Pottery production at Hierakonpolis during the Naqada II period: Toward a reconstruction of the firing technique

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Introduction

Recent excavations at HK11C Operation B (grid squares AB4-5) at Hierakonpolis have revealed an array of pit-kilns dating to the Naqada II period. This discovery is extremely valuable for the study of Predynastic pottery, especially as there has been little structural evidence for kilns on which to base a discussion of firing techniques in this period. However, because this new evidence is preserved only as foundations and debris, the original shape of the kilns and the firing techniques employed are not clear-cut. To fully understand these kilns, it has been necessary to analyze the pottery produced in them.

In this paper, the archaeological context of the kiln remnants is discussed, followed by a presentation of the results of both laboratory analyses and in-depth observations on pottery from Hierakonpolis. Finally, by integrating the data, a possible reconstruction of the firing technique is proposed.

Excavation of HK11C Operation B

Locality HK11C is a large area of settlement remains located on the wadi terrace flanking the south side of the Great Wadi (Wadi Abu Suffian). On the opposite bank and further to the southwest is the HK6 elite cemetery. The excavation site, Operation B (grid squares AB 4-5) is situated about 30 m south of the wadi bed, and less than 10 m from the vat and firebar installation, believed to be a brewery, uncovered in Operation A (squares A6-7) (Takamiya 2008).

Excavations at Operation B began in 2003 and on-going work has revealed at least two different phases of occupation in the 12 x 11 m unit so far investigated (Fig. 1) (Baba 2006; 2007; 2008a). The upper level (Fig. 2), which probably dates to the middle of the Naqada II period, is characterized by a platform kiln structure (Kiln A), remains of a rectilinear fence-like structure composed of wood posts, and several caches of worked sherds, which appear to be tools specifically created for use in pottery-making (Baba 2008b). Most of the caches were found within conical jars set upright in emplacements sunk into the floor. The largest of these caches contained 554 sherd tools. The tool caches and the platform-kiln suggest that the upper level occupation is associated with pottery-making activities, with the wooden fence structure being part of a potter’s house or workshop.

In the lower level (Fig. 3), which can be dated to the first half of Naqada II, an array of five pit-kiln features have been identified. Located immediately to the north of these features is a set of five more or less well-preserved vats containing residue from the cooking of grain. These vats are assumed to be relevant to the production of beer amongst other possible foodstuffs (Fahmy and Perry forthcoming).
Next to each pit-kiln was a segment of wall, crudely constructed of stone and mud, and about 30 cm high. The pits were on average 60–70 cm in diameter and were found filled with kiln debris, which included charcoal, ash, stone slabs, sherd s and burnt mud rubble. Many of the sherd s were highly fired with burnt mud adhering to them, indicating their use as building materials. When considering the firing technique, these materials become important. Based on close observation of the burnt soil’s condition around each of the kiln features, it is clear that the kilns operated individually.

A large quantity of sherd s was retrieved during the excavations. The ceramic assemblage is dominated by straw-tempered Nile silt in both the upper and lower levels. This fabric accounts for over 80% of the total assemblage. In this fabric, the most common shape is the modeled rim jar.\(^1\) Over 60% of all rims recovered were from these jars.\(^2\) Although no complete vessels were recovered or refitted, the frequency of flattened bases (over 70%) suggests that the majority had a shape like that shown in Fig. 7 (see Hendrickx 2008, 65–70 for a discussion of corpus type and date). Therefore, the main product of the kilns was probably straw-tempered modeled rim jars in this specific shape or close to it. The following analyses are focused on this pottery type.

**Analyses**

*ICP-AES analysis to determine clay*

In order to understand kiln technology at Predynastic Hierakonpolis, SEM (Scanning Electron Microscope) analysis was performed on selected sherd s to estimate firing temperature. This method was used to examine the internal morphology that developed during firing. In particular, it was used to compare the extent of vitrification visible in the matrices of ancient pottery and the samples of local clay used in pottery production, which were progressively fired at known temperatures (Tite and Maniatis 1975; Maniatis and Tite 1981).

To create the comparative samples, the clay used to make straw-tempered pottery had first to be determined. Therefore, ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometry) analysis was conducted on various clay samples collected at Hierakonpolis and on archeological sherds now stored in the British Museum. The latter materials were 35 sherd s composed of the straw-tempered, untempered (black-topped and red polished), shale-tempered and marl fabrics, which derive mainly from the excavation of Mound A at HK11C by J. F. Harlan (1982, 14–25) and also from collections made by the late M. A. Hoffman from various areas of the site.\(^3\)

The clay samples were selected on the basis of location and previous studies (Allen et al. 1989; Allen and Rogers 1982; Allen et al. 1982; Hamroush 1982; 1985; 1992). Five clay samples were prepared:

\(^1\) This type is equivalent to the Fabric class 1 and Subjective shape 2b in the Hierakonpolis Pottery System Codes (Friedman 1994).

\(^2\) Other straw-tempered shapes with a significant presence in the assemblage include large vat rims (17%), hole-mouth jars (11%), direct rim bowls of medium size (3%) and large bowls (2.2%). These correspond respectively to Friedman (1994) Subjective shapes 2n, 2a, 1b, 1n.

\(^3\) These sherd s, along with other materials, were exported as a study collection with the permission of the Egyptian Antiquities Organization on 28 March 1980.
Wadi clay was collected at the foot of the Nubian sandstone cliffs directly south of HK11C. This sample corresponds to the cretaceous clay or older shales discussed by Allen and Hamroush (1986). Colour is yellow, texture is dense, clay-silt with high plasticity.

Masmas silt was obtained at the eastern edge of the HK11 wadi terrace. Silts of the Masmas formation at Hierakonpolis are described by Hamroush (1982). Colour is dark brown and texture is silt-sand with moderate plasticity.

Sahaba silt was collected from the low desert approximately 300 m from the edge of the cultivation. These silts are probably equivalent to Sahaba-Darau aggradation 4 as described by Hamroush (1982). Colour is pale brown and texture is silt-sand with poor plasticity.

Ballas clay was obtained from modern potters at Ballas, north of Luxor. As observed, the clay is currently mined from the limestone bedrock on the fringes of the Western Desert (cf. Nicholson and Patterson 1985). This sample was used as a representative of marl clay, since calcareous clays could not be found in the vicinity of Hierakonpolis. Colour is gray and texture is clay, very dense with high plasticity.

Modern pottery was collected to represent Nile alluvial sediment in the modern flood plain. A water jar (ẓīr) was purchased from the local pottery workshop in the village near Hierakonpolis (cf. Pyke 2004). The potters said the clay was gathered from a nearby cultivated field, mixed with ash, chaff and dung and then left to soak in a pit before use.

ICP-AES provides the chemical composition of both trace and major elements at the same time and enables quantitative comparison (Table 1). Taking advantage of its characteristics, cluster analysis was used. Cluster analysis is the most common multivariate statistical method used in the chemical study of pottery (e.g., Bourriau et al. 2004; Mallory-Greenough et al. 1998) because it allows all of the elemental concentrations in each sample to be considered, representing the chemical similarities and differences as a visual tree diagram.

In the diagram shown in Fig. 4, the four cluster groups divided best at a distance of 10. Almost all of the straw-tempered fabrics were included in Cluster 1 with the Sahaba silt sample. This result suggests that silts from the Sahaba formation have the best potential to be the clay used for the majority of straw-tempered pottery found at the site. At Hierakonpolis, the Sahaba silt formation covers the lower desert margins where the main Predynastic settlement

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4 Samples were prepared as powder; a broken edge of each sherd was drilled with a diamond bit and the first few millimeters of the surface layer were discarded to eliminate contamination. ICP-AES analysis was run at the laboratory of the Royal Holloway Enterprise Ltd at Egham, Surrey, UK, using the HF dissolution method.

5 The cluster analysis was carried out by including all elements as variables, calculating standardized squared euclidean distances, and clustering using the farthest neighbour (complete linkage) method. Data processing used free software “College Analysis Ver.3.0” developed by Masayasu Fukui of Hukuyama Heisei University, Japan (http://www.heisei-u.ac.jp/ba/fukui/analysis.html).
is concentrated. However, this diagram also shows a distinctive clustering composed only of straw-tempered sherds and silt collected from the Masmas formation (Cluster 4). Masmas silts are present along the edges of the Great Wadi and underlie the settlement at HK11 (Hamroush 1982, 97; 1985, 41). These silts are therefore easily available and were collected in the vicinity of the Operation B kiln site. The results suggest that most Nile silt pottery was produced using Sahaba silts prevalent in the large settlement area, while at the HK11C there was a special production of the straw-tempered pottery using the locally available clay source (cf. Allen and Rogers 1982; Allen et al. 1989). Test samples were then made from Masmas clay.

**SEM analysis to estimate firing temperature**

The test tiles made from Masmas clay were fired at intervals of 100°C from 600° to 1100°C in the electric kiln under oxidizing conditions. The stages in the development of vitrification are shown in Figure 5. These stages form the data base for estimating the firing temperatures of the archaeological sherds. In this clay, there was no change by 800°C; initial vitrification appears in the range of 800° to 850°C as the glassy filaments developed. Extensive vitrification developed during firing at 850° to 900°C as the cellular structure collapsed. The vitrified surface area expanded at 900°C. Then continuous vitrification formed in temperatures from 900° to over 1000°C, when the vitrification was developed further and the pores became larger and fewer.

The extent of vitrification observed in the ancient straw-tempered sherds was then compared with these results. The firing temperatures for each sherd were estimated as shown in Figure 6. From these results, the straw-tempered fabrics appear to have been fired mainly at low temperatures: under 800°C, but sometimes up to 1000°C. This variation is probably due to the firing conditions or firing method used, and this is a crucial point for understanding the kiln type. Based on ethnoarchaeological studies (Gosselain 1992; Tite 1995), firing in a bonfire is generally characterized by a wider range of temperatures than that occurring in an updraft-kiln. Vessels with a coarse open fabric are less susceptible to firing damage and are very suitable for such primitive firings. From the estimated temperatures, the straw-tempered pottery at Hierakonpolis could have been fired in a bonfire kiln.

**In-depth observation of firing traces**

A method for detecting firing techniques based on firing stain patterns has been developed in Japan (Kuze et al. 1997; 1999; Nagatomo 2006). In these studies, the ancient firing techniques were reconstructed with regard to the kiln type used and the angle, layout and stacking of the vessels inside the kiln.

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6 This analysis was conducted using a CamScan MaXim at Cardiff University.
7 In this experiment, samples were fired with the vent of the kiln open to allow air in and prevent reducing conditions.
8 For detailed descriptions of each stage of vitrification see Tite and Maniatis 1975; Maniatis and Tite 1981.
9 Previous studies have estimated relatively low temperatures: less than 800°C (Allen et al. 1982, 211) and 750–900°C (Hamroush 1985, 313).
For this analysis, complete pots are preferred, but such vessels are absent in the assemblage from the HK11C kiln site. As an alternative test sample, the straw-tempered modeled-rim jars from Tomb 16A in the HK6 elite cemetery were used. These jars have been studied by Hendrickx (2008) and dated to the early Naqada II period. They are thus contemporary with the lower level at the kiln site. More than 66 straw-tempered jars are attributed to Tomb 16A. Of these, 28 jars, which had been mended to or near to completion (Fig. 7), were subjected to detailed examination. As Hendrickx (2008) states, it is unlikely that these jars were intended for actual use, as there are no remains of contents, cooking-soot or heavy use-stains. This lack of use makes these vessels perfect specimens for the observation of firing traces. For this examination, each jar was divided into four faces as shown in Fig. 8: two faces on the interior and two on the exterior.

Kiln type

In an attempt to distinguish the kiln type, the exterior faces of the jars were examined for distinct black stains, or ‘fire clouds’, caused by the uneven distribution of air during the firing (e.g., Rye 1981, 120–21). This stain was observed on 14 of the 28 jars, thus 50% of the total (Fig. 9). Stains of this type are often seen in bonfiring because the fuel and pottery are in close contact. They rarely occur in updraft-kilns where the pottery is separated from the fuel. Therefore, these jars must have been fired in a bonfire, as the results of the SEM analysis also suggest.

Angle in the kiln

The angle at which the pottery was set within the kiln can be identified by the position of ‘ash-stains’ on the interior. Such stains are generally formed when ash from the fuel falls into the pot and accumulates horizontally at the lowest part of the interior. For example, if a pot is set upright, the ash-stain is more likely to form around the base.

Observation of the ash-stains revealed a vertical, or upright, angle for two of the jars, a diagonal stance for two other pots, and a horizontal, or sideways, position for three more (Fig. 10). It follows that vessels placed on their sides horizontally within the kiln are more likely to have a distinct black stain (fire cloud) on the downward side of the exterior. Based on this principle, the angle of a pot with no ash-stains on the interior can still be identified from staining on the exterior. In this way, three additional pots were identified as having been positioned horizontally. The results of this observation suggest that the majority of the jars were placed in the kiln lying on their sides.

Layout in the kiln

Pottery vessels are usually fired in a group rather than individually. When the pots are placed in close contact to one another in a kiln, small ‘spot stains’ form at the places where they touch. For example, if the jars are arranged side by side as shown in Fig. 11.1, the spot-stain will appear at the point of contact on the middle part of the body. Thus, by observing the position of the spot-stains on the exterior, the arrangement of the vessels in the kiln can be deduced (Fig. 12).

Such stains were recorded by dividing the body of each vessel into three parts as shown in Fig. 13. Two stains on the upper part of the body, four on the middle part, and ten on the
lower part were observed. As the spot stains were most frequently found on the lower part of
the body, the arrangement in Fig. 11.5 is the most plausible, and a layout in a radial, flower-like
arrangement may be proposed (see Fig. 15). Although it cannot be said that all pots were fired
in the same way, this is the most likely arrangement during the firing of these straw-tempered
jars.

**Stacking in the kiln**

Spot-stains are also useful for determining whether the pots were stacked in the kiln. In the
assemblage from Tomb 16A, there are pots with two spot-stains on one side of the exterior.
This occurrence suggests that they were fired on their side, but had been placed above and
between two similarly positioned vessels in a lower layer (Fig. 14). Moreover, other jars had
three stains, not only on the underside but also on the topside, which indicates the existence
of more than two layers. These spot stains suggest that the jars were piled-up in at least three
layers.

It is generally observed that in stacked firings, pots in the upper layers tend to be free
of black-stains because they are above and away from the fuel. In addition, spot-stains will
disappear if the flame becomes even and stable. Within the assemblage from Tomb 16A, there
were nine well-baked jars, which exhibited no stains at all. This evidence further suggests that
not only were the jars fired in a stacked arrangement, but also that they were fired with a
stable flame, and this could only be achieved with a covering. The use of a covering allows
heat to be retained inside the kiln and makes the flame more stable. The benefits of using a
covering have been demonstrated by experimental firings (Baba 2005; Baba and Saito 2004).

**Reconstruction of the firing technique**

Finally, putting together the results of the pottery analyses and the archaeological evidence,
we can propose a reconstruction of the firing technique employed at HK11C. This is not
to imply that the jars from Tomb 16A at HK6 were necessarily made in the HK11C kilns,
although it is a distinct possibility; nor do we wish to imply that all firings involved only one
type of vessel. Nevertheless, the large number of jars in Tomb 16A and the evidence for
a single workshop responsible for their production, make it quite likely that these vessels
were fired together without significant mixing with other vessel shapes. Furthermore, the
proximity of the kilns in Operation B to food processing vats strongly suggests that these
jars, which overwhelmingly dominate the assemblage, are specifically associated with the food
being produced nearby. The evidence indicates that the pottery workshop and kilns were not
creating the full range of shapes found in the settlement, but were dedicated to the specialized
production of jars and a modicum of other shapes necessary in the context of industrial-
scale food production. Firings involving only modeled rim jars must have been quite frequent.

For the reconstruction of the firing technique, we have taken the well-preserved kiln feature
3 in Operation B as an example (see Fig. 3). The pit is approximately 70 cm in diameter and
40 cm deep; the wall beside it is 40 cm high. Within these parameters, considering the average
height of the straw-tempered jars as ranging from 25 to 30 cm (Hendrickx 2008, 65, 82–83),
the proposed flower-like layout fits fairly well into the pit (Fig. 15.1).
The firing sequence, based on the kiln debris found filling the pit, can be proposed as follows (Fig. 15.2): First, the firewood and kindling are arranged on the floor of the pit. Sherds or stone slabs are then placed over the fuel to protect the pots from direct contact with the fire. This practice is suggested by the highly fired sherds found in the pit. On top of this, three layers of pots are stacked up, using the wall for support. Finally, the pots are covered with sherds which are cemented together with a coating of mud.

Although there were no in situ remains of the covering, debris found in the kilns contained a number of sherds with burnt mud adhering to them. Moreover, the ancient potter definitely had knowledge of sherd and mud construction, since the adjacent food-production vats were encased and supported by sherds cemented with mud (Fig. 16). It may be suggested that the same technology was employed in kiln construction.

While the proposed firing method is primitive and can be grouped with bonfire types, it is technologically more advanced. The use of a covering allowed the temperature to rise gradually and the heat to be retained inside. In addition, this method is more economical: it needs little adjustment after ignition, and requires less fuel than a simple bonfire. Furthermore, with stacked pottery, the production volume in one firing can be substantially increased. The kilns of HK11C date to the Naqada II period, a time when the mass-production of pottery is becoming increasingly evident as part of the social developments leading toward the formation of the Egyptian state. This easy and economical method would have been welcomed, if not crucial, for the success of this growing industry.

The reconstruction proposed here is preliminary and will be revised in light of future research and discoveries; however, it is hoped that these results with spark further discussion of the production techniques of Predynastic pottery.

Acknowledgements

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Fig. 1: Overview of HK11C Operation B, Lower Level in 2009, looking west.

Fig. 2: Plan of the Upper level as of March 2009.
Fig. 3: Plan of the Lower level as of March 2009.
Fig. 4: Result of cluster analysis of BM sherds and clay samples.
Fig. 5: SEM photomicrographs of fired samples of Masmas clay, with vitrification stages and firing temperature for Masmas clay.

<table>
<thead>
<tr>
<th>Vitrification stage</th>
<th>Temperature ranges (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 No vitrification</td>
<td>&lt;800</td>
</tr>
<tr>
<td>2 Initial vitrification</td>
<td>800–850</td>
</tr>
<tr>
<td>3 Extensive vitrification</td>
<td>850–900</td>
</tr>
<tr>
<td>4 Continuous vitrification FB</td>
<td>900–1000</td>
</tr>
<tr>
<td>5 Continuous vitrification MB</td>
<td>1000–1100</td>
</tr>
</tbody>
</table>
Fig. 6: SEM photomicrographs of selected straw tempered samples, with vitrification stages and estimated firing temperatures of straw tempered sherds.

<table>
<thead>
<tr>
<th>Fabric Group No.</th>
<th>Sherd Part</th>
<th>Vitrification</th>
<th>Estimated Temperatures (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>BM03 body</td>
<td>1: No</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM05 rim</td>
<td>1: No</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM09 body</td>
<td>1: No</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM15 rim</td>
<td>4: Continuous</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM27 rim</td>
<td>1: No</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM28 rim</td>
<td>3: Extensive</td>
<td>600</td>
</tr>
<tr>
<td>Straw</td>
<td>BM31 rim</td>
<td>1: No</td>
<td>600</td>
</tr>
</tbody>
</table>

1) BM31: <800°C
2) BM28: 800–900°C
3) BM15: 900–1000°C
Fig. 7: Modeled rim jars from HK6 Tomb 16A (left: 98/27, right: 176/2).

Fig. 8: Four faces of observation.
Fig. 9: Examples with the distinct black-stains.
Fig. 10: Examples with ash-stains and their proposed angles in the kiln.
Fig. 11: Conceptual position of spot-stains on the exterior.

Fig. 12: Examples with spot-stains.

http://www.britishmuseum.org/research/online_journals/bmsaes/issue_13/baba.aspx
Fig. 13: Frequency of spot-stains on the body.

Fig. 14: Examples with more than one spot-stain and proposed position during firing.
Fig. 15: Reconstruction of the firing technique using the example of Operation B Kiln feature 3.

Fig. 16: Profile of Pottery Vat 2 in Operation B showing sherd and mud construction techniques.
| Sample   | Fabric group | SiO2 | Al2O3 | Fe2O3 | CaO | MgO | Na2O | K2O | TiO2 | P2O5 | SO3 | LOI | CaO | Ba | Co | Cr | Cu | Fe | Mg | Ni | Sc | Sr | V | Y | Zr | Zn | Sr | La | Ce | Nd | Sm | Eu | Dy | Yb | Pb |
|----------|--------------|------|-------|-------|-----|-----|------|-----|------|------|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| BM01     | Untempered   | 14.51| 10.24| 3.19  | 4.96| 1.78| 1.38 | 1.78| 0.54 | 0.154| 560| 30  | 176 | 35 | 16 | 372| 22 | 423| 184| 30 | 98 | 1.36| 28 | 63 | 31 | 5.8 | 1.5 | 3.4 | 2.6 | 7 | |
| BM02     | Snow         | 15.41| 10.09| 2.67  | 5.38| 1.99| 1.71| 1.51 |
| BM03     | Snow         | 13.99| 8.16  | 2.43 | 4.13 | 2.18 | 2.23 | 1.35 |
| BM04     | Untempered   | 11.33| 6.91  | 2.12 | 2.85 | 1.97 | 1.90 | 1.24 |
| BM05     | Snow         | 16.66| 9.03  | 2.57 | 3.43 | 1.72 | 1.91 | 1.63 |
| BM06     | Untempered   | 13.86| 9.42  | 2.73 | 3.83 | 2.14 | 1.73 | 1.66 |
| BM07     | Shale        | 20.80| 10.62 | 2.22 | 2.30 | 1.40 | 1.06 | 1.37 |
| BM08     | Untempered   | 13.41| 8.70  | 2.63 | 4.13 | 1.75 | 1.67 | 1.43 |
| BM09     | Snow         | 14.35| 9.37  | 2.47 | 3.63 | 1.63 | 1.72 | 1.48 |
| BM10     | Untempered   | 15.91| 11.11 | 2.86 | 3.89 | 1.82 | 1.31 | 1.98 |
| BM11     | Shale        | 14.60| 9.39  | 2.30 | 3.21 | 1.72 | 1.84 | 1.69 |
| BM12     | Snow         | 15.19| 9.68  | 2.54 | 3.61 | 2.14 | 1.46 | 1.70 |
| BM13     | Shale        | 16.38| 7.77  | 1.98 | 3.96 | 0.84 | 1.21 | 1.43 |
| BM14     | Snow         | 14.70| 9.56  | 2.48 | 3.20 | 2.48 | 1.77 | 1.58 |
| BM15     | Untempered   | 15.48| 8.64  | 2.69 | 4.72 | 1.32 | 2.18 | 1.93 |
| BM16     | Untempered   | 14.35| 9.27  | 2.64 | 3.69 | 1.99 | 1.81 | 1.61 |
| BM17     | Shale        | 20.24| 9.14  | 2.44 | 3.11 | 1.95 | 1.57 | 1.35 |
| BM18     | Snow         | 14.39| 9.32  | 2.47 | 3.44 | 1.91 | 2.03 | 1.44 |
| BM19     | Untempered   | 12.88| 9.18  | 2.42 | 1.90 | 1.73 | 1.53 | 1.27 |
| BM20     | Untempered   | 14.79| 10.60 | 2.76 | 3.63 | 1.71 | 1.76 | 1.76 |
| BM21     | Snow         | 13.01| 8.34  | 2.25 | 3.49 | 1.30 | 1.89 | 1.35 |
| BM22     | Snow         | 14.99| 8.33  | 3.00 | 4.15 | 1.74 | 1.70 | 1.53 |
| BM23     | Untempered   | 13.06| 10.59 | 2.65 | 3.48 | 1.98 | 1.82 | 1.73 |
| BM24     | Shale        | 22.27| 5.88  | 1.90 | 2.86 | 2.11 | 1.58 | 1.21 |
| BM25     | Sandy shale  | 14.64| 8.17  | 2.66 | 4.74 | 1.17 | 1.74 | 1.27 |
| BM26     | Marl         | 14.32| 6.20  | 2.25 | 1.54 | 0.69 | 1.50 | 0.80 |
| BM27     | Snow         | 15.77| 8.67  | 2.57 | 4.13 | 1.82 | 1.64 | 1.64 |
| BM28     | Untempered   | 15.72| 8.11  | 2.98 | 4.19 | 1.99 | 1.48 | 1.50 |
| BM29     | Snow         | 15.64| 8.88  | 2.84 | 4.87 | 1.41 | 1.51 | 1.46 |

Table 1: ICP-AES chemical data.
## Table 1 (continued): ICP-AES chemical data.

| Sample | Fabric group | Al2O3 | Fe2O3 | MgO | CaO | Na2O | K2O | TiO2 | P2O5 | MoO | Ba | Co | Cr | Cu | Li | Ni | Sc | Sr | V | Zr | La | Ce | Nd | Sm | Eu | Dy | Yb | Pb |
|--------|--------------|-------|-------|-----|-----|------|-----|------|------|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| BM31   | Straw        | 15.30 | 8.83  | 2.56| 4.51| 1.39 | 1.54| 0.26 | 0.136| 0.26 | 0.136| 27 | 143 | 38 | 19 | 95 | 19 | 269 | 158 | 32 | 90 | 142 | 34 | 72 | 38 | 8.3 | 1.9 | 6.5 | 3.3 | 13 |
| BM32   | Marl         | 16.02 | 6.30  | 2.28| 14.90| 0.70 | 1.14| 0.80 | 0.40 | 0.050| 0.050| 771 | 152 | 66 | 69 | 103 | 15 | 463 | 160 | 26 | 137 | 122 | 44 | 74 | 43 | 6.9 | 1.5 | 4.2 | 3.4 | 14 |
| BM33   | Marl         | 16.25 | 7.16  | 2.44| 14.04| 0.76 | 0.93| 0.82 | 0.32 | 0.059| 0.059| 776 | 162 | 43 | 61 | 67 | 17 | 537 | 173 | 32 | 127 | 122 | 44 | 74 | 43 | 6.9 | 1.5 | 4.2 | 3.4 | 14 |
| BM34   | Marl         | 18.68 | 6.65  | 2.22| 14.22| 0.73 | 1.07| 0.92 | 0.36 | 0.057| 0.057| 40 | 17 | 34 | 73 | 16 | 909 | 157 | 28 | 130 | 97 | 38 | 76 | 40 | 8.1 | 1.6 | 4.4 | 2.7 | 9  |
| BM35   | Marl         | 16.81 | 6.21  | 2.28| 13.70| 0.93 | 1.09| 0.92 | 0.35 | 0.071| 0.071| 491 | 17 | 29 | 49 | 71 | 130 | 148 | 28 | 120 | 98 | 37 | 60 | 39 | 7.8 | 1.5 | 4.5 | 2.8 | 10 |
| C1     | Wadi Clay    | 14.71 | 6.04  | 0.80| 2.02 | 1.46 | 1.33| 1.34 | 0.13 | 0.285| 0.285| 320 | 47 | 96 | 42 | 15 | 208 | 16 | 150 | 133 | 23 | 76 | 75 | 40 | 75 | 45 | 8.2 | 1.5 | 8.3 | 2.7 | 13 |
| C2     | Marl         | 14.99 | 9.62  | 3.30| 9.63 | 1.87 | 1.39| 1.45 | 0.18 | 0.140| 0.140| 449 | 29 | 131 | 58 | 23 | 93 | 21 | 364 | 145 | 36 | 83 | 152 | 32 | 69 | 36 | 6.1 | 1.6 | 6.2 | 3.0 | 6  |
| C3     | Sahaba       | 13.89 | 9.62  | 3.30| 9.63 | 1.87 | 1.39| 1.45 | 0.18 | 0.140| 0.140| 449 | 29 | 131 | 58 | 23 | 93 | 21 | 364 | 145 | 36 | 83 | 152 | 32 | 69 | 36 | 6.1 | 1.6 | 6.2 | 3.0 | 6  |
| C4     | Bulac        | 21.44 | 8.70  | 2.36| 13.87| 1.21 | 1.14| 0.81 | 0.35 | 0.050| 0.050| 382 | 20 | 182 | 28 | 130 | 97 | 18 | 391 | 163 | 26 | 208 | 85 | 46 | 81 | 47 | 5.9 | 1.5 | 4.0 | 2.2 | 17 |
| Mo     | Modern pottery| 12.80 | 8.01  | 2.56| 4.95 | 2.37 | 3.28| 1.14 | 0.50 | 0.117| 0.117| 466 | 23 | 123 | 120 | 14 | 99 | 16 | 323 | 142 | 27 | 88 | 128 | 27 | 53 | 31 | 6.5 | 1.5 | 5.0 | 2.9 | 9  |