at a time. A correlation facility maybe used to sort data according to overall similarity.

Polarizing microscopy (Olympus SZX12 and DP10 digital camera system) was used to study the mineral inclusions in the clay matrix, but also the structure of that matrix was considered. The combination of petrology and XRD allows us to describe the 'overall' mineralogy of ceramics: clay constituents, possible altered mineral phases, and non-plastic mineral inclusions.

Finally, for a full understanding of the ceramic's mineralogy, one should also consider its elemental composition, since these two are inter-related. The elemental composition of the pottery and of its inclusions, as well as the composition of the basalt's mineral constituents, was analyzed by scanning electron microscopy (JEOL JSM-6300) with an energy dispersive spectrometer (SEM-EDX). This technique also enabled us to study the pottery's microstructure. The investigated sherds were first embedded in a resin, whereupon their sections were gradually smoothed using water-proof abrasive paper up to grade 4000. A 20 k eV, 1 nA electron beam was used to bombard the samples and signals were accumulated during 100 s (live time). For the determination of the approximate bulk composition, several areas of 10–25 mm^2 were rastered, the exact size of the area and the number of places scanned depending on the size of the sample. Standardless ZAF corrections were used for obtaining quantitative results.

3. Results

A preliminary investigation of the pottery shows that it possesses many of the already mentioned typical cooking pot features. Their shape is rounded; they have a rather open texture, with a fabric containing many large inclusions (Figs. 1 and 2). Although the upper parts of Tell Beydar cooking pots are not particularly thin walled (typical vessel walls having a thickness of 1 cm or even more), the few larger body sherds and more or less complete cooking pots that have been found, indicate that they were significantly thinner
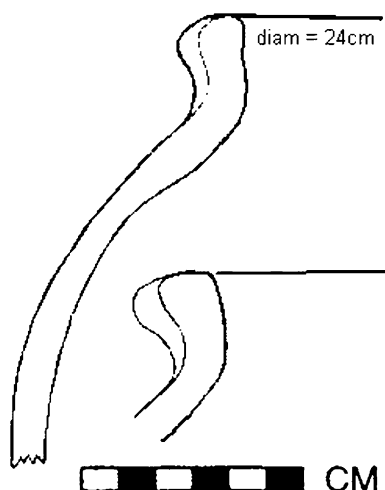
Fig. 1. Cross sections of some typical cooking ware as used in Tell Beydar.

at the base. An ever-occurring feature on cooking ware from Tell Beydar is the burnished outside surface. Most of the few open cooking ware shapes that are found also show this feature on the inside.

Observation by naked eye or using low power magnification may allow a general division to groups of fabrics which can be further identified or subdivided when studying thin section specimens. In this case it can be observed that two different fabrics exist (Fig. 2), both containing a rather large amount (up to 35 vol.%) of big mineral inclusions. The two groups can also be clearly distinguished when studying the cooking ware samples in thin section (Fig. 3). The first group is characterized by large limestone inclusions of up to 2 mm. In addition, fragments of quartz and plagioclase are also present (<250 μm). Often small black opaque iron oxide inclusions, as well as mica (biotite) are found. In some isolated cases hardly any limestone is present, but angular monocrystalline calcite inclusions can be found instead. The second group is differentiated from the first one by the presence of large basalt inclusions (<1.5–2 mm). All mineral inclusions that are present in the samples from the first group are usually also found in the samples from the second one. This means that in the second group, large limestone inclusions exist next to the basalt inclusions, albeit usually in smaller sizes and quantities. The size, shape and quantity of the
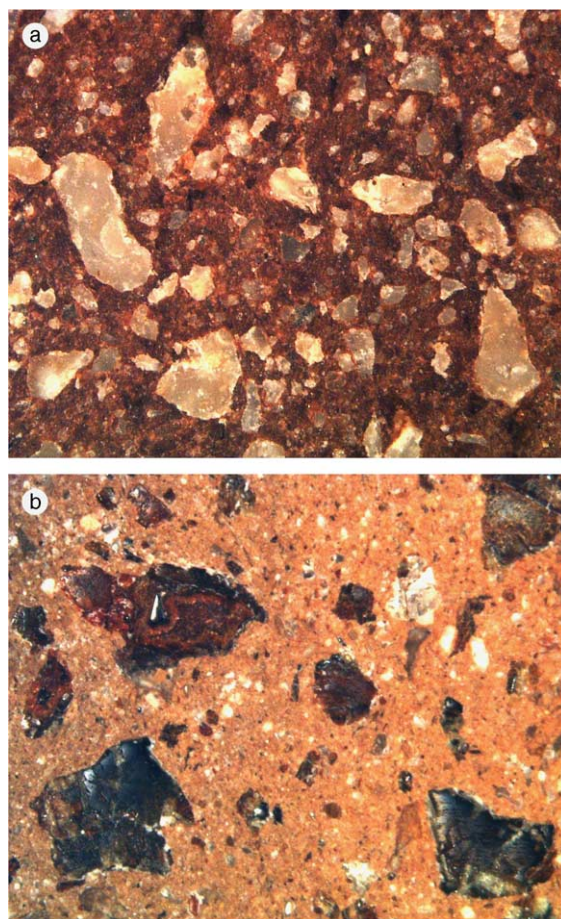

Fig. 2. (a) Micrograph of CW104 showing large calcitic inclusions (×30); (b) micrograph of CW208 showing large volcanic rock inclusions (×40).

large limestone and basalt inclusions indicate that they were added by the potter. This basaltic cooking ware fabric is also attested at some other sites in the region, e.g. Tell Rad Shaqrah [3], Tell Brak [4] and Tell Bderi [5]. Several elements indicate that the basalt, which was used for tempering cooking ware, was taken from outcrops only a few hundred meters west of the site (the Ard esh-Sheikh plateau). As an example, Table 1 shows the elemental composition of pyroxenes in basalt from the plateau to be very similar to that of pyroxenes in basalt fragments in Tell Beydar cooking ware.

The twofold division of the cooking ware samples (limestone tempered versus basalt tempered) is
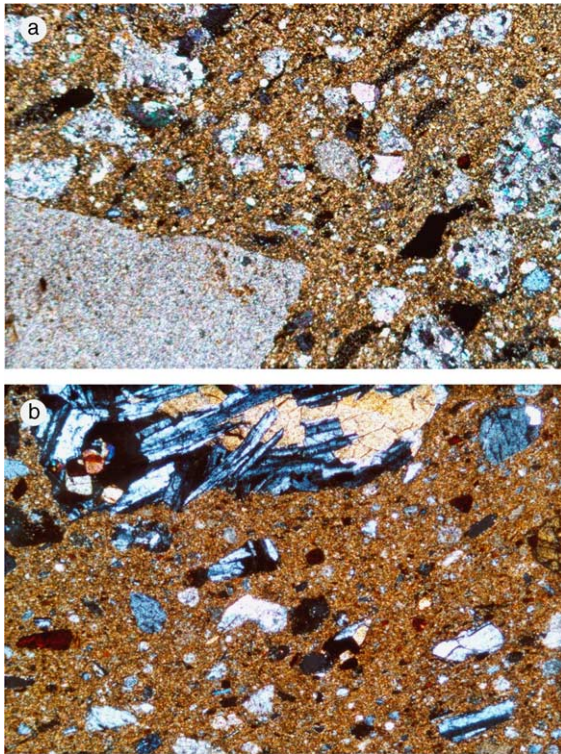
Fig. 3. (a) Petrograph of CW117 showing limestone inclusions (XP, ×80); (b) petrograph of CW210 showing basalt and limestone inclusions, top right corner shows quartz (XP, ×80).

also clearly visible in the SR-XRD results (Table 2). In the first group calcite outnumbers all other components (hence the lower quartz values), while the second group contains pyroxene and more plagioclase, resulting from the basalt inclusions. Although the large limestone inclusions are clearly added by the potter, Table 2 shows us that also the soil samples have calcite as their major constituent, followed by quartz. Calcite is not the only carbonate material in the soil samples, since also some dolomite is present. The actual clay minerals are illite, kaolinite and montmorillonite. Finally, also plagioclase is present. The mineralogical composition of the seal impressions and of the unbaked clay object is very similar to that of the soil samples, only small differences in illite and montmorillonite are observed. In addition, the relative abundance of dolomite in some of the seal impressions is higher. These differences might be caused by a possible preparation of the raw materials before using them, thereby altering the relative abundances of the constituents [6]. However, it is not excluded that also postdepositional factors play a role. The predominance of calcite in these samples indicates that local resources are rich in calcium.

Most of these carbonates and clay minerals are also present in the cooking ware samples. Their presence in the pottery samples indicates that it was

Table 1
Elemental composition of pyroxene in basalt rock samples and cooking ware basalt inclusions from Tell Beydar as revealed by SEM-EDX (wt%)

	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	CaO	MgO	TiO_2	K_2O
BL1	45.4	5.0	14.3	0.1	20.9	10.1	3.7	b.d.l.
BL2	47.4	4.5	10.2	0.1	21.7	12.7	2.6	b.d.l.
BL3	47.1	4.5	11.6	0.1	20.8	12.4	2.9	b.d.l.
BL4	47.1	4.2	11.3	0.2	21.1	13.0	2.6	b.d.l.
BL5	45.3	5.1	13.6	0.3	20.7	11.1	3.6	b.d.l.
BL6	48.8	2.9	12.5	0.3	20.0	13.4	1.7	b.d.l.
BL7	46.1	5.0	12.2	0.2	21.0	11.8	3.2	b.d.l.
BL8	44.7	5.4	13.1	b.d.l.	21.2	10.8	4.1	b.d.l.
cs204px1	47.3	4.8	9.5	1.2	19.9	14.1	2.3	0.1
cs205px1	46.7	5.0	9.9	b.d.l.	21.6	13.3	2.8	b.d.l.
cs206px1	47.8	4.6	9.8	0.4	20.9	13.7	2.4	b.d.l.
cs206px2	46.7	4.8	12.3	0.2	20.5	11.8	3.3	b.d.l.
cs207px1	43.9	6.4	12.4	0.5	20.8	11.1	4.5	b.d.l.
cs208px1	47.0	5.0	10.3	0.4	21.5	12.8	2.8	0.1
cs209px1	46.3	4.7	13.0	0.3	20.3	11.9	2.9	b.d.l.
cs209px2	46.6	4.8	11.2	0.4	20.7	13.0	3.0	b.d.l.

First 8 samples are rock samples, Fe_2O_3t = total iron oxide, b.d.l. = below detection limit.

Table 2
Mineral phases of Tell Beydar clay samples, seal impressions and cooking ware samples as revealed by SR-XRD

	Q	Ca	Dol	Plg	Ill	Kao	Mm	Px
Clay	xx	xxx	x	x	x	x	x	
Seal impressions + object	xx	xxx	x(x)	x	x+	x	x−	
Cooking ware 1	x	xxx	(x−)	x−	x		(x)	
Cooking ware 2	xxx	xxx	(x)	x(x)	x		x	x(+)

Q = quartz, Ca = calcite, Dol = dolomite, Plg = plagioclase, Ill = illite, Kao = kaolinite, Mm = montmorillonite, Px = pyroxene; xxx = major phase, xx = present in large quantities, x = present, brackets = not in all samples.

fired at a relatively low temperature. While kaolinite loses its stability rather abruptly at 500–600 °C, montmorillonite and illite dehydrate more slowly, and the loss of OH water is often only complete after firing up to 900 °C [7,8]. Table 2 shows that, assuming our clay samples represent or are similar to the clay that was used in the production of cooking ware, the temperature at which kaolinite loses its stability has been exceeded in the firing of cooking ware. The absence of any calcium aluminosilicate phases, in combination with the presence of montmorillonite and illite, indicates a temperature of 850 °C as the upper limit in the estimated range for the firing temperatures. Based on the analytical results, it is preferable to suggest a firing temperature in the range of 600–850 °C. The presence or absence of any sintering or vitrification in the SEM micrographs could cut this broad range as greater or less than 750 °C.

It is not excluded that the firing technology differed between the two cooking ware groups, given their differences in dolomite and montmorillonite contents. This could suggest a lower temperature, a shorter firing cycle, a different firing atmosphere, or a combination of these factors for the basalt-tempered subgroup. However, the lower values for dolomite and montmorillonite in the limestone-tempered subgroup could also be caused by the extremely high value for calcite, its high peak lowering the relative amounts of the other minerals (as it is probably the case for quartz values).

4. Conclusions

It is obvious that third millennium cooking pottery from Tell Beydar shows several of the 'typical' cooking pot attributes. On a macrotechnological level, these attributes are roundness of shape, thin walls (especially the lower parts of the pots) and the burnished surface.

Calcite has a thermal expansion coefficient that is similar to that of clay. Therefore the addition of large limestone inclusions reduces thermal stresses that are generated within the ceramic during subsequent heating and cooling. Our mineralogical data indicates that a relatively low firing temperature was used during firing of the pottery. A low firing temperature prevents calcite from decomposing. If temperatures high enough for decomposition would be attained during firing of the pottery, the thermal expansion coefficient would not be similar to that of clay anymore. In addition, lime blowing would occur. With such large amounts of calcite present in the paste, this would result in the complete destruction of the pot.

It is not clear why basalt-tempered cooking pottery was made next to the limestone-tempered ware. The shapes of the vessels made with the two fabrics show no difference, nor do any of their other features. The possible differences in firing technology might indicate that the two kinds of cooking pottery represent different potting traditions or workshops.

References

[1] P. Rice, Pottery Analysis. A Sourcebook, The University of Chicago Press, Chicago, 1987.

[2] A.P. Hammersley, O. Svensson, M. Hanfland, A.N. Fitch, D. Hausermann, High Pressure Res. 14 (1996) 235.

[3] M. Daszkiewicz, G. Schneider, Polish Archaeol. Mediterranean 7 (1996) 171.

[4] K. Fielden, Tell Brak 1976: the pottery, Iraq 39 (1977) 245.

[5] P. Pfälzner, Tell Bderi 1985. Bericht über die erste Kampagne, Damaszener Mitteilungen 3 (1988) 223.

[6] M.J. Blackman, in: H. Neff (Ed.), Chemical Characterization of Ceramic Pastes in Archaeology, 1992, p. 113.

[7] R.E. Grim, Clay Mineralogy, McGraw-Hill Book Company, New York, 1968.

[8] M. Maggetti, in: J.S. Olin, A.D. Franklin (Eds.), Archaeological Ceramics, 1982, p. 121.