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ETHNO-ARCHAEOLOGY OF POTTERY FIRING IN DARFUR, SUDAN: IMPLICATIONS FOR CERAMIC TECHNOLOGY STUDIES

Summary. *In 1982 the author spent six months in Darfur, Sudan, studying a group of itinerant female potters. This paper examines their method of manufacturing and firing, and discusses data observed from 21 pyrometric readings. The use of a bonfire for firing ceramics is described and it is concluded that, despite the apparent simplicity of the technique, the Kebkebiya potters control the appearance of their ware to a surprising degree, since surface colour and quality of vessels to suit a particular function can be regulated by the firing technique. A study of the preparation of raw material shows that these potters never take a single clay but use a mixture from three distinct sources, and petrological analysis and firing tests of the original clays indicate that none of the source clays is workable individually. Different fillers (millet-husk and donkey-dung) are added to clay used to form different sections of the pot (body and neck respectively) and the effect of these is discussed. The extent of the potter's control over the technological process is emphasised.*

INTRODUCTION

Until comparatively recently it had been widely assumed that the bonfire firing of pottery was a primitive technique, prone to many risks, surrounded by uncertainties and confined to limited situations. However, an increasing body of archaeological evidence suggests that bonfire firing was a method widely employed in the past, not only in Africa (Chittick and Tobert, in Chittick forthcoming) but even in some of the larger and more important industries of the Roman period, such as those of the Black Burnished 1 and Dales ware (Farrar 1973, 91; Loughlin 1977, 88).

The renewed interest in bonfires for firing ceramics has induced archaeologists to make a number of attempts at experimental firings using various raw materials and methods (Cheetham 1983; Martlew 1983). But there are still relatively little detailed ethnographic data of value to the archaeologist on this subject. In spite of the fact that ethnographic information on manufacturing technology and firing is being collected, rarely is it correlated with laboratory analysis to determine why the potters themselves choose specific methods and materials. Rye's analysis of tempering agents used with Papuan pottery is an exception, as is

Arnold's research into the mineralogy of Ticul ware (Rye 1976; Arnold 1971).

The present paper surveys the methods of pottery manufacture and firing and summarises the results from observations of a large number of firing sequences, complemented by pyrometric data and petrological analyses. The choice of fillers is discussed to determine whether their use aids the process of manufacture or the vessel-function after production. Techniques involved in the production of 'red and black' gloss pottery which have aroused the interest of archaeologists ranging from Predynastic Egypt (Allen *et al.* 1982) to Greece (Tite *et al.* 1982) are also examined: the potters surveyed choose how they fire their ware to give red, or red and black, surface finishes, which can be related to the function of the vessel. Laboratory tests were undertaken on both source and prepared clay to determine the maximum and minimum firing temperatures possible. These results were then related to the practical requirements of the potters and the range of temperatures achieved in practice.

The determination of the firing temperature and other technological characteristics of excavated pottery is an area of major interest to archaeological scientists (for example, Tite 1969; Maniatis and Tite 1981; Maggetti and Schwab 1982). However the results presented often consist only of a small group of measurements from a particular archaeological context, and their bearing on our understanding of the mode of production is not always clear. In order to interpret these data, models based on ethnographic studies are extremely useful, as has been recognised by many authors (Shepard 1958; Nicklin 1979; Peacock 1982). Information for this paper was obtained during a field-trip to Sudan (from January to June 1982), when a study of the material culture of a group of Zaghawa potters in Kebkebiya, Northern Darfur, was undertaken.

The Potters

The Zaghawa potters at Kebkebiya are migrant, setting up camp on the outskirts of the town in straw shelters during the dry season from January to June. Some live there for the full six months; the rest pass through on their way to and from other centres, potting there only a short time. All belong to the Koubeh branch of Zaghawa, and all are *Hadahid*, that is, their husbands are 'blacksmiths'. They are despised by other Zaghawa, who regard them as slaves and will not intermarry; thus Zaghawa potter/blacksmiths in Northern Darfur form an endogamous group. Those at Kebkebiya have their permanent homes in a number of villages in the surrounding district, at least two of which are made up exclusively of *Hadahid*. By the beginning of the rainy season (July) the potters leave camp and return home to prepare their fields for the cultivation of millet (*dokhn*). A few animals are owned: cows and sometimes camels, usually obtained as part of the bride payment.

The majority of potters serving Kebkebiya are Zaghawa, although Fur women from Shoba village (90 minutes away on foot) frequently arrive on market days with a basket carried on the head containing up to ten vessels, usually cooking-pots. A Zaghawa potter may earn up to 25 Sudanese pounds a week from the sale of her work, but this money must support her and her children in food and clothes throughout the dry season and, if the harvest fails, then for a further year. In April 1982, sugar was being sold for a pound a pound, as was the staple millet. A family may be expected to

consume at least three pounds of cooked millet each day.

Kebkebiya town

The Government Offices of the Rural District Council are based in Kebkebiya, which lies on the El Fasher to El Genena road, to the north of the Jebel Marra range of mountains (latitude 13.30 to 13.45, longitude 24.00 to 24.15). This range is drained by the Wadi Borgo, which rises for a short time during the rains but on whose banks and bed the potters camp in the dry season. The area lies on a plateau between the Jebel Gurgie and Jebel Marra, and has a micro-climate receiving proportionally more rain than the surrounding area, with blustery winds towards the end of the dry season. The land between the foothills is extensively used for millet cultivation.

Kebkebiya serves as a market centre twice a week (Thursdays and Sundays) and is attended by Fur peasant farmers selling grain and vegetables, and by Risekat and Mahadiya 'Arab' camel nomads offering leather goods, oils and milk. The population of the town itself is divided between Fur, Tamur and 'Arab' ethnic groups, with smaller communities of Zaghawa and Gimr.

POTTERY PRODUCTION

The potters work individually to a seven-day cycle, each firing around thirty vessels (Fig. 1) on the morning of one of the market days. At Kebkebiya, twenty-two vessel-functions were noted in 1982 and these included the following: vessels for the transportation and storage of water *jerr, zir*, and *gulla*, washing bowls *tangel, khasal*, pottery for the storage, preparation and cooking of food *khammara, gumbang, borma* and *colol* (ceramic dishes are never used for serving food). The *dahalob* is variously used for soaking grain, curing leather and making perfume. Vessels used for ritual purposes include the ablution jug *ibrik*, the incense burner *mukhbar*, and the Koranic doctor's ink-pot *dawaiy*. Many of these vessels are made up of a spherical or semi-spherical body with a trumpet-shaped neck. Slight variations in the proportions of the body to the neck denote differences in function, for example a *khammara* and a *jerr* may have the same body diameter but the neck of the former will be several centimetres wider. (For a more detailed, illustrated outline of the function-types see Tobert, forthcoming b, fig. 2).

Raw Materials

Clay is collected from each of three sources: two from the river bank opposite the camp, and the third from an area by the brick kilns a kilometre away. These three clays are mixed in equal proportions, crushed, then soaked in large pottery jars. The spherical body and neck of the vessel are each formed using different techniques; although the same clay is taken, it receives a different temper depending on which part of the pot it is used to produce. Clay for the body is kneaded with a large proportion of millet husk (in a volume ratio of 1:1) which gives it considerable damp strength, whereas clay for coiling the neck is mixed with crushed donkey-dung, giving it greater plasticity.

Method

The spherical body is beaten out with a rounded hammerstone on a fibre mat, using a hollow in the sand as a mould (a technique noted by Arkell 1939, Haaland 1976, and further described and illustrated in Tobert,

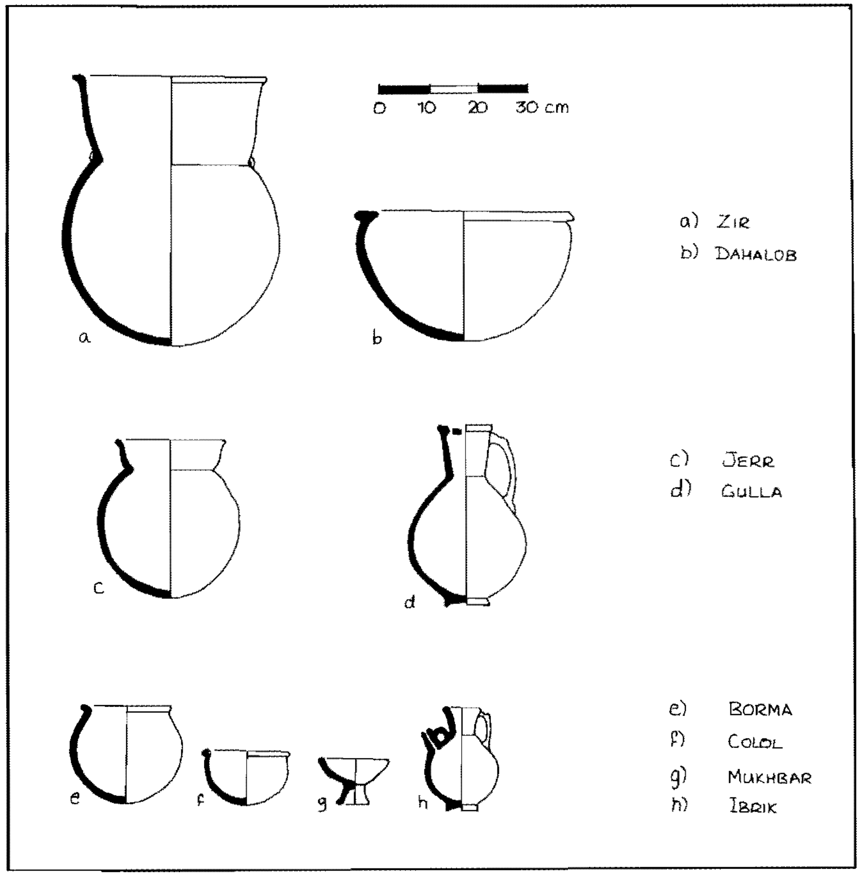

Figure 1
In one week a potter can produce around thirty vessels. This may include: 10 zir, 4 dahalob, 6 jerr, 3 borma, 3 borma, 3 colol and 2 mukhbar. Vessels such as the gulla and the ibrik are usually made to commission.

forthcoming a, b). The neck of the vessel is coiled several days later, to enable the body to dry out a little. On the evening before firing, vessels are coated with a fine haematite and mica slip, then burnished either with plaited leather thonging or with a stone, and finally polished with a soft cloth. The ware is preheated around a small fire, the vessel mouth always facing the flames.

Firing

As a rule each woman fires alone in her own area, although occasionally two sisters will fire together, or help may be given to a sick woman. The 'kiln', of bonfire type, consists of a circular shallow hollow in the sand of varying diameter (one metre for a small firing, three meters for a larger one). The hollow used in firing just a few pots will

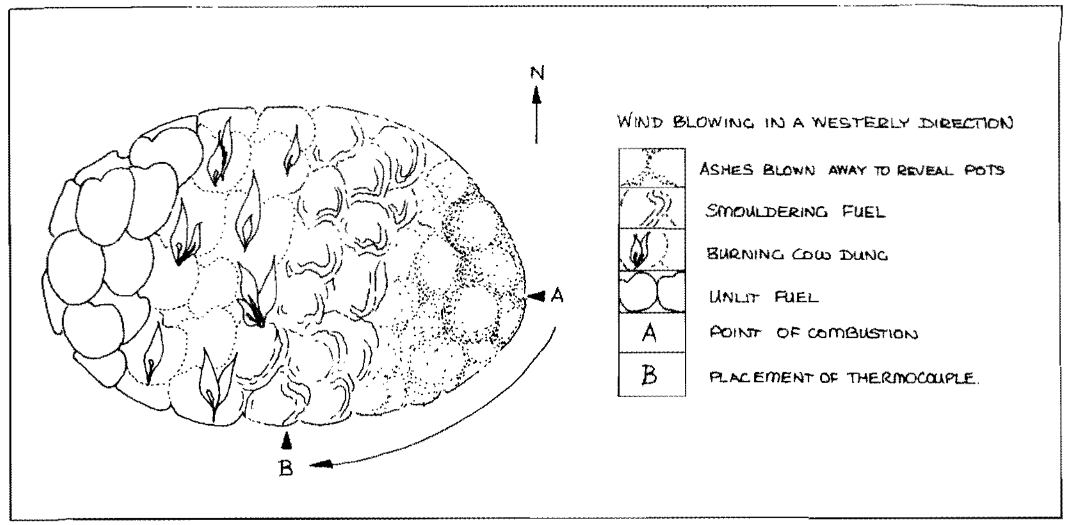

Figure 2
Three-quarter view of a firing. The fire is lit at the edge which faces the oncoming wind, so that the fuel is consumed progressively in a line. On a calm day, by the time that one end of the firing is in cinders, the other may not yet have caught light.

be scooped out from one side of the site of a previous larger firing. The base is covered with a layer of either goat-dung and straw or broken-up cow-dung and straw, then larger vessels are laid mouth to base in the centre, with smaller vessels placed around.

Care is taken to position the pottery so that a degree of oxidisation or reduction appropriate to the vessel-function is achieved. Water-storage jars, *zir*, are always fired red, so are placed on their sides to allow air in, whereas some water-carrying jars, *jerr*, and cooking-pots, *borma*, have carbonised black interiors and so lie upturned, their mouths resting flush with the ground. Large open bowls, *dahalob*, may be either red or black inside. They are fired upside down, but if the potter requires a red oxidised interior she will raise the vessel's rim on a support of stones, so that oxygen is freely available during the firing.

Spaces between large *zir* are covered with pieces of sheet metal or larger sherds, then the whole area is laid over with just enough clods of dry cow-dung to cover the surfaces: the dung is never 'piled high'. Large stones or bricks are used to limit the edges of the firing, to keep the dung in position, to retain the heat, and to protect the fuel from very fast combustion in the case of a high wind. The fire is lit using bundles of straw, at the edge which faces the oncoming wind, but if there is little wind it may be lit at three or four places along the same edge. This method means that the fuel is consumed progressively in a line and by the time one end of the firing is in cinders, the other end may not yet have caught light (Fig. 2).

On a calm day the firing will be left alone and allowed eventually to burn out, whereas if there is a high wind the potter will tend the kiln frequently, adding extra clods of dry dung to cover the pot-surface (to prolong firing) or extra ashes (to protect the pots from too rapid a cooling).

Post-firing treatment

A slip of fresh cow-dung is applied to the exterior of certain water-jars, *zir*, and cooking-pots, immediately before they are taken to market, which may be done to lessen permeability (Rye 1976, 119). The junction between the spherical body and trumpet neck of the Zaghawa pots is particularly vulnerable to superficial cracking, and an extra thick coat of fresh dung is at times used to mask this area. Cracks and other faults were noted on days in which a high wind caused a rapid rate of firing and cooling. (On two occasions a potter was seen applying smouldering plastic bags to fill these cracks before coating with dung.)

The vessel neck and rim seem to suffer more breakages than the body, and this may be for two reasons: the rim may not be thoroughly dry prior to firing, or it may simply be that the neck and rim are in a much more vulnerable position than the body.

Other faults such as spalling occur; vessels could be heard 'popping' in the fire during the rise to maximum temperature, which the potters put down to incomplete drying of vessels. This could indeed be the case since only once did a vessel spall in a firing used for pyrometric readings, and this during the penultimate recording. (As a rule temperatures were recorded from the first potter ready to fire in the morning, for this eliminated the need to take readings in the scorching mid-day sun.) The potter would have burnished and preheated her wares the previous night allowing excess water to evaporate, whereas those women who fired late in the morning and whose vessels showed more of a tendency to spall may have been less conscientious in preparing their vessels for firing, notably with regard to preheating after the application of slip.

PYROMETRY

This report is based on observations of twenty-five pottery firings taken during the 1982 field-trip, twenty-one of which were taken in Kebkebiya. Only the results of the twenty-one firings are examined here. In all cases pottery was fired in a bonfire with cow-dung as the fuel. A hand-held digital pyrometer, kindly lent by the Institue of Archaeology, London, was attached to a single eighteen-inch porcelain sheath, housing two metre-long wires (chromel-alumel) joined at one end. A coil of plastic-coated wire joined the thermocouple leads to the pyrometer, and the highest temperature that could be recorded was 900 degrees Centigrade. Higher temperatures were not achieved in the firings studied.

The thermocouple was always placed at the edge of bonfire, either at 90 degrees to, or directly at, the position of initial combustion. It was believed that a small knob of clay (between 7 and 10 mm, i.e. wall thickness) attached to the end of the thermocouple would give a more meaningful reading of the firing-rate of the pottery itself, rather than that of the flames around, and furthermore, this would be more relevant to the experiments of archaeological scientists. Occasionally an attempt was made to protect the end of the thermocouple from gusts of very strong wind by placing it between vessels or behind the outer bricks. The temperature was recorded every minute, except during the fall from maximum temperature, when it was read every five minutes.

Of the 21 firings, clay was placed on the thermocouple end on 14 occasions; none was used for the remaining 7 readings. The leads were rather short, so it was not possible to place the thermocouple in the centre of the fire, as did Nicklin on the two occasions that he took readings with Ibibio potters (Nicklin 1981, 350). However, a reading from the centre of the kiln was not felt to be imperative, because the flames moved across the kiln (Fig. 2) and were not in the centre any longer than at the other points. Firing-temperature and rate of firing could vary enormously not only from one side of the firing pit to the other, but also from one side of a pot to the other. This has been shown by Lauer (1974, 57) and Woods (forthcoming), both of whom used three thermocouples to take the temperature in various positions in the fire: top, base, and centre.

In the following notes and tables, each firing range is given from initial combustion *at the position of the thermocouple, until the removal of the first pot from that same position*. This point is important, since if the thermocouple was at 'B', 90 degrees to the point of original combustion 'A', temperature-rise might begin as much as half an hour later than the first flames at point 'A' (Fig. 2).

The quantity and function of vessel-types in each firing was recorded (Fig. 1). If the firing was large, the potter would frequently unload only enough vessels to take to market, leaving the rest covered in ashes until the following day, and for this reason it was not possible systematically to record breakages.

The Results

The results of the readings are summarised in Table 1 as means of maximum temperature and time taken to reach it,

TABLE I

MEAN TEMPERATURES OF TWENTY-ONE PYROMETRIC READINGS, SHOWING THE MAXIMUM TEMPERATURES, AND THE TIME AND TEMPERATURE OF THE REMOVAL OF THE FIRST POT.

MEANS OF 21 PYROMETRIC READINGS—KEBKEBIYA 1982

	mean	range	with clay	without clay
maximum temperature	763 deg	659–891	733	823
time to max. temp.	25 min	8–50 min	28	20
time over 550 deg. C	35 min	20–80	36	34
removal of first pot, thirteen examples				
temperature	305 deg	140–470		
time from combustion	85 min	65–120		
time from max. temp.	40 min	27–90		
final temperature recorded, eight examples: (pottery was removed after recording ceased)				
temperature	162 deg	85–200		
time from firing	75 min	50–95		
time from max. temp.	58 min	35–82		

effect on the rate and range of temperature of clay on the thermocouple, and the time and temperature of the removal of the first pot. The final reading was usually taken when the first pot was taken out, but in eight cases the firing was particularly fast and reading ceased when the temperature had fallen to below 200 degrees. No record was made of the time of removal of the last pot, since this frequently occurred the following day.

The average maximum temperature of all 21 readings taken at Kebkebiya was 763 degrees, which is lower than those of Shepard (1936), Colton (1951), Lauer (1974), and Nicklin (1981) (see Table 2). Shepard recorded firings of the Pueblo Indians ranging between 625 and 940 with cow-dung as the main fuel, although she noted that the addition of corn cobs gave a higher firing-temperature. Colton registered 17 firings of the Hopi Indians who used sheep-dung as a fuel, with an average maximum of 810 degrees (Colton 1951, 73–4). Two Ibibio firings (Nicklin 1981, 356) produced an average of 865 degrees. Lauer published six examples of pyrometric readings in the d'Entrecasteaux Islands, using three variously-placed thermocouples, which produced maximum readings of between 270 and 880 degrees, (the accuracy of a pyrometer giving a maximum reading of 270 may be questioned, even for a base-level thermocouple). It would perhaps have been preferable to use three thermocouples at Kebkebiya if for no other reason than to strengthen Lauer's statement that 'placing the thermocouple at different levels in the fire showed that the pottery was not uniformly fired but was subjected to three varying intensities of heat' (Lauer 1974, 57). The Kebkebiya results show a wide range of maximum temperatures in the 21 examples, that is from 659 to 891 degrees. (A Berti reading from El Fasher gave an even lower maximum temperature-reading of 615 degrees.) Placing the thermocouple in the direct path of the wind gave a faster rate of temperature-increase than if it were protected.

TABLE 2

A SELECTION OF (ETHNOGRAPHIC) PYROMETRIC READINGS TAKEN FROM BONFIRE-TYPE 'KILNS', GIVING THE RANGE OF MAXIMUM TEMPERATURES AND MEANS.

Pyrometric readings—Bonfire-type kilns		
author	max. temp. range	mean
Shepard (1936)	625–940	792
Colton (1951)	720–885	810
Lauer (1974)	270–918	—
Nicklin (1981)	790–940	865
Tobert	659–891	763
Woods	649–837	—

The two sets of results at Kebkebiya (Fig. 3) indicate that the maximum temperature-averages using clay on the end of the thermocouple were noticeably lower than those without (733 degrees compared to 823), the latter presumably recording the temperature of the flame rather than that of the vessel fabric.

There was considerable variation in the amount of time taken to reach maximum temperature, ranging from 8 to 50 minutes (Fig. 4). It is suggested that the wind or lack of it mainly accounted for this variation, but clay on the end of the thermocouple also affected the apparent rate of temperature-change: its presence produced a slower rate of rise to maximum temperature (28 minutes average) than its absence (20 minutes).

The size and volume of a firing may also have an effect on the maximum temperature since larger vessels (notably *zir*, water-amphorae, max. diam. 50 cm, ht. 60 cm) require a greater quantity of fuel to cover

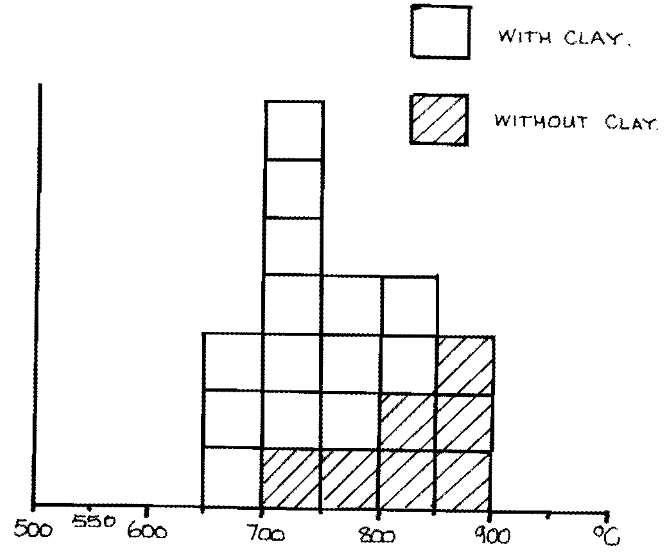

Figure 3
Histogram indicating the maximum firing temperature as affected by the presence or absence of clay on the thermocouple sheath.

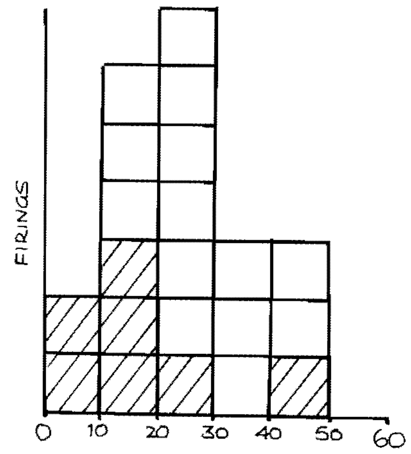

Figure 4
Time taken to reach maximum temperature (21 firings).

them. A 2.5–3 metre fire gave a range of maximum temperature between 700 and 891 degrees; smaller firings gave a lower cluster of temperatures. However, a more systematic method of recording is required to determine whether size is a meaningful criterion for explaining temperature-differences.

Nicklin observes that the Ibibio potters removed the first pot from the firing one and a half minutes after a maximum temperature of 880 degrees was reached (firing A) and in a second firing (B) at the precise moment of maximum temperature (790 degrees). Lauer gives similar reports of the potters of the Amphlett Islands; in no circumstances was this system observed in Darfur. The firing was always allowed to cool (Fig. 5). The earliest a pot was removed was 27 minutes after the maximum temperature (710 degrees) was reached, 65 minutes after the start of firing. (One potter had a tendency to fire late in the morning, and was consequently late for market; on three occasions she was recorded as removing pots early and at high temperatures: 27 minutes, 440 degrees; 35 minutes, 470 degress; 35 minutes, 350 degrees.) On only one other occasion was a temperature of over 400 degrees recorded at the time of removal of a first pot: this was on a particularly calm day, when the fire reached a maximum of 659 degrees after 30 minutes and the first pot was removed a further 65 minutes later at 408 degrees, the result of a very slow temperature-fall (see Fig. 7 firing no. 20).

Of the 13 recorded removals of the first pot (Fig. 6), the average 'waiting time' was 85 minutes from the start of firing, with the first removal occurring at an average of 305 degrees, in a range of temperature from 140

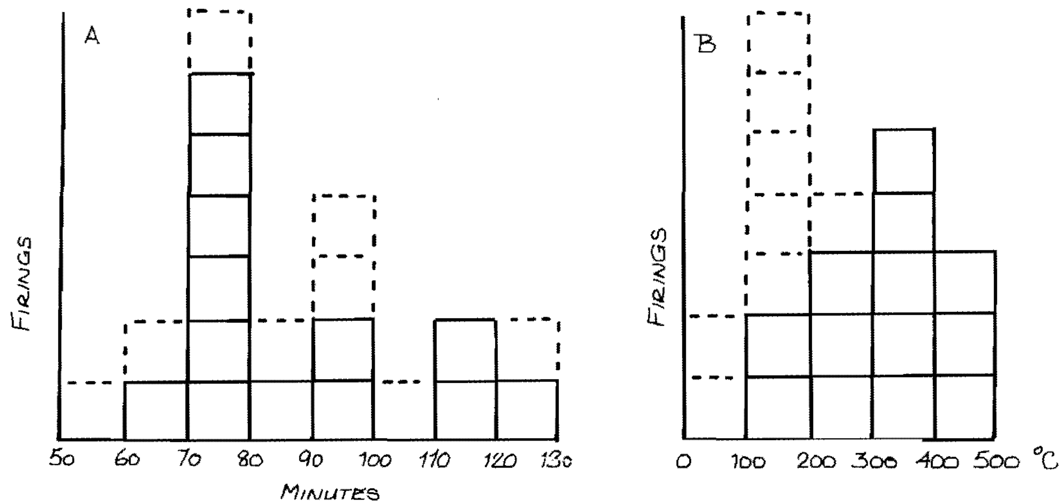

Figure 5
Examples indicating (A): the length of firing until the potter removes the first vessel, and (B): the temperature.
Dotted lines indicate occasions when recording ceased after the temperature fell below 200°C.

to 470 degrees. The longest wait occurred when recording ceased after 130 minutes at a temperature of 260 degrees. On that day there was no wind, and on similar occasions the firing was left for over two hours before the removal of a pot. The potters are aware that a low wind requires a long cooling-down period, a high wind the reverse. In two further examples, the first pot was removed after 110 and 120 minutes respectively at temperatures of 325 and 315 degrees. Two graphs illustrated here depict fast and slow firing-rates (Fig. 7, nos. 15, 20). These two examples seem to show that there is a relationship between a high maximum temperature and a short firing, but an examination of all the material indicates that other variables may also be involved, notably wind-speed and the position of the thermocouple, and no consistent relationship could be demonstrated.

LABORATORY TESTS

Analysis of Clay and Ceramics

Samples of source clay and prepared clay were obtained from the potters. These were submitted to various tests to determine the petrological inclusions and the temperature at which the clay becomes ceramic.

The Zaghawa potters at Kebkebiya use equal proportions of clay from three sources to make up their working fabric. A sample of each source clay ('x', 'y' and 'z') was taken and formed into individual briquettes with no filler added. These were fired up to 750 degrees. Thin sections were made and a petrological examination undertaken by A. Vince (Museum of London) to determine (i) the characteristics of the individual clays; (ii) whether the clays themselves were of different geological origin; and (iii) if it were

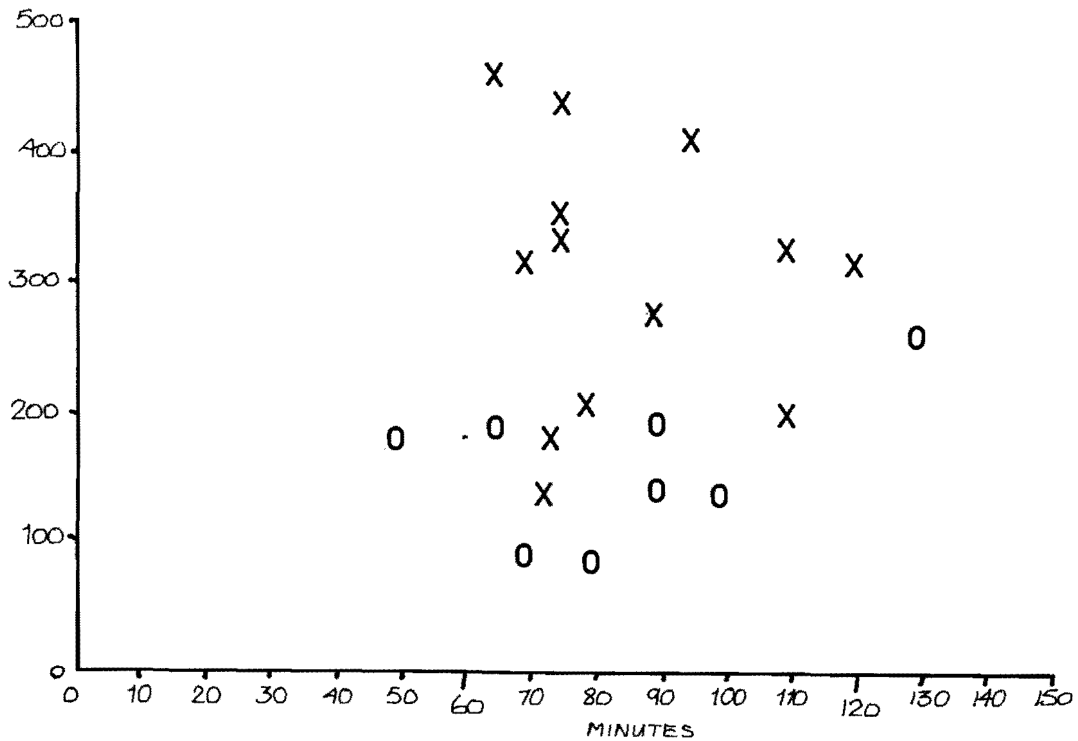

Figure 6
Showing the length of firing until the removal of the first vessel (x), or the last recording (o).

possible to tell that three clays had been mixed in the prepared fabric.

The three briquettes contained no organic filler, and any inclusions were natural, as quarried. Samples 'y' and 'z' fired without mishap but sample 'x' exploded in the kiln. All had a red core.

sample 'x': Although not a pure clay, it has a dense matrix made up of weathered biotite, containing sparse angular and sub-angular quartz (up to 0.2 mm). It is too fine to be used on its own since there is not enough filler in it to allow water vapour to escape.

sample 'y': This consists of many rounded inclusions ranging up to 0.4 mm, but there is little clay to bind the body together: on its own it would make a brittle fabric. The inclusions consist of quartz, granite, chert, tourmaline and black and red iron ore, the latter giving colour to the clay.

sample 'z': This has the same range of inclusion types as 'y', although they are much larger, mostly between 1–2 mm. There is a fine ground-mass with abundant angular quartz and sparse rounded quartz. It may be possible to use it on its own, although the clay is rather dense.

A further series of tests was undertaken with the prepared fabric. Approximately 10 grammes of clay was taken for each sample

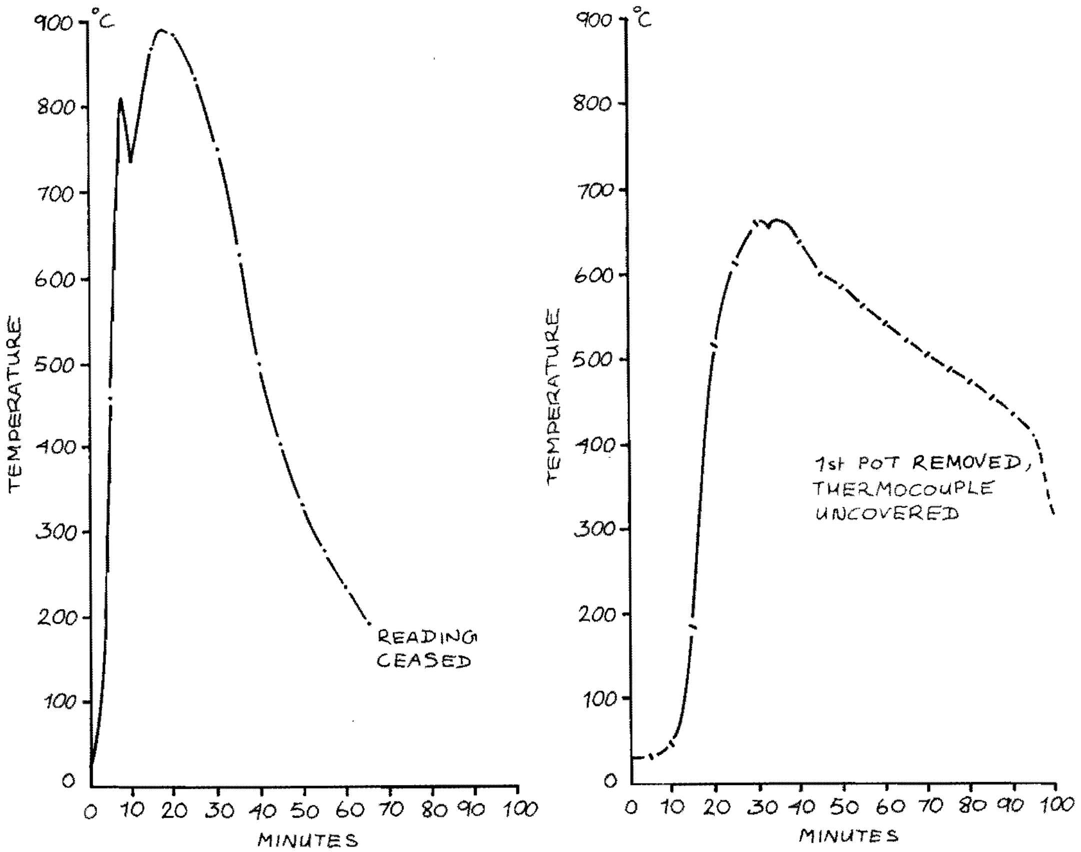

Figure 7
RATE OF FIRING—TWO EXAMPLES

03.05.82 Firing no. 15
Wind: very strong from the East
No. of vessels: 39
Diameter: 3 m.
Thermocouple: placed high in the fire at point of combustion; no clay on the end.
A maximum temperature of 891°C was reached after 18 minutes. Readings ceased 65 minutes after combustion when the temperature had cooled to 195°C.

24.05.82 Firing no. 20
Wind: mild, from South East
No. of vessels: 24
Diameter: 1½ m.
Thermocouple: placed low 15° from point of combustion; clay on the end.
The temperature was static for the first five minutes, rose slightly as fuel near to the thermocouple ignited, reached a maximum temperature of 675°C after 30 minutes. An hour later the first pots were removed at 408°C.

and mixed with one of three fillers, (millet husk, donkey-dung and cow-dung, the latter used by Berti potters but not by the Zaghawa at Kebkebiya). Six samples of fabric with each filler were produced and the briquettes fired in sets of six to temperatures ranging from 450 to 900 degrees. They were heated in an electric furnace at the Institute of Archaeology, London, in an oxidising atmosphere, with a rate of temperature-increase of 15 minutes per 1000 degrees.

TABLE 3
KEBKEBIYA PREPARED CLAY; FIRING-TEMPERATURE AND FILLER.

FIRING TEMPERATURE AND FILLER						
filler	prepared clay					
millet husk	1	2	3	4	5	6
donkey-dung	7	8	9	10	11	12
cow-dung	13	14	15	16	17	18
Firing temp.	450	500	550	650	750	900

450 degrees: All fired darker; carbon from the organic temper had not completely burnt out from the surface of the brickette. The surface could be scratched with a finger-nail. Black core.

500 degrees: Fired to a more even brown colour, but the surface carbon had still not completely burnt away. The surface could be scratched with a plastic stylus.

550 degrees: The carbon had completely burnt away on the exterior surfaces, giving an even tan/red colour which could be scratched only with a scalpel blade.

650 degrees: All samples have an even colour with a black core.

750 degrees: All samples fired to an even red with a thick black core, and there were no mishaps except for 'x' (see above).

900 degrees: The samples suffered; no. 6 had slight cracks, and 12 and 18 had deep cracks and fissures.

Nine briquettes of fired clay were taken (1–3, 7–9, 13–15) and soaked in individual containers of water for several days, to determine the lowest temperature at which the clay had become fired pot. Cardew suggests that 550 degrees is the critical temperature (Cardew 1970, 11), so samples from 550 degrees and below were taken. After three days it was noted that the samples fired at 450 degrees (1, 7, and 13) had each quite disintegrated; those fired at 500 degrees (2, 8, and 14) could easily be broken up; whereas those taken up to 550 degrees remained ceramic.

DISCUSSION AND CONCLUSION

Analysis of the three source clays indicates that they are either too fine or too brittle to be used alone. Mixed together but without the addition of opening materials, it is probable that the fabric would not possess adequate resistance to withstand the rapid firing/cooling of a bonfire, nor would it allow gases to escape. It is not possible to determine from a petrographic analysis of the prepared clay that three source clays have been used since the mixture looks homogeneous, and furthermore the individual clays do not have specific mineralogical characteristics.

Why is it that these potters choose to use two different fillers, millet husk for the body and donkey-dung for the neck? The reasons could be technological, relating to manufacture, drying or firing, or they could be related to the function performed by the vessel. It was noted that clay with an addition of millet husk was very 'short' while damp, but once leather-hard it could withstand considerable stress, the fabric being firmly bound by the filler. The actual technique of beating out a spherical body requires such a clay, with minimum plasticity, and in fact no extra water is added during the manufacture of the base. Such a process is very suitable to arid zones where the water-supply is limited. In contrast, the neck is formed by a process which requires a very plastic clay. Leavens tells us that 'in dung, alone of all the organic tempering materials, the presence of gel-forming, hydrated organic polymers increases the clay's plasticity,' (Leavens, quoted by London, 1981; 193). Certainly powdered donkey-dung gave the clay sufficient plasticity to enable it to be coiled easily.

As well as reducing the problems caused by uneven shrinkage when joining clays of different states of dryness, the potters believe that organic materials help the fire to consume a fabric, and that the open pores caused by the burning-out of organic material are essential for vessels such as water-storage jars to keep their contents cool through evaporation. Finally it is maintained that it is impossible to bonfire fire a vessel without the fabric being 'crammed' full of filler in order for gases and water vapour to escape during firing (Nicklin 1981, 356; Rye 1976, 109; Woods, forthcoming). Thus the choice of a particular filler affects both the manufacturing and the firing process, and can increase the porosity of a vessel. In the past, the potters must have conscientiously tested and selected local clays to enable them to use not only a mixture of three source clays but also to choose two fillers, each of which serves to aid a particular forming process.

In spite of the fact that the same potters, using the same fuel and firing in the same pits, were used as a study group at Kebkebiya over a period of several months, there was still a 250-degree range recorded of the maximum temperatures. With this in mind, archaeological scientists carrying out temperature-analysis tests should ensure that they examine a large enough pottery sample to allow such variations to show up, since small samples may not reflect the range of temperatures achieved. It is interesting to note that laboratory tests showed that the stability of the Kebkebiya clay rests within the maximum and minimum temperatures of this range (659–891 degrees). The test briquettes fired at 500 degrees and below slaked when left in water whereas those fired at 550 degrees remained ceramic; all briquettes fired at 900 degrees developed cracks and fissures.

Particularly high temperatures may occur in the months immediately before the rainy season because of the strong winds, but the potters themselves make no attempt to raise the temperatures of their firings by the addition of heaped-up fuel (even though it is both plentiful and free). On the contrary, they try to control the tendency to overfire when it is windy by adding extra ashes. On the subject of control of firing-temperature: on two occasions when a *gulla* was manufactured, it was fired alone, with a sheet of metal placed so as to keep the wind from causing fast combustion and high temperatures. A *gulla*, also called *thelaaja* or 'refrigerator', is used to keep drinking-water cool, and so must retain maximum porosity, a quality which the potters try to control by lowering the firing temperature, thus reducing the extent of vitrification.

It can be seen that vessels with a red exterior and a black reduced interior surface are produced deliberately, depending on how the potter fires them, and are not, as is

sometimes inferred for archaeological material, the result of poor firing. In the case of the Zaghawa pots, the occurrence of a red or black interior is of further significance to the archaeologist since it denotes a difference of vessel-function. A red oxidised interior gives more porous vessel-walls than those with a carbonised surface. Water-storage jars required to keep water cool are always fired red, on their side, whereas water-carrying jars and cooking-pots are placed mouth downwards during the firing. A reduced firing slightly lowers the temperature at which vitrification begins (Maniatis and Tite 1981, 61), and this as well as carbonisation would lessen porosity. Thus the colour of the interior and exterior of a pottery sherd may be used in certain cases by the archaeologist as an indicator of vessel-function.

Pyrometric readings of both Lauer and Woods indicate that temperatures may differ considerably from one point to another in an open fire. This is confirmed by the present measurements since they too show a wide range. Rye states that to withstand this variation a pot should possess certain properties: a strong vessel-shape, high porosity, and controlled mineral inclusions (Rye 1976, 109). The Kebkebiya pots are spherical, have a high content of voids left from the burning-out of organic materials, and the mineral inclusions are affected by the selection of different clays to form the main fabric. The potters have achieved a level of sophistication in all aspects of their potting: in their choice of clay, filler, fuel, and manufacturing and firing techniques.

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FLINT-WORKING IN THE METAL AGE

Summary. *This paper considers the relationship between flint technology and the development of metalworking in Britain. The gradual adoption of metals is reflected by changes in the range of flint flakes being produced, the efficiency with which the raw material was worked and the number of implement types that continued to be made of stone. The main types to remain in use were those for which flint was a more suitable material than bronze. The intensity of flint-working as a whole may be one clue to the accessibility of metal in different areas.*

I. INTRODUCTION
by Stephen Ford and Richard Bradley

There has been an increasing number of studies concerned with the question of how lithic materials were collected and exchanged and with the influence of these processes on the basic techniques of stone-working. The common element in many of these studies is an analysis of inter-site variation in relation to lithic sources and their mode of exploitation. This paper is concerned with a rather different question, and investigates the relationship between lithic technology and the accessibility, not of stone sources, but of metals.

This question has provoked surprisingly little discussion, particularly in the British Isles where it is generally accepted that metal was used for several centuries alongside a formally Neolithic material culture (Burgess 1980). Paradoxically, this area has seen perceptive studies of the organisation and development of bronze-working (Rowlands 1976; Burgess 1978). The changing relationship between the two technologies deserves much more attention.

The current literature is remarkably limited, but contains three principal strands. Some writers have argued that lithic technology was effectively extinct by the mid-first millennium bc (Saville 1981a), or even by the end of the second (Green 1980, 194). The more extreme view is inconsistent with the results of recent excavations and relies heavily on published sites with very small amounts of flintwork. It seems likely that such material was overlooked because of its remarkable crudity, or in some cases mistaken for the results of plough damage. The present writers have experienced no difficulty in locating flint industries dating from the earlier first millennium, either in existing collections or in their own fieldwork.

The second approach has been taken to British lithic industries of all periods. Substantial samples of apparently unused flakes have been measured in the hope of recognising stylistic variation (Pitts 1978; Jacobi and Pitts 1979). Such variations seem to offer an acceptable chronological framework for lithic studies, although their relations to contemporary technology are much more