Ceramic technology in Upper Egypt: a study of pottery firing

Paul T. Nicholson and Helen L. Patterson

> The Nile was never empty. . .it was a 'working river'. On this early evening there was a minor traffic jam on the waterway. Half a dozen, ghiassa, Nile boats. . .made slow progress. . . .One carried. . .a huge load of earthenware water jugs, mainly a load of ballâs, the kind of jugs made in Upper Egypt which women carry on their heads. A native Cairene could even tell the area where the jugs had been made by the faint difference in colour.
>
> 'That load of ballâs came from near Kena', Serena cried. 'Look. They have a greenish tint.'
>
> A sudden flurry of wind blew across the bridge. 'Watch out', she laughed as without warning the gust blew up her pleated skirt.
>
> Barber (1985) *A Woman of Cairo*

Introduction

Perhaps because of the distractions caused by the Cairo weather Serena was misguided in her attribution of Ballâs vessels to Kena on the basis of colour alone.

It was partially with the aim of better understanding the relationship between firing and fabric colour that the writers undertook fieldwork at Deir el-Gharbi, near Ballâs in Upper Egypt (Figs 1 and 2).

This work followed on from the first Ballâs Pottery Project undertaken by the writers in 1984 (Nicholson and Patterson 1985a, b, c) which examined the technology of the potting industry in general as part of an ethnoarchaeological study. However, it was realised at that time that a fuller survey should be made of the critical stage of vessel firing, since it is at this point that the clay material changes state, from a re-workable plastic to an intractable ceramic.

The second Ballâs Pottery Project therefore sought to make such a study whilst supplementing the earlier photographic and documentary archive. The following supercedes the more general work on firing done in 1984.

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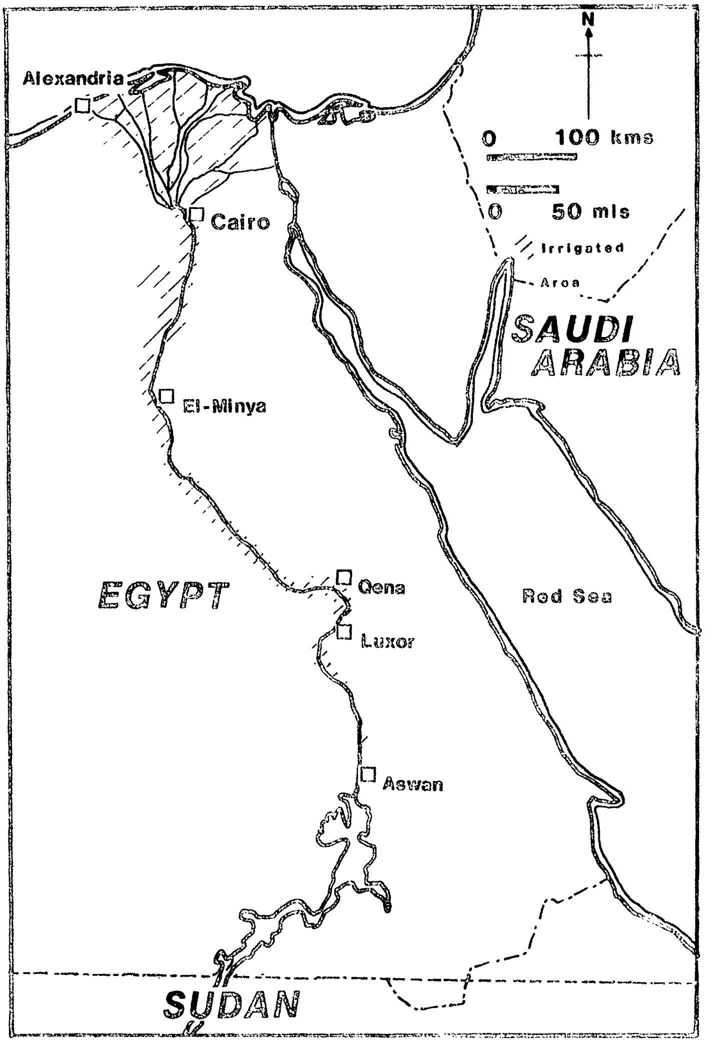

Figure 1 Map of Egypt showing key towns and cities.

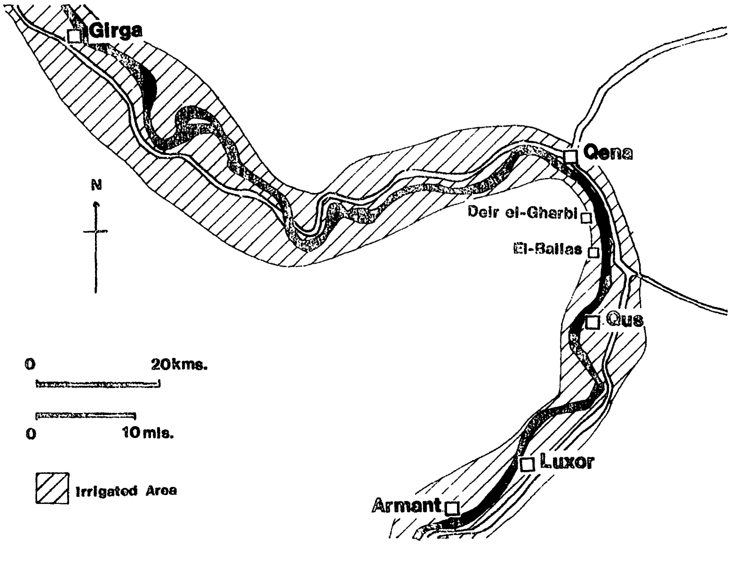

Figure 2 The Qena area, showing the location of the potteries at Deir el-Gharbi.

Fieldwork

In 1984 work on the firings had been confined to recording a single firing using only one thermocouple, which failed during recording. Refiring work in the laboratory later yielded an estimate of the peak temperature of the firing, but there was no way of cross-checking the results achieved by these means.

Work in 1987 was more specific in nature and better prepared. The aim of this part of the project was firstly to provide a full and accurate record of the rate of temperature increase, duration of firing and peak temperature whilst also obtaining material from a firing for examining the accuracy of the thermal shrinkage method of temperature determination.

In addition to the usual alumina covered thermocouples a flexible mineral insulated (*Inconel*) thermocouple of the same type (K-type, chromel-alumel) was used. This latter thermocouple is considerably more durable than the cheaper alumina type and better able to withstand field use. The superiority of this instrument over the usual type is evident from the following and it is recommended for any future work of this nature.

Buller's Rings were also taken into the field to provide some kind of record should the thermocouples fail and to give a cross check on the results obtained from them and from refiring.

Work was undertaken at the same workshop as most of that done in 1984 since here a good relationship had been established with the potters, and their work was judged to be representative of the industry as a whole.

The kilns used at Deir el-Gharbi are large updraught structures set into mounds of ash and kiln debris. They are built of mud brick which fires in situ. From the floor of the stoking pit to the rim of the kiln the height is 3.40m and the diameter of the structure is approximately 4.50 metres. The perforated floor which divides the fire from the vessel load is arranged in a complicated pattern shown in the plan (Fig. 3). There is no central support for this floor, it is sprung rather like a perforated dome from the walls of the kiln (Fig. 4). At the front of the kiln (Fig. 5 and Pl.1) a small stoke hole, approximately 0.53m wide and 0.44m high, is located at about waist level. This is set within a larger arch which serves to strengthen the structure and helps to protect the stoke hole from draughts.

Before each firing, permission to insert thermocouples and to observe the process was sought and on the first occasion Ms Clarissa Burt, our interpreter, was on hand to explain our wishes and to relay any such information as the potters might wish to give as to the progress of the firing.

It was on this first occasion that ten of the medium sized Ballâs jars were purchased in their green hard state for firing.

These green hard vessels were taken from the hundreds drying in the yards behind the workshops. As the completed vessels leave the workshop they are taken into the drying yards where they are stood upside down, that is on their rims, whilst the bases dry out in the sun. The rim is well able to withstand this treatment because it is already partially dry, having been produced the previous day, since the making of Ballâlîs is a two stage operation (see Nicholson and Patterson 1985a). The total time for which the

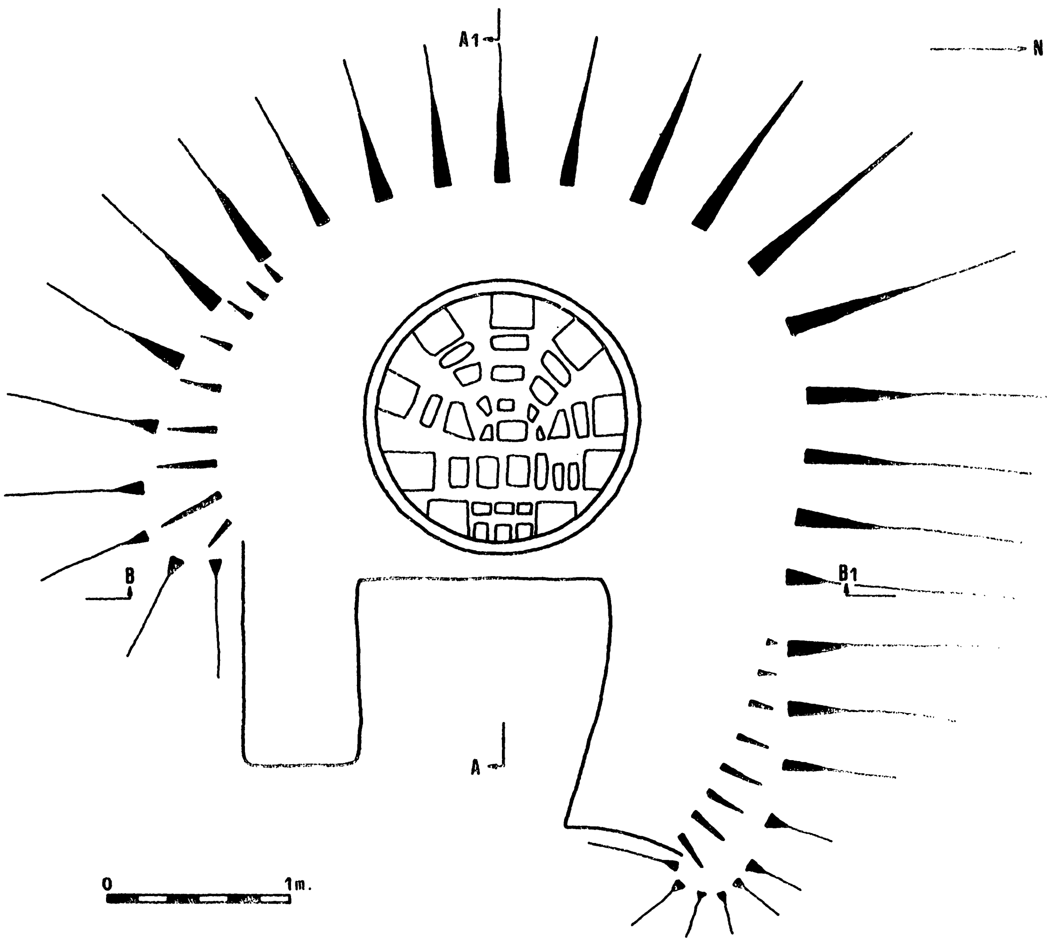

Figure 3 Plan of kiln, gridded floor pattern is accurate though the scale of this feature is approximate.

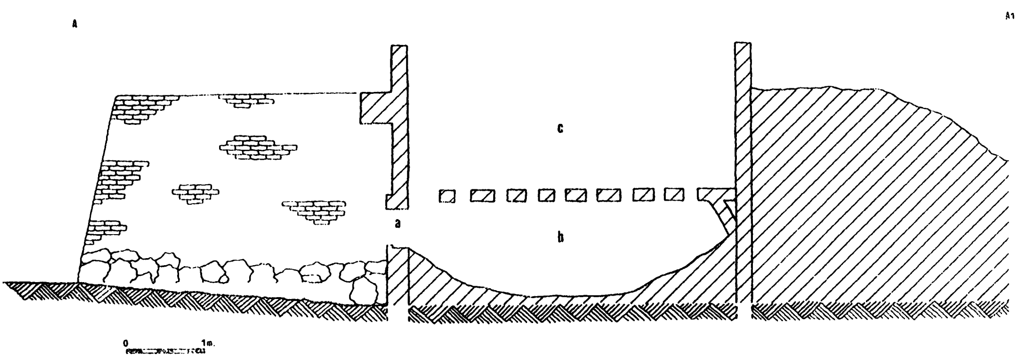

Figure 4 Section through kiln along line A–A1 (see Fig. 3).

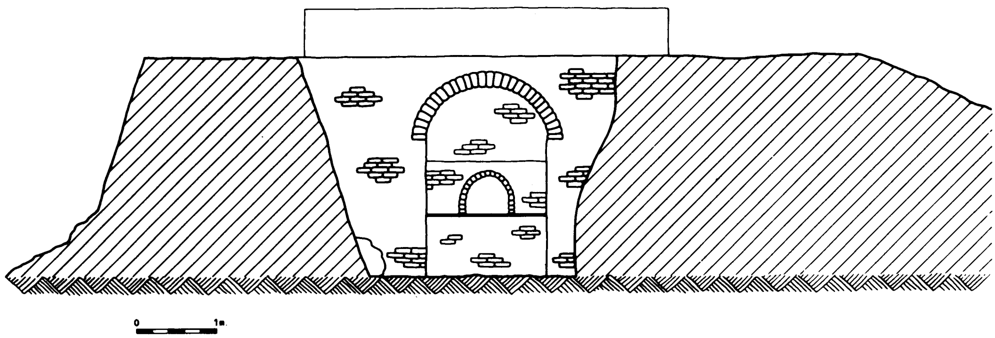

Figure 5 Elevation of kiln.

Plate 1 The stoke hole of a kiln, the potter is using the hoe-like poker, the winnowing type of poker can be seen leaning against the kiln to the left.

vessels remain in the sun varies considerably, since those first taken outside must wait until more than 600 are completed and ready for firing (a matter of several days) though the minimum drying time is about twelve hours.

After several hours (the time varies according to the air temperature) the vessels are stood upright in the sand. Where their convex bases are in contact with the sand the salts which migrate to the surface of the clay, and which give it its characteristic whitish colour when 'correctly fired', are not brought out and leave a dark patch. This dark patch shows up as a pink mark on the base of the fired vessels. It had at first seemed, and was initially explained to us, that this patch resulted from the way vessels were

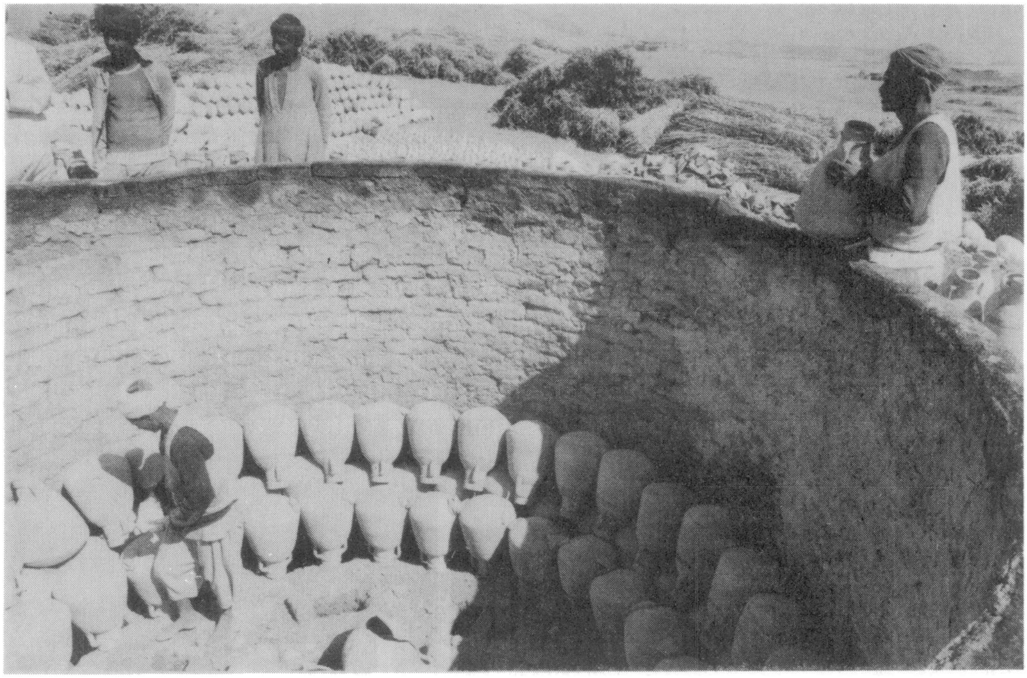

Plate 2 Loading the kiln for firing 1. One of the numbered vessels can be seen standing upright to the left of the potter.

stacked in the kiln, each layer separated by sherds (Nicholson and Patterson 1985a:234) but this is clearly not the case. It was similarly noted that a small vertical line may appear on the neck of some vessels where the handles of one jar have been in contact with the neck of another. Some of these are apparent during drying but, like the patches on the bases, they are greatly accentuated by firing.

The ten vessels chosen were then incised with numbers and as the kiln was loaded on the day preceding the firing they were placed in predetermined positions. Ten was the maximum number which the potters were prepared to allow to be placed in specific locations within the kiln. Since it was desired to examine temperature distribution across the profile, as well as through the section, they were placed at given levels rather than at every level.

The vessels are normally inverted in the kiln and slope slightly to lean against its walls (Pl.2). However, since it was required that Buller's Rings be inserted in the jars ours (after considerable debate) were stacked right way up. Five were placed in the second level, four in the fourth and one in the fifth (Fig. 6). Two Buller's Rings were inserted in each jar. These medium sized vessels, the most common type, are stacked in five layers of approximately 125 vessels each.

The vessels are very tightly packed into the kiln and are, in effect, wedged by sherds placed between them and by their sloping positioning. So densely are the vessels packed that the stacker is able to stand on each successive layer and to move around on them whilst covering the kiln top with a layer of broken sherds.

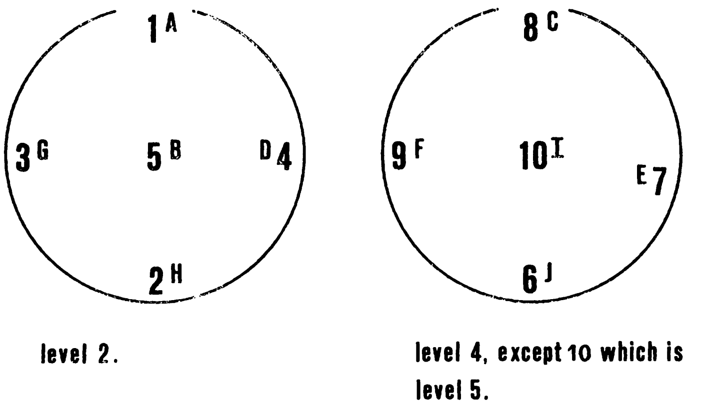

Figure 6 Sketch plan showing the location of the ten vessels purchased for firing 1 and their rankings in terms of shrinkage.

It cannot be too strongly stressed that no mud dome is used on the top of the kiln, and that the covering is in no way fixed down, the sherds being simply laid on top of the unfired vessels. It is certainly true that some kilns, both in Egypt (e.g. some of those at Fustat, Cairo, Golvin et al. 1982) and elsewhere, are, or were, covered in a more permanent way but this need not be assumed to be the norm. A covering of sherds readily suggests itself in a pottery yard since they are easily available, unlike in most experimental situations (Bryant 1971).

The kilns are fuelled using stems of sorghum millet (*Sorghum bicolor bicolor* race durra) commonly called *durra* and this is preferred above other waste products of agriculture which are said not to burn with such prolonged and intense heat. An analysis on a small, and not statistically valid, sample of the millet undertaken by the Department of Fuel Technology, Sheffield University, yielded a calorific value of 4,030 calories/gramme (16,880 joules/gramme). This may be compared with an approximate figure for coal for domestic use (5 per cent ash content) which has a value of 6,940 calories/gramme (Dr M. Smith, pers. comm.)

Before a firing begins large bales of the sorghum, averaging 3.80m in length and approximately 2.90m in circumference, are brought in from storage areas located at a short distance into the desert and stacked close to the kiln (Pl. 3).

The first firing recorded took place on 27 April 1987 and recording began at 05.45 just as dawn was beginning to break. Thermocouples were placed on the northern side (Inconel – T1) and western side (alumina clad – T2). The stoke hole faced due east. The thermocouples protruded into the kiln to a depth of 1.33 and 1.20 metres respectively, although T1 ran 0.39m horizontally along the top of the kiln whereas T2 went straight down the wall. These depths place the thermocouple tips in the second level of vessels where our vessels 1–5 were located, indeed the thermocouple T1 must have been resting very close to vessel 3 with T2 near vessel 2.

The feeding of the fire begins slowly, this is presumably to allow a gradual rise up to slightly above 100 degrees centigrade so that remaining moisture is driven off as steam. This process is known as 'water smoking' and prevents the rapid build-up of steam in the vessel walls, which would lead to deformation of the vessels. The rapidity of the firing gradually increases so that in the latter stages of firing the intervals between inserting bales could be as little as 2–3 minutes (Fig. 7).

Plate 3 A firing in progress. Note the bales of Sorghum brought close to the kiln for fuel.

At first the fire burns loosely in the fire chamber, the smoke thickens but is not dense. While one man attends to the stoke hole another brings fuel and collects ash and small pieces of sorghum which he then throws onto the kiln top possibly as a means of preventing flames breaking through the vessel stack, or perhaps as some form of insulation. The smoke becomes more dense, and this is followed by the fire roaring audibly, the smoke blackening and forming a column. As more damp ash and fuel are thrown onto the kiln top the smoke grows very dense and obscures the kiln from view. At this time the stoker, feeding a bale gradually into the fire box, turns his back to the stoke hole and begins to lever downwards on the protruding end of the bale. The bale is pivoted on the lip of the stoke hole and the rocking action caused by this makes it serve as a fan to drive up the hot gases through the kiln and to invigorate the fire.

Between bales, as the fire begins to lessen, a poker made from an iron rod with the end bent into a loop is used with a winnowing action to ensure that no material remains unburned. At intervals, as the remains of the fuel mound up in the kiln, another iron poker, this time shaped like a common (or English) hoe, is used to level out the pile.

At times when fanning is not taking place the smoke becomes a less dense grey or white cloud.

During the first firing a wind developed after about an hour, and after about two and a half hours became a considerable problem. Bricks were placed on the upper edge of the kiln on the windward side, and eventually waster vessels from earlier firings were placed on top of the layer of sherds at this same, north western, side in an attempt to deflect the breeze.

Toward the end of the firing it became increasingly obvious that the potters were worried that the temperatures they were achieving would be much reduced by the strong winds and vigorous attempts at fanning and stoking were made. None the less, the maximum recorded temperature achieved during this firing was only 690 degrees centigrade on the northern side, thermocouple T2 failing after about two hours of this three hours and twelve minute firing. Peak temperature was achieved after a hundred and seventy-one minutes. The total number of bales burned was twenty-nine.

The second firing, recorded on 1 May, followed the same basic pattern in terms of the actions carried out at the stoke hole but was not subject to abnormal winds. This firing began at 05.05 and lasted for three hours and three minutes, during which time twenty-eight and a half bales of fuel were consumed. This time, peak temperature was reached after a hundred and seventy minutes, though it was higher giving 850 centigrade on thermocouple T1 which was now on the southern side, and 855 centigrade on T2 (replacement alumina clad instrument) which remained on the western side (Fig. 7).

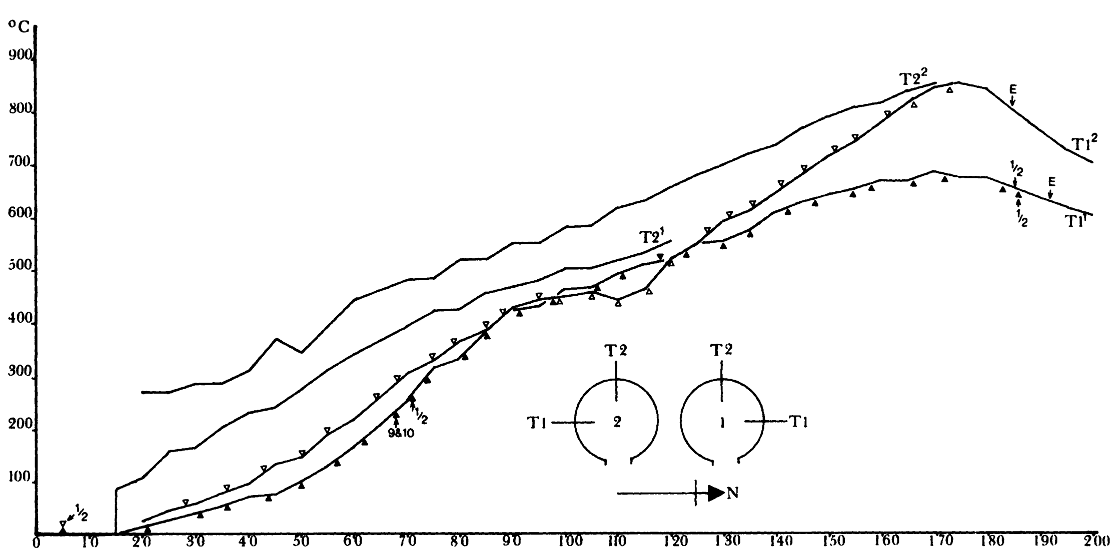

Figure 7 Time-Temperature Graphs for firings 1 and 2 for thermocouples T1 and T2 (firing number shown in superscript, E marks end of firing). The times at which sorghum bales were fed into the kiln are also shown, filled triangles indicate firing 1, open triangles firing 2. The sketch plans show the location of the thermocouples for each firing.

It will be apparent from this that there was a remarkable degree of consistency between the firings in terms of duration, fuel consumption and time at which peak temperature was achieved. At no time did the potters use a watch to time the firing, so that it can be said that this consistency stems wholly from practice. They were also aware that the strong wind was adversely affecting the kiln temperature. As a means of testing when the vessels are well enough fired the assistant takes a couple of pieces of sorghum stem and inserts them into the kiln top between the sherds and the wall. He observes the reflected glow from the vessels onto the sorghum and estimates how long it takes to catch light. He then relays this information to the stoker.

At the cessation of firing the kiln is simply abandoned and left to cool. The stoke hole is not blocked up to prevent rapid cooling and no other precautions are taken (cf. van der Leeuw 1976:130). Some potters, such as those working with silt clays at Deirut (near Mallawi, Middle Egypt, and some of those in Fustat) have been observed to close off the stoke hole and other openings, and this may be common among those working with silt clays.

The kiln is allowed to cool for one to two days. The cooling after the second firing was for approximately twenty-four hours, unloading beginning at 09.15 on 2 May. This process was also recorded in detail, in order to gain some idea of the range of colour variation down, and perhaps across, the profile of the kiln.

Firing two had consisted of 627 medium sized Ballâlîs in the usual five layers. The top level (five) comprised 127 vessels, level four 125, three 126, two 125 and one 124. The uppermost level were coloured the desired white, though some were rather pale, except on the windward side (this time the north) where they were pink. The same phenomenon was observed in firing one. There were no unsaleable vessels (wasters) from this level. Level four produced the desired white vessels as did three but both had two waster vessels. Level two produced vessels which were olive green or white and here five wasters were encountered. The most striking layer however was layer one with olive green vessels, some highly vitrified and glassy, of which twenty-one were wasters.

From the whole firing there were some thirty wasters, only 4.78 per cent of the total load. Though only part of the unloading of the first firing was observed, the same range and distribution of colours was noted and confirmed at other kilns.

The numbered vessels and Buller's Rings were removed and the vessels broken so that large sherds could be taken back to England for laboratory analysis of the firing temperatures in order to examine the accuracy of the thermal shrinkage method of refiring.

Laboratory analyses

Work in England sought to quantify the amount of temperature variation within the kiln, so that a meaningful margin could be given to the results of refiring tests, rather than an over precise figure. Similarly, it was believed that details of the actual firing might serve to provide a calibration for firing temperatures obtained in the laboratory.

Initial work concentrated on the Buller's Rings. These give a measure of 'heat work

Table 1 Measurements of Buller's Rings.

Unfired Ring Measures 63.45mm

Ring No.	*Mean Measurement (mm)*	*Ranking*
1	60.625	A
2	63.313	H
3	63.275	G
4	62.437	D
5	62.050	B
6	63.375	J
7	62.475	E
8	62.175	C
9	63.250	F
10	63.350	I

done' which does not have any strict meaning since a short but intense heat treatment can yield the same results as a gentle but prolonged one. Measurement of the rings with a gauge made for that purpose is used to obtain this measure which can then be used to give a Buller's Ring temperature, which need bear no relationship to the actual kiln temperature.

To obviate the confusion which can be caused by quoting the usual Buller's Ring measures we were advised to measure them without reference to the usual gauge. For this purpose a dial caliper was used. It was quickly apparent that the assumption that there was variation across the kiln profile was a valid one.

Table 1 shows the means of measurements on the two rings from each vessel with their ranking. The rankings are shown diagrammatically next to the vessel position in Figure 6, and it is evident that there are some clear trends in heat distribution.

It will be noted that vessel 1 has the highest ranking (A), that is it showed the greatest shrinkage and is located immediately above the stoke hole, next in rank is the central vessel (5) followed by vessel 8 in level 4, which like vessel 1 is above the stoke hole. Ranked fourth and fifth are vessels 4 and 7 on the southern side while those on the northern and western sides – particularly in the uppermost levels – record the least shrinkage. This is entirely consistent with the wind direction, and serves to illustrate the effects of weather even in a country which might be considered to have almost ideal weather conditions for potting.

Unfortunately, the thermocouples were placed in this north western quadrant and therefore recorded the lower range of temperatures in this area, the maximum temperature being 690 centigrade recorded by T1. Given the results of the Buller's Rings it is evident that the southern half of the kiln and the area around the stoke hole were the hottest parts and it can be suggested that these areas reached temperatures in excess of 700 centigrade.

The sherds taken from the numbered vessels were refired at the Department of Ceramics, Glasses and Polymers, Sheffield University using the thermal shrinkage

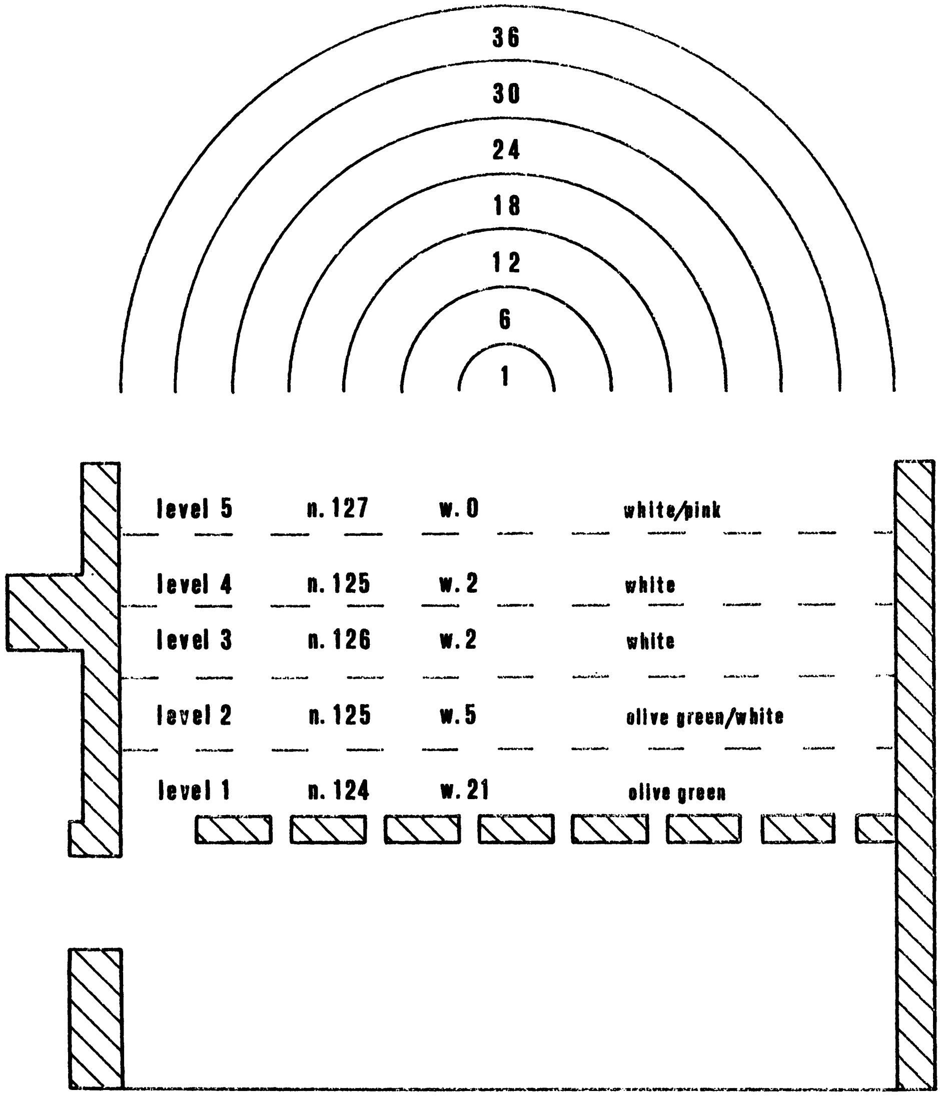

Figure 8 Schematic section showing for each level number of vessels (n), number of wasters (w) and vessel colour. The number of vessels per stacking ring in level 5 is also shown in plan above.

technique (Nicholson 1986, see also Roberts 1963, Tite 1969, Tite and Maniatis 1975, Nicholson forthcoming, for details of refiring techniques).

It is clear from the thermocouple and Buller's Rings data that all the vessels were fired above 600 degrees, that some were above 700 degrees and, on the basis of the second firing recorded, that none were likely to have been above 860 degrees. This information was of value in interpreting the refiring results, which were often equivocal. It is sufficient here to say that sherds from vessel 1 yielded a refiring temperature in excess of 800 degrees centigrade and given the accuracy of the technique this may be placed in the 800–900 centigrade range, which is as one would expect. Other sherds proved more difficult to interpret, perhaps because of a variation in kiln temperature insufficient to be readily recognisable using this technique, and only very general trends were visible.

Work on colour changes as a guide to firing temperature was also attempted in the way suggested by Hulthen (1976a). However, few changes were detected in this material. The hue particularly tended to remain stable up to temperatures of 1,000 degrees or beyond, and frequently there was no change in value or chroma either. An unfired sherd was included in the firing for comparison and its hue remained stable over a long temperature span, from 400 to 750 then from 800 to 1,050 degrees. This colour stability is an obvious disadvantage when trying to determine firing temperatures of already fired sherds by such a means. Also, if the colour method of temperature determination is really valid for calcareous clays which (albeit on a single sample) show stability, then one is left with the problem of explaining why there are consistent and marked colour differences through the profile of a kiln which would seem to vary by no more than 200–250 degrees between hottest and coldest points (Fig. 8). It is provisionally suggested here that the colouring of the calcareous clays is a factor of the time for which they are subjected to a given heat treatment and of the peculiarities of the kiln atmosphere; that is they do not merely depend upon temperature; this may render the colour determination method invalid on these clays.

Conclusions

The fieldwork undertaken at Deir el-Gharbi has served to provide information for examining and, it is hoped, eventually refining a technique of temperature determination suitable for archaeological material and has also thrown considerable light on the meaning of the potters' actions during firing.

It is most notable that although firing is the critical stage in the manufacture of pottery, and despite the financial hardship which would be suffered by these very poor potters were a firing to fail, it is approached without great trepidation. Part of the reason for this is obviously practice as well as confidence in their own skills on the part of the potters. There may, however, be a further factor.

It was notable that during the first firing, which began rather later than usual, the potters were taken unawares by the presence and severity of a wind from the north west. It was clear that this was a source of worry and efforts were made to cope with it, especially in the building of wind breaks and deflectors on the kiln top. Only half a bale of fuel more than that for a normal day was used, however, and the firing had the apparently usual duration of just over three hours.

It would seem that the reason for this relative lack of worry is to be found in the tolerance of the Ballâs marl clays. Although at low temperatures more vessels fire at a pink colour than is desired, all are functional and saleable. This characteristic is likely to hold good at the opposite extreme also, so that when too great a temperature is achieved most of the vessels will not undergo significant deformation until well beyond their usual firing temperature. Maniatis and Tite (1981:75) have noted that stable calcareous clays (those with above 15 per cent CaO) remain stable in the range 850–1050 centigrade. This has been noted by one of us (PTN) in previous refiring work where the clay shows only minor dimensional change in this range, followed by sudden collapse. This relative stability, compared to most non-calcareous clays, may be a further factor in making some refiring results difficult to interpret.

The evidence from the two firings would suggest that the peak temperature aimed for for the load as a whole is approximately 850 degrees centigrade, which means that the lower most vessels are probably subjected to temperatures as high as 900 and in some cases 1,000 degrees. This is apparently considered to give the best balance of mechanical strength, colour and porosity for the minimum use of fuel. One potter has recently begun to supplement the usual Ballâlîs with zirs (large, and more porous, water storage jars) made from a mixture of silt and marl clay and it would be interesting to investigate whether he is able to work at still lower temperatures.

The Buller's Rings proved a valuable guide to temperature distribution and, like the mineral insulated thermocouple, their use would be advocated in the future. They showed convincingly, what was to be expected intuitively, that there were differences in temperature across the kiln section as well as in profile and these are to some extent confirmed by the refiring results.

Refiring work combined with field measurements would also suggest a difference of 100–150 degrees between different parts of a kiln of this size. On these grounds caution must be urged when examining the results of any kind of refiring study before conclusions as to different types of kiln or more advanced technology are reached. Sherds from the same firing of a single kiln could yield markedly different results as well as appear sufficiently different to be thought of as different or variant fabrics.

More work needs to be done on the firing properties of different types of clays and the refiring results they produce and this is currently being begun by one of us (PTN). This is particularly important for the interpretation of refiring graphs since on ancient sherds where no maximum temperature is known mis-interpretation could easily result.

It is certainly clear that Serena was making a very coarse assumption in assigning vessels to Kena on the basis of colour alone. She could, however, have diagnosed their likely position within the kiln and suggested a broad firing temperature. Perhaps she would have done so had it not been for that gust of wind.

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In Britain we received useful and detailed information on Sorghum from Dr Peter Rowley-Conwy of Cambridge University. Work on the calorific value of Sorghum was kindly undertaken by Dr P. J. Foster of the Dept of Fuel Technology, Sheffield University, while comparative calorific values for coal were provided by Dr M. Smith of British Coal's Wath-upon-Dearne laboratories.

The refiring work was undertaken at the Department of Ceramics, Glasses and Polymers, Sheffield University, under the supervision of Dr P. Messer and with the assistance of Mr D. Marshall, to both of whom we are particularly grateful. General advice on the project was provided by Prof. K. Branigan and Dr R. Hodges of the Department of Archaeology and Prehistory at Sheffield, and from Mr Barry J. Kemp, Ms P. J. Rose and Ms J. Bourriau of Cambridge University.

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Department of Archaeology and Prehistory
University of Sheffield

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Abstract

Nicholson, Paul T. and Patterson, Helen L.

Ceramic technology in Upper Egypt: a study of pottery firing

Firing is the most crucial stage in the manufacture of pottery, since at any earlier stage the raw material can be reprocessed: yet it is also one of the least well recorded ethnographically. By recording firings in the field, both in terms of temperature and the actions of the potters it was hoped to obtain data which would help refine laboratory techniques of temperature determination on ancient ceramics. One of these techniques, thermal shrinkage, is examined in the light of this ethnographic study and the variation in firing temperatures within individual kilns highlighted.