Newsletter

IV – 1986

Department of Pottery Technology

UNIVERSITY OF LEIDEN - THE NETHERLANDS

NEWSLETTER

Department of Pottery Technology

IV – 1986

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INFORMATION

(1-11-1985 to 1-1-1987)

On September 1st, 1986 E.P.G. Mulder joined the Department of Pottery Technology as a laboratory worker. He was charged with making thin sections and the preparation, execution and administration of experiments within the Ceramic Laboratory of the Department of Pottery Technology.

Also on September 1st, dr. P. van de Velde joined the Department of General Archaeology of the Faculty of Arts of which the Department of Pottery Technology forms a part. Dr. van de Velde is a prehistorian/computer expert, and was engaged to give instruction in the use of computers in archaeology and to give guidance to archaeological research projects for which computer programs are used.

A. van As participated in the annual conference of the Theoretical Archaeology Group (TAG 85) held in Glasgow/Scotland from December 16th to 18th 1985. During the conference sessions took place on different subjects. Within the session on "Artefacts: experimentation and analysis" A. van As delivered a paper on "Integrated technological/experimental and ethnoarchaeological pottery research".

At the request of Prof. M.N. van Loon (University of Amsterdam) L. Jacobs stayed at Tell Hammâm et-Turkmân, Syria, from June 15th to 29th, 1986 in order to fire a number of clay tablets, which had been excavated shortly before by a team of the University of Amsterdam. Travel and lodging expenses of L. Jacobs were paid by the Netherlands Organization for the Advancement of Pure Research (Z.W.O.)(see also this Newsletter, p. 4-11).

From October 8th to November 6th, 1986 A. van As and L. Jacobs continued their technological research on Palaeo- and Meso-Babylonian pottery at Tell ed-Deir, Iraq. This research was carried out within the scope of activities of the Belgian Archaeological Expedition to Iraq and the Working Group on Mesopotamian Pottery (see also this Newsletter, p. 21-28).

From January 2nd to 23d, 1986 J.P. Dessel (University of Arizona, Tucson, U.S.A.) worked in the Department of Pottery Technology, carrying out research for his Ph.D.

From August 22nd to 27th, 1986 I. Edwards (Victoria College, Burwood Campus, Burwood, Australia) visited the Department of Pottery Technology in order to discuss ways of cooperation with respect to his research project on "Bronze Age pottery from Pella in Jordan: Standardization of production and its implications".

On November 6th, 1986 dr. Gloria London (University of Washington) gave a guest lecture on "Female potters on Cyprus" in the Department of Pottery Technology.

The request for a new research project of the Department of Pottery Technology, called "Explaining the technical aspects of the pottery craft within the frame of the archaeological discipline" (see Newsletter III, p. 2, 3) has been approved by the Board of the Faculty of Arts of the University of Leiden.

In the period from 1-11-1985 till 1-1-1987 the Department of Pottery Technology was working on the following projects:

- Qaryat al-Fau (Prof. A.R. al-Ansary, King Saud University, Riyad, Saudi Arabia).
- San Sisto Vecchio/Rome; Roman pottery (drs. Josine Schuring, Leiden).
- San Sisto Vecchio/Rome; medieval pottery (dr. M. Beatrice

Annis, Leiden).

- Sardinia; ethnoarchaeological research (dr. M. Beatrice Annis, Leiden).
- Tell Deir Alla Jordan; Late Bronze Age pottery (Prof. H.J. Franken).
- Tell ed-Deir, Iraq; 2nd millennium pottery (Prof. L. de Meyer, University of Ghent, Belgium).

Service:

- Instruction on research of non-plastics in pottery in connection with pottery research in Egypt (drs. C.M. van de Brink, University of Amsterdam).
- Firing of clay tablets from Tell Hammâm et Turkmân, Syria (prof. M.N. van Loon, University of Amsterdam)(see also this Newsletter, p. 4-11).

Rectification

Newsletter III, p. 21. "Fig. 5. Lower parts of water jars drying in the sun" should be "Fig. 5. Water jars drying in the sun".

L. Jacobs

FIRING OF CLAY TABLETS IN THE FIELD

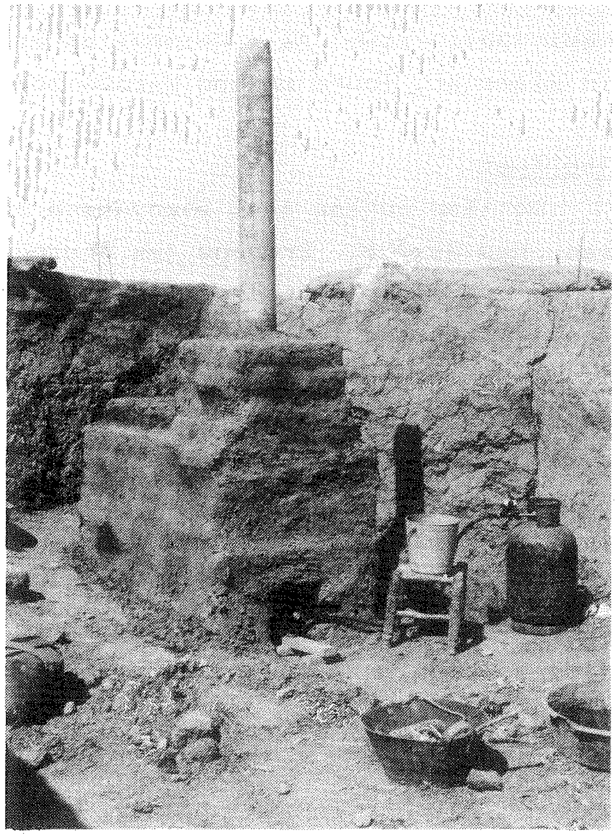
Introduction

At the request of Prof. M.N. van Loon and dr. D.W.J. Meijer (University of Amsterdam) some clay tablets excavated at Tell Hammâm et-Turkmân in the Balikh valley, about 60 km north of Raqqa (Syria), have been fired. Firing is the best conservation method for clay tablets (see literature below). By firing the clay turns into a hard material which cannot disintegrate in water, enabling the tablets to be handled more easily and be better impregnated, glued and repaired. After firing salts, if any, can easily be removed, if necessary with the aid of water.

As the firing had to be done in the field (1), a kiln was built on the excavation site in about three days. Materials available in the nearby surroundings were used as much as possible.

The kiln

A downdraft kiln was built of unfired mudbricks (Fig. 1). The size of the pottery chamber was about 30 x 40 x 40 cm, large enough for firing some clay tablets. A larger chamber would have consumed too much gas. The mudbricks were placed lengthwise in order to keep the outer size of the kiln within reasonable bounds: 90 x 90 x 150 cm. Clay tempered with chopped straw was used as "cement" between the mudbricks. The chopped straw, by-product of the harvest, was added to the clay in order to strengthen the paste and to reduce shrinkage. The result was a rather solid clay wall. The inside of the kiln was finished with a more heat resisting clay. For better insulation glasswool was used in the roof and the door of the chamber. The mudbricks appeared to insulate very well indeed. They contained the heat for a considerable long time. After



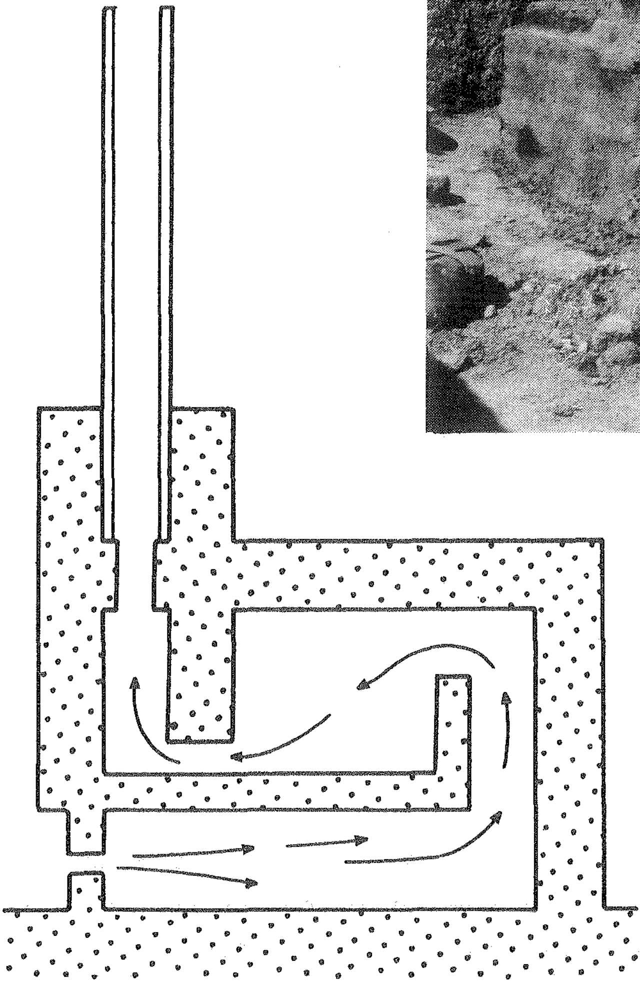


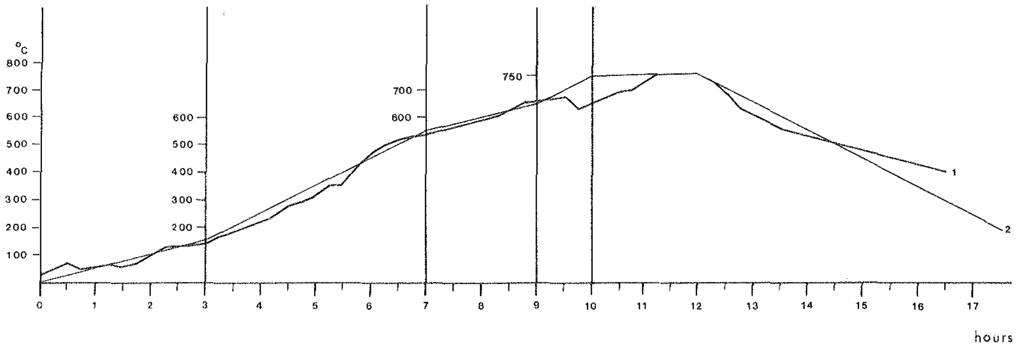
Fig. 1. A downdraft kiln built of unfired mudbricks.

eight hours of firing the temperature of the kiln had not remarkably risen. As a chimney an asbestos cement pipe, 18 cm in diameter, found on the excavation site, was used.

The fuel

Bottled butane gas, everywhere available in the Near East, was used as fuel. Propane gas produces a higher flame temperature, but is practically not available there. As a fuel for small kilns and test kilns bottled gas has various advantages. It is cheap, easy to transport and last but not least it enables the temperature in the kiln to be controlled closely. With respect to this temperature control gas is only equalled by electricity. The risk of the use of electricity, however, is that damage may occur to the ware in case of power failure.

As a manifold that could draw from two or more tanks equally was not available, the tanks had to be changed during firing, causing a slight drop in temperature (see graph 1: 1) (2).



Graph 1.

The burner

A stainless steel burner with air openings placed far backwards was used. The tube of the burner can be put into the kiln without hampering a free flow of air. A pressure gauge installed between the gas tube and the tank, was required to control and read the gas pressure. A firing temperature curve was made in advance and followed closely during firing (see graph 1: 2). It was important that the firing temperature did deviate from this curve as less as possible. A fairly close control, mainly important for the temperature range below 100 °C, was reached by enlarging or reducing the distance between burner and kiln mouth.

Kiln drying

In order to dry out the kiln structure thoroughly, the kiln was slowly fired for about 17 hours, an operation which took two days. Even after this period the water had not been totally expelled, because the mudbricks and especially the cement contained a lot of water (40 litres in the cement).

Test firing

Purpose of the test firing was to drive out the remaining water and to get to know the behaviour of the kiln in order to be able to control the conditions during the firing of the tablets as adequately as possible. To this end temperature graphs were made. During the critical firing the temperature, especially in the rather humid pottery chamber, was not allowed to rise very quickly. By way of a test a rectangular tray made of ceramic materials, filled with sand and small fragments of the tablets was fired. This was done to determine the insulating effect of the sand on the tablets during firing and to what extent the sand could eliminate temperature fluctuations. A sherd from an unfired object found at the tell was fired as a check. One part of this sherd was covered with sand, the other part was left uncovered. The firing results yielded information on the influence of the sand covering during the firing process. The firing results showed that sufficient heat had penetrated into the part of the sherd covered by sand.

The firing of the clay tablets

The clay tablets were fired in a ceramic tray filled with sand (Fig. 2)(3). This was done to avoid as much as possible any shocklike increase and decrease of the temperature in the tablets. The sand covering also prevented any wet sintering occuring on the surface of the tablets. The sand used was calcined sand obtained from the test firing. During firing the temperature increased 100 °C per hour and at the critical phases an increase of 50 °C per hour was pursued (see graph 1: 1). This curve was drawn. With the aid of of the available temperature graphs it could be established whether more or less gas pressure was needed. The entire firing and cooling

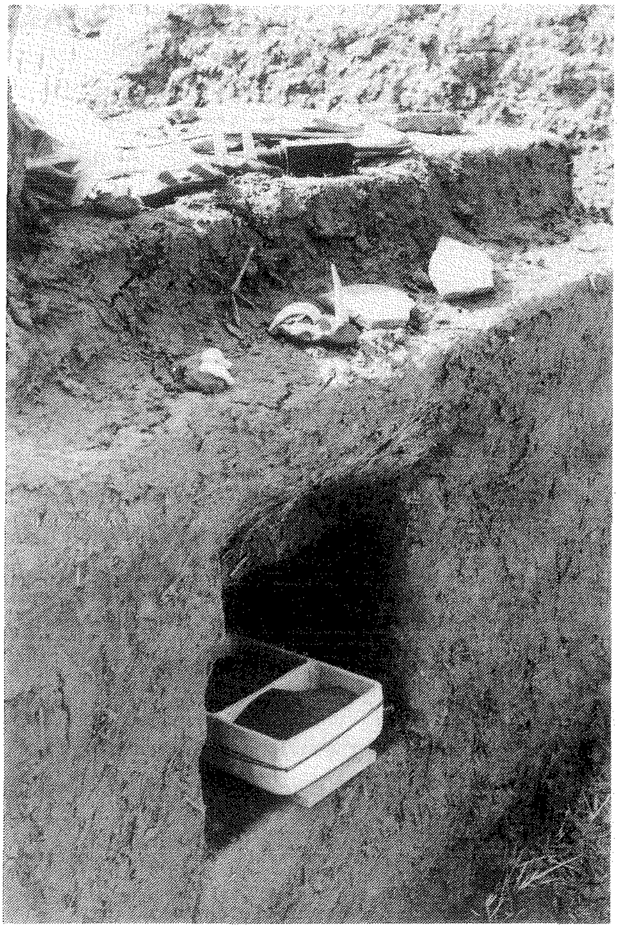


Fig. 2. The clay tablets were fired in a ceramic tray filled with sand.

process lasted about 12 hours. The maximum firing temperature was 750 °C (4). This temperature was maintained for more than one hour, whereupon the kiln was fired down to 500 °C in three hours. Then the burner was shut off and the openings at the upper and undersides were closed. The mudbrick kiln appeared to contain the heat for rather a long time, enabling the temperature in the kiln to decrease slowly.

Temperature recordings

Every fifteen minutes the temperature was measured with the aid of orton cones. In addition, a pyrometer was used to record temperature movements. This combination of measuring methods appeared to be very satisfactory.

Lime grains in the tablets

After firing the tablets and tablet fragments were impregnated by immersion in a benzine/lacquer solution. This treatment was applied to strengthen the material and to avoid any damage that calcium oxide grains present in the tablets might cause to them by taking humidity from the air and expanding afterwards. This method is also suitable to treat tablets damaged by frost. Such tablets are even after firing not very solid. Their strength can be improved by impregnation (5).

Notes

1. Travel and lodging expenses were paid by the Netherlands Organization for the Advancement of Pure Research (Z.W.O.).
2. Four gas tanks of a content of about 10 litres each were available. This was sufficient for the drying, test firing, and firing operations. In total approx. 25 litres of fuel were fired. Four tanks were necessary, however, because after eight hours of firing the gas pressure had decreased so much that a new tank had to be taken. Each new tank was placed in the sun before being connected in order to increase the gas pressure a little. A pressure of 3 atmo-

sphere could easily be maintained for a couple of hours. The gas tanks had to be changed quickly. Otherwise the temperature in the kiln would drop too much. For safety reasons the burner was taken out of the kiln mouth during the replacement operation and lighted again outside the kiln. It is also possible to keep the burner in the kiln mouth, provided the temperature is high enough (if the kiln is red-hot). Under these conditions the new gas supply will ignite in the kiln. But if the temperature is too low for the gas to become ignited or in case of an incorrect gas/air ratio the kiln will be filled with gas. In that case one has to wait for about 10 minutes before lighting the burner again, which will cause the kiln temperature to drop considerably.

3. The tray was made of excellent ceramic material. It was supported by blocks in such a way that the hot air could pass on all sides (Fig. 2).
4. The tablets were fired at a temperature not exceeding 750 °C. Minor temperature fluctuations and deviations in the measuring equipment were allowed for. At 750 °C the forming of calcium oxide does not yet take place. Above 750 °C this is a gradual process. It is nevertheless advisable to impregnate the tablets as soon as possible after firing or to put them in water, so that any possible calcium oxide will be slaked.
5. Tablets glued with a glue soluble in aceton can be also impregnated with the benzine/lacquer solution. The glue in the joint was not affected by the benzine. The solution consisting of one part of lacquer and eight parts of benzine did not leave behind a gloss on the tablets. If this nevertheless occurs the tablets can be brushed with benzine. To avoid fastening the tablets were dried on a grid made of tnreads. If necessary the tablets could be repaired and strengthened with gypsum afterwards.

Literature

Bateman, C.A., V. Crawfood, G.F. Dales and L.J. Majewsky (1966), Preservation and Reproduction of clay tablets and the conservation of wall paintings, London.

A. van As
L. Jacobs

A TECHNOLOGICAL STUDY OF SOME POTSHERDS FROM SABA AND ST. EUSTATIUS (DE JOSSELIN DE JONG COLLECTION)

Introduction

In preparation for a technological investigation of pottery recently excavated in St. Eustatius by a team of the University of Leiden headed by dr. A.H. Versteeg (Versteeg et al. 1984) a collection of sherds from the Ethnological Museum of Leiden was studied by the Department of Pottery Technology in 1984 (1). The sherds concerned had been excavated by J.P.B. de Josselin de Jong in 1923 (De Josselin de Jong 1947).

The results of this study are given below. The 53 analysed sherds come from the nr. 2049 series and were excavated partly in Saba (1, 6, 9, 32, 49, 63, 75, 79, 83, 84, 85, 98, 117, 118, 127, 137, 174, 186, 187, 189, 190, 198a, 205, 209, 221, 232, 236), partly in St. Eustatius (454, 525, 552a, 661, 674, 676, 698, 700, 702, 814, 884, 886, 906, 931, 966, 972, 973, 1004, 1024, 1055, 1118, 1240, 1311, 1318, 1337, 1345). The shaping and decoration techniques, firing conditions and raw materials used in the past were studied. The results cannot yet be considered as definite. For this purpose more sherds will have to be investigated and the conclusions and hypotheses presented below will have to be tested by investigating the pottery recently excavated in St. Eustatius.

Shaping technique

Some of the sherds were no more than fragments. Therefore, it was not always possible to make a reliable reconstruction of the shaping technique. The difference in type of sherds - there were base, wall and rim fragments - also affected the possibility whether to recognize the shaping technique or not. Also for this reason the conclusions mentioned in table 1 should be read with some reserve.

Five basic shaping techniques could be established:

1. pressing out a flat base
2. pressing out a flat base on a small mat
3. coiling
4. coiling on a mould-made base
5. pinching

Decoration technique

The following decoration techniques have been observed (see also table 1):

1. slip; monochrome cream all over
2. slip; red all over
3. slip; white on red
4. slip; red on a black body
5. slip; red, white, cream
6. scratched lines delineating the coloured parts
7. burnish (gloss)
8. burnish (hardly any gloss)
9. applied clay motives
10. scratched lines; in a stage drier than leatherhard
11. scratched lines; leatherhard

The unpainted faces of most of the decorated sherds were black or greyish black. This was the natural colour of the clay body caused by a high percentage of carbon in the clay which had been fired in a neutral or reducing atmosphere. The carbon was not intentionally rubbed in or applied, but it was naturally present in the clay. The red slip was a fine clay slip with a high iron content and had been applied before firing. The white decoration had been applied with a white clay slip before firing. The pure white colour was not caused by the presence of calcium in the clay but by a complete absence of iron oxide and other impurities. The absence of calcium was established with the aid of the HCl-test. HCl reacts on calcium but there was no such reaction on the white slip of the sherds examined. With a number of sherds, however, HCl did seem to react with the white slip. But this reaction was caused by a secondary fur consisting of a lime containing kind of loam covering the white slip. A number of sherds (for instance 931) were entirely covered with this loam fur, others only partly (for instance 63, 79, 84, 117, 118, 189, 236, 525, 674, 698, 700, 814, 884, 886, 906, 1004, 1055, 1240, and 1337). The loam fur was not identified as a scum layer, as in that case the sherds would have contained a high percentage of finely distributed lime. In addition, the fur had a reddish colour and a much larger thickness than is normal for a scum layer. The fur layer was very weak. After refiring the reddish colour turned white.

Firing conditions and raw materials

Of each sherd a small piece was broken off and refired in an oxydizing atmosphere at 850 °C for about 45 minutes in order to establish the firing colour of the clay. All sherds, except for the numbers 9, 221 and 661 became 2.5 YR-5/8 (red) (2). Sherd nr. 221 became 7.5 YR-7/2 (pinkish gray). This light colour may be explained by the presence of finely distributed talc in the clay. The sherds nr. 9 and 661 disintegrated after refiring due to the presence of lime particles in the clay (disintegration caused by absorption of humidity from the air, $CaO + H_2O \rightarrow$ expansion). This means that these sherds must have been fired between about 700 °C and 820 °C and possibly higher for a short time only. If they had originally been fired in a strongly reducing atmosphere, the maximum firing temperature could have been somewhat higher since the lime contained in them could remain longer in the carbonate form.

The remaining sherds contained hardly any lime particles and hardly any finely distributed lime. The following non-plastics could be observed under 40 x magnification: aegerine, quartz, milk quartz, talc and feldspars. The small number of sherds examined did not allow to seek a correlation between the non-plastics and other characteristics of the sherds and for this reason a quantitative analysis has not been carried out. This will be done as soon as the sherds recently been excavated in St. Eustatius have become available.

The colours found on the fresh break of a sherd can provide the following information on the firing conditions:

- the rate at which the tempreature rises, i.e. the time period in which a certain temperature is reached
- the maximum temperature reached
- the time during which the maximum temperature is maintained
- the amount of available oxygen (firing atmosphere)
- the extent to which oxygen can penetrate into the sherd

From about 750 °C to 800 °C carbon reacts violently upon oxygen, and starts to burn ($C + O2 \longrightarrow CO2$), provided there is sufficient oxygen and time to enable the reaction to take place. The outside of a sherd is generally exposed to a higher temperature than the core (direct radiation heat). The higher the firing temperature and the longer the firing time, the more oxygen will be able to reach the core and the more carbon will burn.

To investigate the firing conditions of the sherds, where after breaking off the test pieces, fresh breaks had become visible, the fracture surface of each sherd was subdivided in a number of zones (Fig. 1):

1. skin on the outside surface
2. outside zone
3. core
4. inside zone
5. skin on the inside surface

From the colour variations observed between these zones the amount of oxygen available during firing could be gathered.

O = oxygen available (oxydation), 10 R-4/6 (red).

FO = few oxygen available (neutral), 5 YR-6/3 (light reddish brown), 10 YR-7/1 (light gray), 5 YR-6/2 (pinkish gray), 5 YR-4/2 (dark reddish gray), 7.5 YR-5/4 (brown), 5 YR-5/3 (reddish brown).

NO = no oxygen available (reduction), 5 YR-2/1 black), 5 YR-5/1 (gray).

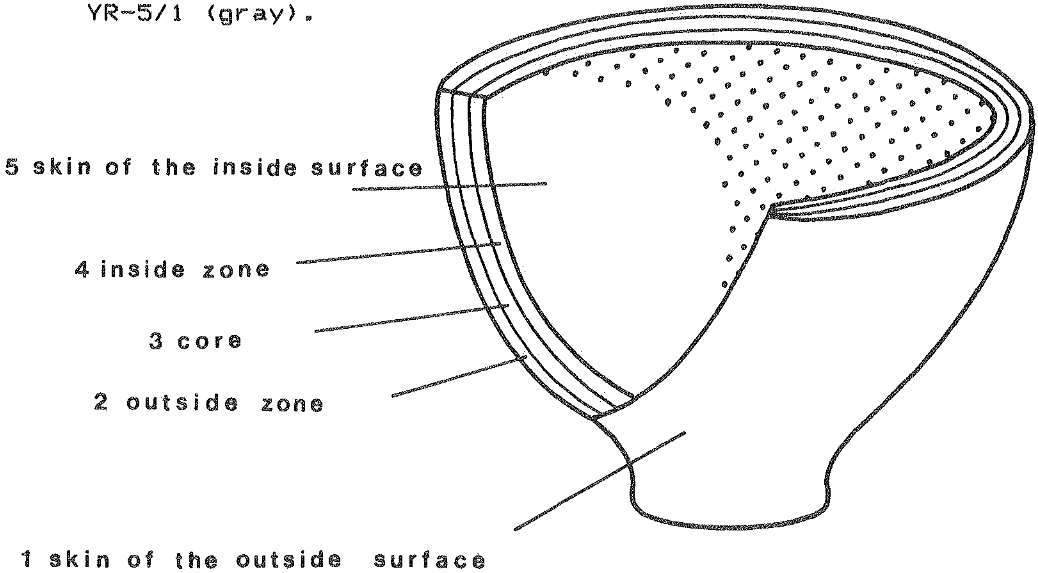


Fig. 1. A number of zones in the fracture surface of a sherd.

Some zones showed more than one colour. In total 22 different combinations of colour zones were observed which could be reduced to 5 models.

	I	II	III
1.	O/FO	FO/NO	O/FO/NO
2.	FO	FO/NO	FO
3.	FO	NO	NO
4.	FO	FO/NO	FO/NO
5.	FO/NO	FO/NO	O/FO/NO

	IV	V
1.	FO/NO	O/FO/NO
2.	NO	NO
3.	NO	NO
4.	NO	NO
5.	FO/NO	O/FO/NO

These models may have been subjected to the following firing conditions from which, in turn, the location of the pots in the fire could be deduced (Fig. 2). It was assumed that the pots have been fired in a bonfire on the ground or in a pit.

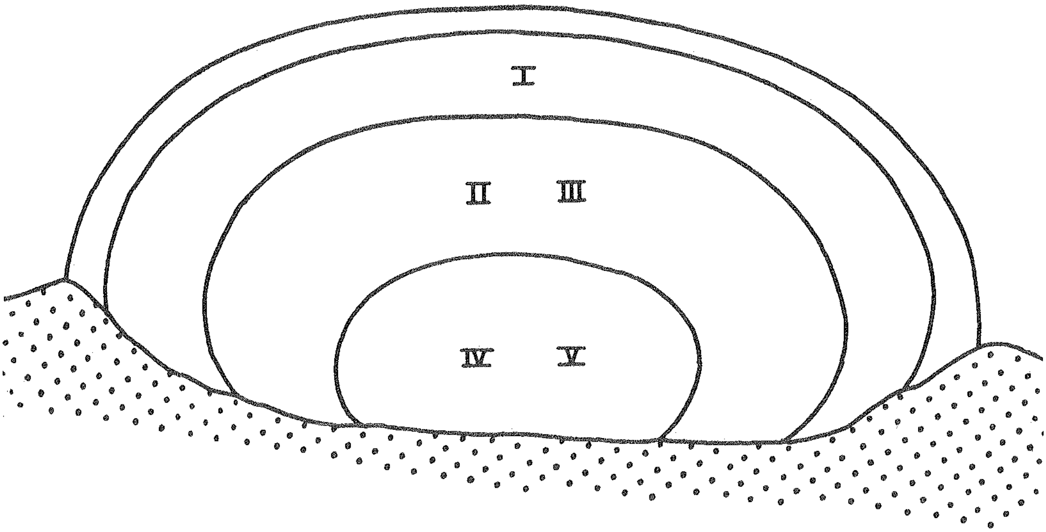


Fig. 2. Location of the pots in the fire.

I The black core has disappeared. The firing time was long enough and the temperature high enough (between 800 °C and 900 °C) to allow the carbon to burn away. Nonetheless, the atmosphere of the fire was not entirely oxydizing.

II The pottery was fired in direct contact with the flames. The maximum temperature was not very high (about 800 °C to 850 °C or perhaps 900 °C to 950 °C for a very short time).

III The temperature of a bonfire may be higher at the outside than at the inside, as at the outside more oxygen can enter, which causes a better combustion. These pots were probably located at the outside of the fire.

IV This pottery must have been located in the centre of the bonfire, where there was only few or no oxygen at all, causing a smothering atmosphere. Under these conditions there is no optimal combustion. The temperature was low and the fire lasted very shortly (black core). Combustion of carbon could not take place because of the low temperature.

V This pottery showed traces of oxidation on the skin only, caused by opening the burnt-out, but still hot fire.

Conclusions

As already stated above, the technological study of 53 sherds from Saba and St. Eustatius does not allow definite conclusions to be drawn. The study did show that there was no technological difference between the pottery of Saba and that of St. Eustatius. In table 1 the observed characteristics are given.

Table 1

1 = pressing out a flat base
2 = pressing out a flat base on a small mat
3 = coiling
4 = coiling on a mould-made base
5 = pinching
6 = slip; monochrome cream all over
7 = slip; red all over
8 = slip; white on red
9 = slip; red on a black body
10 = slip; red white cream
11 = scratched lines delineating the coloured parts
12 = burnish (gloss)
13 = burnish (hardly any gloss)
14 = applied clay motives
15 = scratched lines; in a stage drier than leatherhard
16 = scratched lines; leatherhard
17 = model I
18 = model II
19 = model III
20 = model IV
21 = model V
22 = disintegration after refiring

SABA (27 sherds)

characteristics:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
sherd nr:																						
1			x										x			x					x	
6			x					x											x			
9			x														x					x
32							x					x		x				x				
49			x				x					x	x				x					
63			x				x						x				x					
75			x											x				x				
79								x		x								x				
83								x		x		x					x					
84												x				x		x				
85			x												x		x					
98							x					x			x		x					
117												x			x			x				
118			x				x					x		x		x	x					
127					x	x							x					x				
137				x			x						x						x			
174			x										x			x						
186	x		x																	x		
187				x									x					x				
189			x					x		x		x					x					
190			x															x				
198a			x				x					x							x			
205			x															x				
209	x																x					
221			x				x												x			
232			x				x							x				x				
236		x																		x		
Total	2	1	16	2	1	1	9	4	0	3	0	9	7	4	3	4	9	10	4	2	1	1

ST. EUSTATIUS (26 sherds)

characteristics:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
sherd nr.																						
454															x			x				
525							x				x	x				x					x	
552a			x									x			x					x		
661																		x				x
674	x						x					x		x		x						
676			x				x											x				
698			x					x				x						x				
700	x		x				x				x					x				x		
702			x						x		x			x		x				x		
814			x				x						x		x			x				
884			x					x			x		x			x	x					
886	x		x														x					
906	x		x										x						x			
931			x														x					
966			x							x		x				x			x			
972			x					x												x		
973			x					x				x				x	x					
1004			x					x			x	x				x	x					
1024			x				x					x						x				
1055			x					x				x							x			
1118			x					x				x	x		x	x	x					
1240			x				x				x	x				x				x		
1311								x				x									x	
1318			x											x							x	
1337								x				x							x			
1345												x				x				x		
Total	4	0	19	0	0	0	7	9	1	1	6	14	4	3	4	11	6	6	4	6	3	1

Table 1.

Notes

1. The sherds were made available by courtesy of dr. Th.J.C. Leyenaar.

References

Josselin de Jong, J.P.B. de (1947), Archeological material from Saba and St. Eustatius, Lesser Antilles, Mededelingen van het Rijksmuseum voor Volkenkunde, Leiden No. 1.

Versteeg, A.H. et al. (1984), De archeologie van St. Eustatius en Saba: intra-insulaire en inter-insulaire ontwikkelingen in het Caraïbisch gebied, interim rapport, Leiden.

A. van As

L. Jacobs

TECHNOLOGICAL STUDY OF PALAEO- AND MESO-BABYLONIAN POTTERY - A REPORT ON THE 1986 SEASON AT TELL ED-DEIR (IRAQ) AND SOME PRELIMINARY RESULTS

Introduction

From October 8th until November 6th, during the 1986 season of the Belgian Archaeological Expedition to Iraq headed by Prof. L de Meyer (University of Ghent), the technological research program on Palaeo- and Meso-Babylonian pottery from Tell ed-Deir (Iraq), started in 1985 (Van As and Jacobs 1985), was continued on the spot. This program fits in with the scope of work of the Working Group on Mesopotamian pottery: the establishment of a corpus of Mesopotamian pottery that will go beyond a traditional shape typology.

Fieldwork

The 1986 field activities were in the first place focussed on checking and specifying the shaping techniques as reconstructed during the 1985 field season and as verified by experiments with clay samples from Tell ed-Deir, conducted in the Department of Pottery Technology. The shaping techniques of some pottery not studied before were described. Within the scope of the aims of the Working Group on Mesopotamian Pottery initial research work was done in Sippar and Isin/Ishan Bahriyat (Fig. 1). Since the seventies excavations have been carried out here, headed by prof. W. Al-Jadir (University of Baghdad)(Al-Jadir 1986) and Prof. B. Hrouda (University of Munich)(Hrouda et al. 1977; 1981) (1).

In addition to the clay samples taken in 1985, some more samples of clay and sand were taken for workability tests and material analyses.

Some recent brickworks and potteries northeast of Baghdad

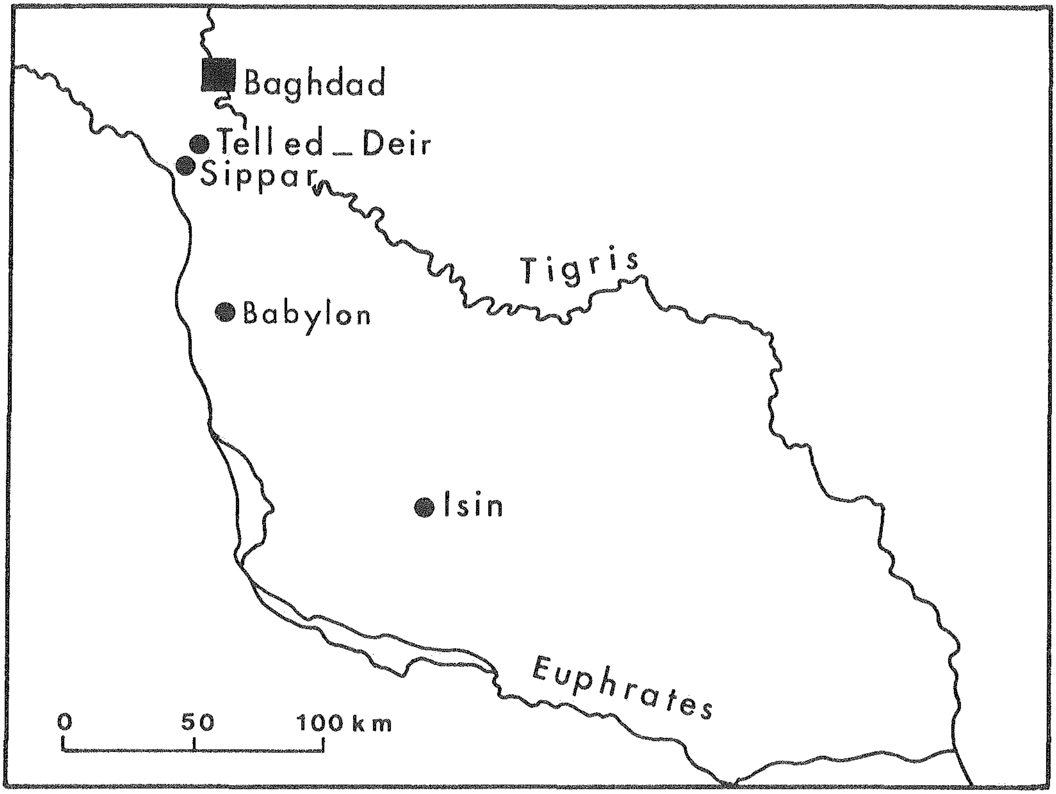


Fig. 1. Map of Mesopotamia.

were visited to gather data which may be important for the final interpretation of the excavated pottery. Furthermore, the framework for a classification system of Palaeo- and Meso-Babylonian pottery was set up.

The shaping techniques of Palaeo- and Meso-Babylonian pottery from Tell ed-Deir, Sippar and Isin/Ishan Bahriyat (2)

Most of the Palaeo- and Meso-Babylonian pottery from Tell ed-Deir has been thrown on a fast potter's wheel. A minor part was made with the help of a tournette and only a very small part was made by hand. The techniques applied to make the thrown pottery could be split up in four categories: thrown from the cone, thrown out of one piece of clay, thrown in coils and thrown in cylinder parts. The use of these specific techniques was directly related with the shape, size and function of the pottery: dishes, bowls, large bowls with flat bases, goblets etc. Several technical variants were observed within each technique. These variants were generally recognizable by the profiles of the pots, for instance the various techniques of finishing the rims (thickening by pushing, folding etc.). In some cases, however, the technical variants could not be recognized by the shape of the pottery, such as the technique of scraping the base by hand in various directions and that of scraping the base on a fast moving wheel. At the current stage of the investigation it is not yet clear whether the technical/shape variants have any chronological meaning. This will have to be established in combination with stratigraphical data and pottery frequencies. The technical/-shape variants may also reflect local developments as well as differences between workshops or individual potters. Comparative studies of contemporary pottery repertoires from other sites will have to elucidate this.

A first short study of the pottery from Sippar led to the provisional conclusion that the techniques applied here are generally similar to the ones of the pottery from Tell ed-Deir. In Isin/Ishan Bahriyat, however, some technical differences were observed with respect to the shaping techniques of the goblets. The characteristics of the Tell ed-Deir goblets point to the potter's difficulties in making a good base. If the potter cut the goblet too high from the cone, this resulted in a hole in the base which had to be repaired afterwards. Cutting the goblet too low from the cone resulted in a base which was too thick in relation to the wall. As a consequence, the base cracked during drying and firing. By "pot reading" it could be ascertained that the potters had found out a method to prevent cracks caused by cutting the goblet too low from the cone (Van As & Jacobs, in preparation). The impression was obtained that in Isin/Ishan Bahriyat the problems with the bottom cracks did not occur as frequently as in Tell ed-Deir

(3). The reason might be that the potters who made the goblets in Isin/Ishan Bahriyat were better skilled. The quality of the raw materials used might be another reason. This will have to be studied in more detail.

From the stretching traces observed on the Palaeo- and Meso-Babylonian pottery it could be deduced that this pottery was made of rather short clays. It may be assumed that the raw materials have not been selected with great care (4). The clay was generally tempered with a lot of organic material, probably to make a cohesive clay body.

A second visit to the potteries northeast of Baghdad

As was done last year, this year too, a short visit was paid to the pottery workshops northeast of Baghdad, just within the Diyala district on the road from Baghdad to Baquba. Unlike last year no pottery was thrown during our visit. In one of the two compartments of an updraft kiln pottery was fired. The other compartment was unloaded. The fired pots were

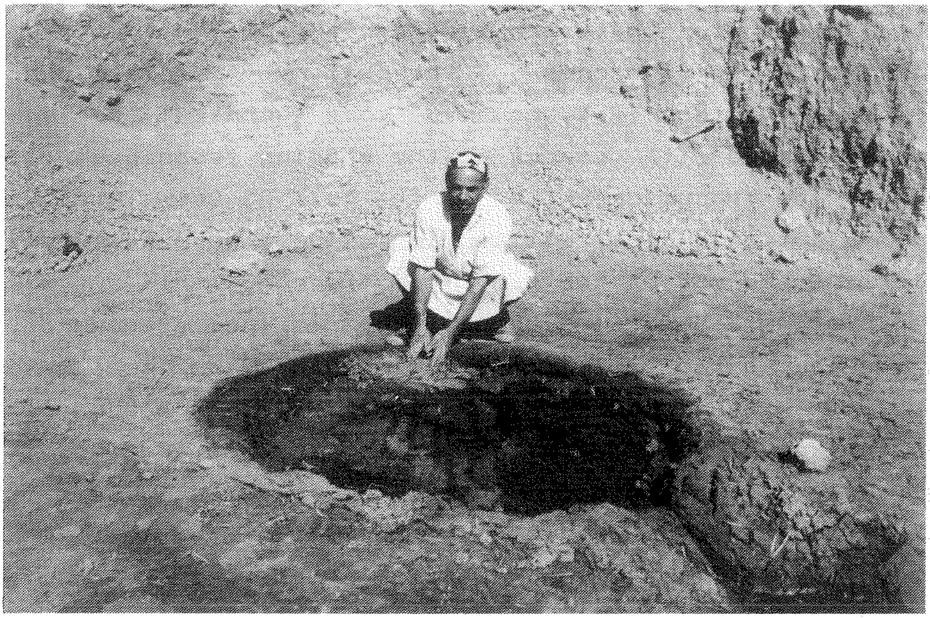


Fig. 2. The clay is soaked for 24 hours in a shallow pit.

put in a storage room waiting for transport to places in Iraq. Additional information could be gathered on the production process. The clay used for the pottery production is got in the immediate neighbourhood of the workshops. The wide surroundings of the potteries where also many brickworks are located, consist mainly of clay. The raw materials used at the brickworks also visited by us, varies from clay to loamy sand. The brickworkers are not very precise in their raw material selection. The same is true, though to a lesser degree, with regard to the selection made by the potters. The clay used by them is soaked for 24 hours in a shallow pit (Fig. 2) to which

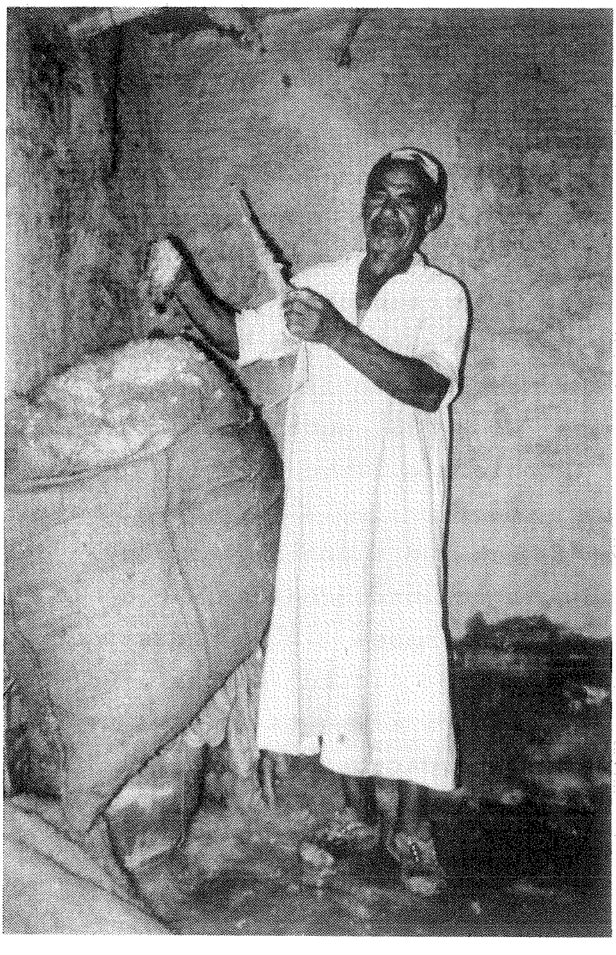


Fig. 3. Reed fluff which is added to the clay.

water from a well is supplied through a dug out gully. Reed fluff is added to it before kneading, which, according to our informant, makes the clay more cohesive (Fig. 3). Although the clay body is rather short, as the stretching traces occurring during the shaping process show (Van As and Jacobs 1985: Fig. 7), it is nevertheless soft and of good workability. A sample was taken for workability tests. The results of these tests will be compared with the ones to be performed with the clay samples from Tell ed-Deir taken in 1985.

A "reference work" of pottery shapes

The framework of a classification system for the Palaeo- and Meso-Babylonian pottery of Tell ed-Deir was discussed. This system is intended to be applied also to contemporary pottery from other sites in the Mesopotamian plain. It should be a simple and conveniently arranged "reference work of pottery shapes". The pottery shape has been chosen as the main classification criterion. This was done on purpose, since every archaeologist is able to observe the shape of a pot. This is, however, not the case with respect to the technological aspects of pottery. The data obtained from the technological study of the Palaeo- and Meso-Babylonian pottery will be integrated in the "reference work" in such a way that the relation between shape and technique will be clearly presented. The following individual shape criteria have been established: presence/absence of a neck and shape of the body. The body shapes will be distinguished into conical, biconical, cylindrical, globular and granate shapes (5). A distinction will also be made between open and closed shapes. The rim shapes will be regarded as secondary elements in the system. The base shapes will also be secondary, although they give more information on the shaping technique of the pottery than the rims.

Working Group on Mesopotamian Pottery: towards a corpus of Mesopotamian pottery

The aims of the Working Group on Mesopotamian Pottery set up during the 1985 season of the Belgian Archaeological Expedition to Iraq (Newsletter III Department of Pottery Technology, 1985 and Van As and Tunca, 1986) are now sharper outlined. They are focussed on the establishment of a corpus of Mesopotamian pottery, that will go beyond a traditional shape typology. The starting point is the study of the Tell ed-Deir pottery. In the opinion of the members of the Working Group, however, the corpus should be based on the study of pottery from various sites in the Mesopotamian plain and the area beyond. Technological, (ethno)archaeological and historical data will have to be included in the corpus. The members of the Working Group realize that their aim is rather pretentious. The chance of success depends mainly on the willingness of fellow archaeologists to participate in the activities of the Working Group. The Working Group rejoices at the support and cooperation of Prof. W. al-Jadir (Univ. of Baghdad) and Prof. B. Hrouda (Univ. of Munich) enabling the pottery study of Tell ed-Deir to be placed in a wider context. In April 1987 the Working Group will meet in Ghent to discuss the preliminary results and future research activities.

Notes

1. We thank Prof. W. al-Jadir, Prof. B. Hrouda, dr. Stephan Fitz and Mrs. C. Wolff for their kind cooperation.
2. A report has been made on the shaping techniques, which will be incorporated in the final publication. Parts of this report will be published somewhere else in advance.
3. Some reserve has to be made because the collection studied may not be representative in every aspect.
4. The analysis of the raw materials used in antiquity will have to prove this.
5. The terminology of the classification units will be

discussed later.

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P. Stienstra

SYSTEMATIC MACROSCOPIC DESCRIPTION OF THE TEXTURE AND COMPOSITION OF ANCIENT POTTERY - SOME BASIC METHODS

Contents

1. Introduction

Materials research on ancient pottery is receiving, justifiably, a growing amount of attention from archaeologists as a potentially valuable tool in archaeological research. It is recognized that the investigation of the matter of which an ancient object is made may provide (additional) insight into provenance, method of fabrication, and use. Investigating material characteristics places new demands on archaeological research techniques. Familiar methods may need adaption, and new ones may have to be introduced. Because of the mainly mineral composition of pottery many useful new methods may be derived from the earth sciences, especially (sedimentary) petrology.

Evidently, not all standard petrological techniques will be acceptable as new archaeological standard methods. The necessary petrological equipment is not usually available in archaeological laboratories, and neither is the proficiency in operating such equipment or in rating the test results at their true value. It is therefore in many cases important to seek the cooperation of earth scientists when questions are asked or when research techniques are needed which go beyond the limits of the field of traditional archaeological research. At the same time, however, more simple techniques which do not necessitate sophisticated equipment or know-how may be introduced easily by archaeologists, both in the field and in the laboratory.

The aim of this paper is to identify such methods. Firstly, the properties which may be studied using only simple macroscopic techniques. Some standard investigatory methods and a descriptive terminology for every feature are then proposed. For the sake of completeness some methods are mentioned in section 4 which are already well known in standard archaeological investigations.

2. Describable properties

The fundamental material properties of pottery fall within three classes: texture, fabric, and composition, which can be defined following common petrological practice as follows:

- Texture: the external characteristics (shape, size etc.) of the individual components.

- Fabric: the spatial arrangement and orientation within a body of the components.
- Composition: the mineral and chemical build-up of a body and/or its components.

Texture and fabric are relatively easy to describe without advanced equipment or know-how, but this is by no means the case as regards composition. This paper will therefore focus primarily on the description of texture and fabric. The description of composition will only be dealt with briefly. The methods proposed in this paper are derived primarily from standard sedimentology and sedimentary petrology. A short list is given at the end of the text showing titles of some major handbooks on basic sedimentology and sedimentary petrology, and reference is made to a few titles on applied petrology in archaeology.

3. Methods

As always, the scientist has to take care to apply standard research methods in order to get repeatable observations which can be compared with similar observations from elsewhere, provided the scientist at the other location has used similar descriptive terminology. It is therefore important to apply standard methods when choosing and preparing samples. Furthermore, the observations made have to be recorded using standard descriptive terminology.

3.1. Equipment necessary

The equipment that is necessary is limited in terms of both quantity and sophistication. In the first place a hand lens (magnification about 8 to 12 times) is necessary, whereas in the laboratory a (binocular) microscope (magnification 20 to 40 times) may also be useful, especially when this contains a measuring occular and a separate lamp with which to light the sample from above. Furthermore, a pair of pincers may be needed for cross-sectioning sherds. A diamond-set rocksaw, when available, may greatly improve the quality of the cross-sections, especially when the cross-section is slightly polished on a glass plate with the use of fine polishing powder. In addition, some other simple expedients which will be described in the following sections may be applied.

3.2. Choosing the (sub)sample

When whole objects or large fragments are available the archaeologist should choose one or more sub-samples. When making a choice it should be realized that not necessarily all parts of one object are similar as regards composition and texture. For instance, the bottom of a vessel may be relatively richer in coarse(r) grains than its walls because of the potter's use of coarse litter to prevent the vessel being made from excessive adhesion to the wheel. Furthermore differing clay-mixtures may have been used to shape the different parts of the pot (ears, neck, spout, decorations) because of the different workeability characteristics necessary if shaping each of the different parts mentioned. In general one may expect that a certain heterogeneity exists within one object the range of which will increase with increasing size or complexity of shape. This principle should be taken into consideration when comparing the composition of sherds from different parts of pottery. If enough samples are available it may be advisable to compare only fragments derived from similar parts of pots, e.g. wall fragments only, or rim fragments only.

3.3. Sample handling

When preparing the sample for investigation it is essential not to destroy any information, or (unwittingly) to select certain groups of data at the cost of others. Each piece of pottery, when excavated, may bear a wealth of valuable (and in part vulnerable) information. Composition and texture may reveal each individual phase of the life of the object:

- raw-materials phase
- phase of preparation of the clay-body
- production phase (shaping, firing and finishing)
- application/use phase
- burial phase
- excavation phase
- restoration/research phase

It is evident that any treatment during the last two phases may jeopardize information on each of the preceding ones. As water (or any other liquid) may act as a perfect medium for import and export of components (both chemical and fragmental) pottery should be exposed as little as possible to watery solutions (in cleaning for example). Instead, only dry methods such as brushes to remove dry dirt from the surface, or a spatual to remove crusts should be used. Alterations brought about during the cleaning process (such as the removal of crusts) should be recorded and the material removed kept for later reference.

3.4. Preparing for examination

Many material characteristics may be investigated on the surface of the object. No further preparation is necessary. Observations beneath the surface, however, call for more consideration and preparation.

In order to be able to investigate the interior of sherds a cross-section of the sherd must be made. Before doing this (either manually, or with a pair of pincers or a rock saw) it should be realized that the direction of the cross-section may well influence the observations. This is especially true in pottery which has been thrown on a fast turning potter's wheel where preferential directioning of non-equidimensional components (like elongated mineral grains) may occur. In such cases the direction of the cross-section influences the appearance of the components of the cross-section to a great degree. The features seen on the "horizontal" section (parallel to the direction of rotation of the potter's wheel) will differ from those on the "vertical" section (perpendicular to the direction of rotation) (Fig. 1: A and C, respectively). If sufficient material is available and the direction of rotation can be defined (e.g. on the basis of surface striations) it is advisable to make two perpendicular cross-sections: one in the horizontal and one in the vertical direction. If a choice is not possible care should be taken to note the direction of observation.

The type of cross-section may also be of importance.

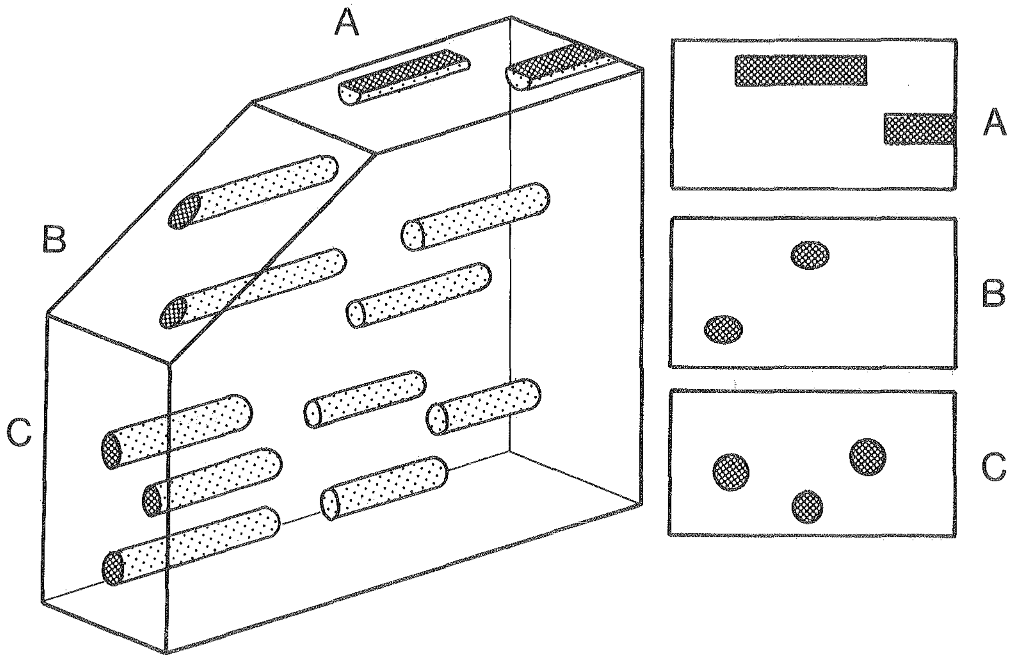


Fig. 1.
Schematic cross-section through a sherd containing cylindrical texture elements (grains or pores). The apparent shape, size and amount of the elements (expressed as percentage of total area) is strongly influenced by the orientation of the cross-sections with respect to the throwing direction: A: parallel; B: oblique; C: perpendicular.

Normally it will be sufficient to simply break the sherd along the desired tracks. The degree of roughness of the resulting surfaces will provide a measure of the coarseness and hardness of the pottery. Furthermore protruding grains are visible in more than two dimensions, which may increase their ability to be recognized. At the same time, however, the roughness of the surface may considerably hamper the quick quantification of each of the components which is based on estimating the area occupied by the components relative to the total area (see section 6). On rough surfaces it may be very difficult to make a sound estimate. In such cases it may be worthwhile either to flatten the surface by careful polishing on a glass plate using medium polishing powder, or to make another cross-section using a rocksaw. There always is a great risk, especially when sawing the sample, that some of the larger grains may become dislocated and are subsequently washed away instead of being cut.

3.5. Descriptive terminology

As previously stated a standard descriptive terminology is necessary to guarantee both the repeatability and comprehensibility of description irrespective of scientist or location. It is proposed here to follow the terminology common in sedimentary petrology as closely as possible, as this terminology is well documented all over the world.

4. Description of overall characteristics

The description of wall thickness, wall curvature and colour are well known techniques in archaeology. For the sake of completeness some notes on each of these issues are included in the subsequent sections. In addition some remarks are made on the measurement of hardness.

4.1. Wall thickness and curvature

The wall thickness is a criterion for the size, shape and degree of sophistication of pottery. It is measured (in mm) perpendicular to the wall. Too much precision in measurement is superfluous since minor fluctuations in wall thickness may occur within very small distances indeed.

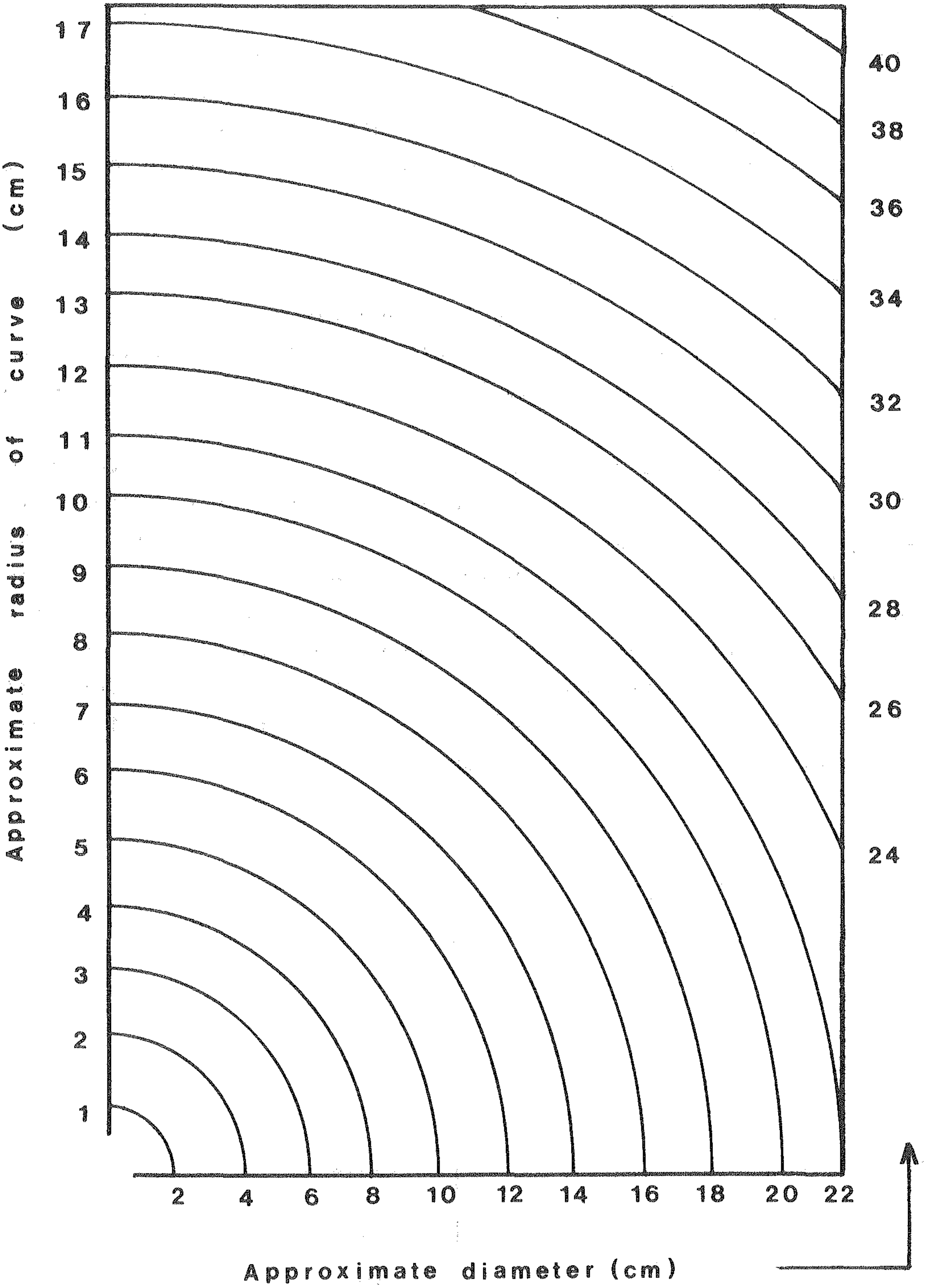
Curvature is another indication of the size of the pot: the greater the degree of curvature (measured in the horizontal direction), the smaller the diameter of the pot at the position of the sherd. It is usually accurate enough to estimate the approximate diameter using a diagram as shown in Fig. 2.

4.2. Colour

In the context of material research the colour of a sherd is the colour of the inner material visible along freshly broken cross sections. The colour of ancient pottery is a complicated feature. In one respect it may provide valuable information on the type of clay used or the firing temperature and atmosphere. However, it should be realized that a greater or lesser degree of difference in colour does not always indicate different types of earthenware. Pots made of the same clay and fired in the same kiln may display a different (shades of) colour due to relatively small differences in firing temperature and/or atmosphere within the firing chamber. Such differences may even cause colour differences within one object. Furthermore, primary colours may be changed due to secondary processes (use, burial in a reducing environment, reheating as in accidental fire etc.).

Changes of colour do not always affect the whole sherd through and through. It may therefore be worthwhile to describe, at least in basic terms, the colour build-up of the cross-section. Normally the terms "homogeneous" or "zoned"

Fig. 2.
Diagram to translate the curvature of a circle segment to average radius and/or average diameter of the complete circle.



Approximate radius of curve (cm)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
24
26
28
30
32
34
36
38
40
2
4
6
8
10
12
14
16
18
20
22
Approximate diameter (cm)

will suffice, and the main colours of each of the zones present (often a central zone enveloped by two external zones) may be indicated using the Munsell colour identification system. A set of standard colours arranged according to the Munsell system is available in most soil and earth sciences libraries.

4.3. Hardness

The hardness of pottery is usually expressed as its relative resistivity to scratching by given objects. When object A scratches object B, A is harder than B. In the 1880s Mohs defined a hardness-scale based on the relative hardness of different crystalline minerals. In general practice some everyday objects may also be applied because their hardness is defined relative to the standard minerals. One should realize, however, that pottery is a polymineral entity. Therefore, the hardness of pottery is a composite characteristic which depends on a combination of independent features, such as mineralogical composition, grain-size distribution, degree of fusion due to firing temperature, and porosity. Table 1 shows the principal hardness standards.

hardness	mineral	common object
1	talc	finger
2	gypsum	fingernail
3	calcite	copper coin
4	fluorite	
5	apatite	glass
6	feldspar	steel knife
7	quartz	
8	topaz	
9	corundum	
10	diamond	

Table 1.
Mineral hardness (Mohs-scale) related to the hardness of everyday objects.

5. Description of texture

When describing texture one first has to identify the composite elements which constitute the textural framework. Three groups of framework components may be distinguished:

1. the grains
2. the matrix
3. the non-material framework elements; pores, cracks etc.

These elements will be dealt with successively.

5.1. Grains

Grains may be defined as all particles which are the smallest separable or distinct units within the object. They may be mineral (either monomineral: e.g. a quartz grain, or polymineral: e.g. a fragment of granitic rock) or non-mineral (e.g. plant fibres). In this paper we only concern ourselves with those elements which can be observed with the naked eye or with only limited magnification, that is to say: macroscopically. It is known from petrography that the smallest grains discernible macroscopically are about 100 micrometres in diameter. It is proposed here to name these grains macro-grains, and to refer to all smaller grains as micro-grains. In macroscopic research micro-grains are considered to be part of the matrix. Several grain characteristics can be distinguished. The most important ones will be dealt with in the following paragraphs.

5.1.1. Grain-size

All grain-sizes fall within one of the grain-size classes of the Wentworth-Lane size classification system which is used worldwide in sedimentary petrology. A part of the system is summarized in Fig. 3. It becomes clear from the figure that the use of a term such as "sand" may cause confusion. "Sand" in grain-size terms is clearly defined as all granular material smaller than 2 mm but larger than 64 micrometre (=0.0064 millimetre). Similar confusion may arise with regard to the

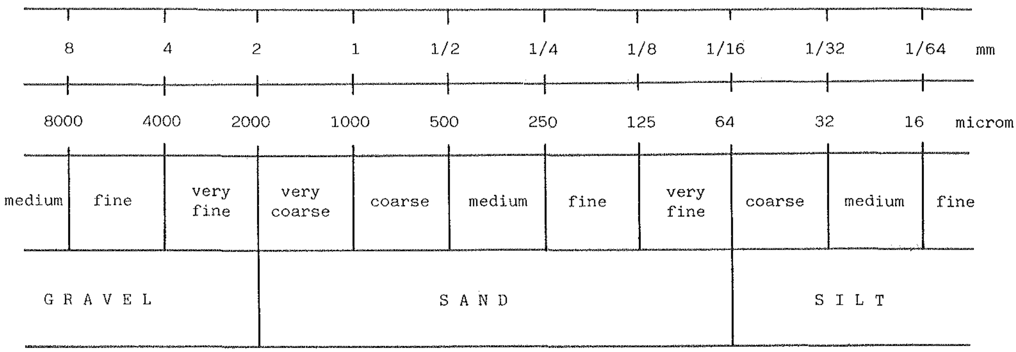


Fig. 3. Standard grain-size classes.

term "clay". This term is used to indicate the material the potter uses to make pottery. It is important to realize, however, that this "clay" often only partly consists of clay-size material, whereas the remainder is silt and sand.

The size of the macro-grains and the grain-size distribution may povide important clues as to the origin of the coarse material: was it added by the potter when he or she prepared the body, or were the grains natural components of the raw material? An estimate should therefore be given of the average grain-size of the macro-grains, and of the range of grain-sizes of the bulk of macro-grains within one piece of pottery. Special reference should be made to exceptionally large grains.

The measurement of size can be performed using exact measuring devices. However, the evaluation may generally be significantly accelerated (and still remain sufficiently accurate) when measuring is substituted by comparison: the size of the grains in the object investigated being compared with granular samples with a known range of grain-size. It is recommended to prepare eight reference standards (by sieving mixtures of dry sediments from several environments) which match the normal grain-size classes from fine gravel to coarse silt (Fig. 3). The resulting fractions may be kept in separate holders, but they may also be combined in a transparent perspex tube (diameter about 1.0 to 1.5 cm). Similar amounts of each of the eight fractions should be brought into the tube in descending order, each fraction being separated from the preceding one with cotton wool. Both ends of the completely filled tube should be sealed tightly. The resulting device is placed alongside the sherd under investigation whereupon average grain-size and grain-size range are estimated by comparison.

5.1.2. Grain-shape

Grain-shape is a feature which depends in the first place on the composition and internal organization of the grain itself. The crystallographic characteristics of monomineral grains and the texture and composition of polymineral grains very much determine the shape. Furthermore, grain-shape is influenced by secondary processes such as mechanical or chemical abrasion. Many systems have been devised to express shape in quantitative and qualitative terms. However, the grain-shape may generally be defined sufficiently accurate by comparison with three basic standard shapes (Fig. 4):

- equant (A; spherical or cubic grains)
- tabular or bladed (B; sheet- or plate-shaped grains)
- prolate (C; elongated grains: pillars, rods etc.)

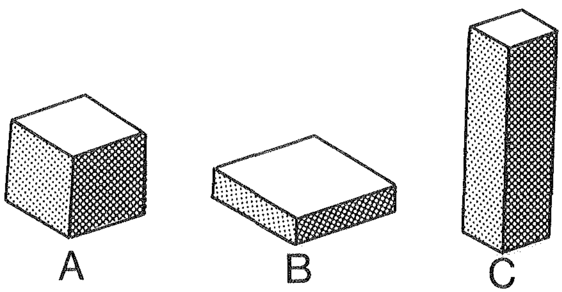


Fig. 4. Main grain-shape types; after: Pettijohn 1975, Fig.3-18.

5.1.3. Roundness

Roundness is the degree of rounding of edges and corners of a grain, irrespective of its general shape. Again sophisticated definitions regarding roundness do exist but it can be defined most easily by visual comparison with representatives of the five main roundness classes (Fig. 5):

- angular (A)
- sub-angular (SA)
- sub-rounded (SR)
- rounded (R)

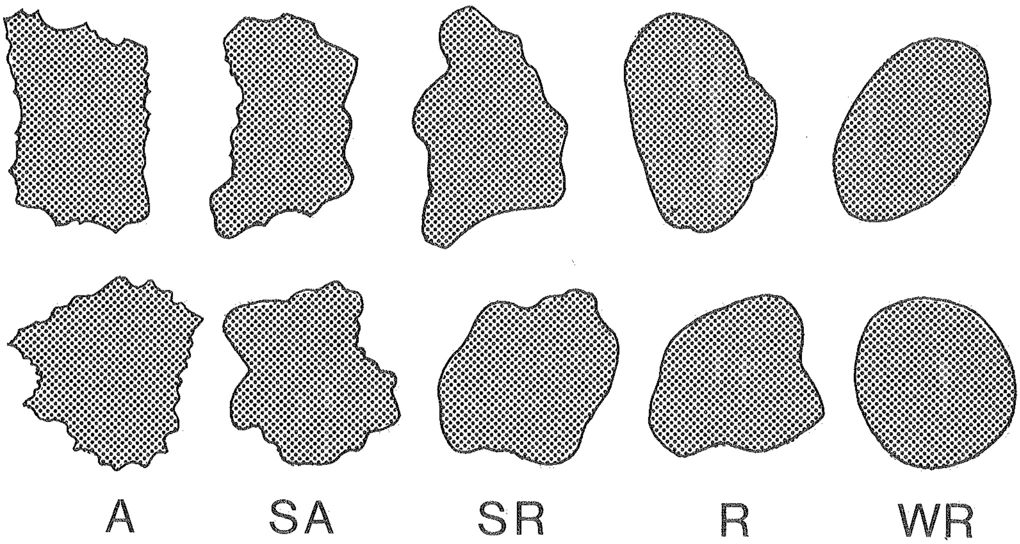


Fig. 5. Main roundness classes; A: angular; SA: sub-angular; SR: sub-rounded; R: rounded; WR: well rounded; based on Müller 1964, Abb 36.

5.2. Matrix

Matrix is the fine-grained ground-mass in which the coarser particles in a heterogeneous mass are embedded. In pottery the matrix mainly consists of clay-minerals which, to a greater or lesser extent, are fused. Description of the matrix using macroscopic techniques is virtually impossible. One can only define some gross characteristics like overall fineness or compactness, or the spatial variability thereof which may show as zonation in colour, grain-size etc.

5.3. Non-material framework elements: pores

Pores are parts of a solid body which are not occupied by solid material. In pottery they are just as significant framework components as grains, and they should therefore also be described. The principles of pore description do not differ significantly from those of grain description. The only pores which may be described macroscopically may be called macro-pores (characterized by diameters of at least 100 micro-metres), the smaller ones being micro-pores. Similarly, the average pore-size and pore-size distribution may be estimated using the standards described in section 5.1.1, whereas pore-shape may be defined using the procedures outlined in sections 5.1.2. and 5.1.3.

It may be worthwhile distinguishing between primary and secondary pores. Primary pores are the open spaces which remained after the final handling of the clay-body by the potter. They are commonly vacuoles filled with air or water and may in part have been closed during the firing of the object. Secondary pores are voids which originate during firing or use as a result of the expulsion of solid matter: e.g. through the burning of solid organic elements (e.g. straw) or the partial decomposition of specific mineral grains (e.g. break-down of carbonate grains due to expulsion of carbon-dioxide during heating, or the gradual leaching of salt crystals during use). The size and shape of secondary pores may provide important information as to their origin. For instance, burned-out grass will leave thin, flat, elongated pores with prints of the plant fibres on the walls, but a leached-out salt crystal may leave an equant, angular pore with flat faces, more or less like a cube.

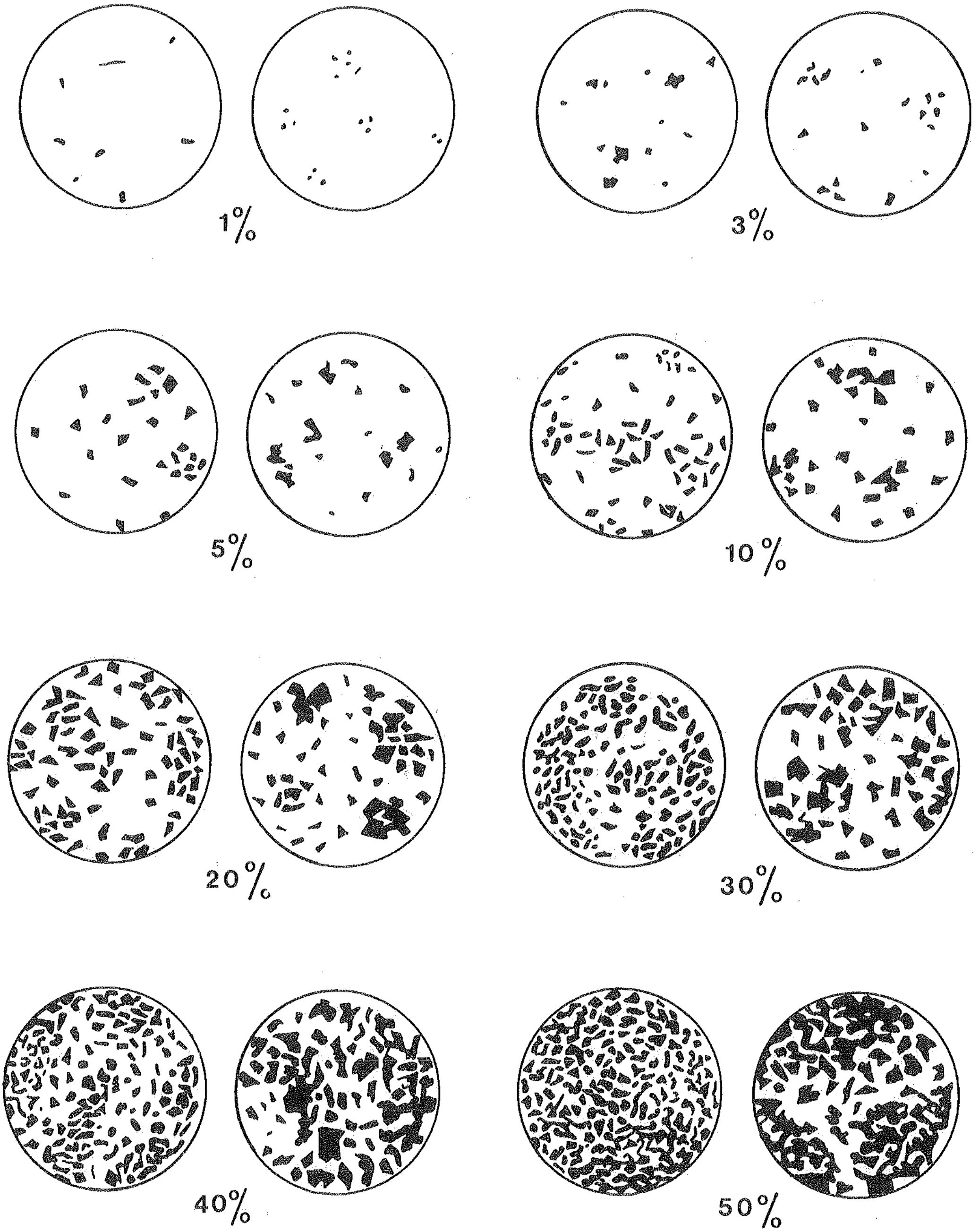


Fig. 6. Diagram to estimate amount of texture elements as percentage of total area (black areas: components to be quantified; redrawn from Müller 1964, Abb. 49.

6. Quantification of texture elements

The quantity of textural elements per unit of volume is usually estimated from the amount of those textural elements per unit of area as seen on freshly broken cross sections. This quantity may be estimated using a diagram as shown in Fig. 6.

7. Description of fabric

Fabric is the spatial arrangement of, and relationship between the components. The degree of regularity of distribution of components (as seen in the cross-section) determines whether a homogeneous or (alternatively) a heterogeneous fabric exists. It is not possible to define the full range of possible heterogeneous patterns which may occur.

Zoned fabric (Fig. 7a): the most common heterogeneous fabric is the zoned fabric. Here the heterogeneous areas are arranged as zones parallel to each other and to the surface of the object. Zoned fabric occurs frequently in pottery. The type of zonation may be described by defining the discriminative characteristics of each of the identified zones and the thickness of the zones.

Lineated fabric (Fig. 7b): very thin zones may show up as thin seams or lines instead of as actual zones.

Spotty fabric (Fig. 7c): when the zones are discontinuous and short relative to their width.

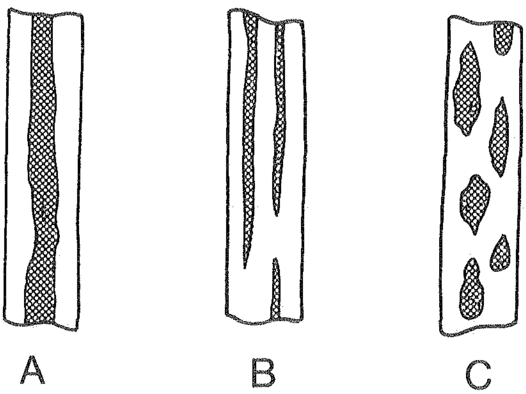


Fig. 7.
Schematic cross-sections showing zoned fabric (A), lineated fabric (B), and spotty fabric (C).

8. Mineralogical identification

Reliable identification of the mineral components present in pottery requires a more than casual knowledge of mineralogical characteristics, and often necessitates the application of more sophisticated equipment than is available in the average archaeological laboratory. In principle, therefore, absolute mineralogical identification appertains to the field of multidisciplinary cooperation between geologists and archaeologists.

Nevertheless relative mineralogical identification of the larger macro-grains is possible with only limited expert knowledge and equipment and may be executed after some basic training. Relative description may be defined as establishing objectively the mineralogical characteristics of each of the different graintypes present in the pottery without attempting to name the mineral. Such description is carried out by qualifying and quantifying the features of each of the important grain-types, using a checklist of basic characteristics to be observed. Such characteristics are: colour, streak colour (that is: the colour of the powdered mineral as may be judged after streaking the mineral on a piece of white porcelain), lustre, cleavage (the internal breaking of mineral grains according to crystallographic plains), fracture (the external breach), hardness (based on the Mohs scale), and crystal habit. Occasionally some specific characteristics may be defined by applying simple chemical tests. In many cases it will not be possible to define all these characteristics on macro-grains in pottery. Even the largests grains may often be too small or to worn to facilitate exact description. The colour, lustre, and general grain-shape (which in part follows the original crystal habit) are then the dominant descriminative features. Relative mineralogical identification will provide insight into the presence and relative importance of (groups of) grains with similar characteristics. The absolute identification of the minerals of each of these groups may be

Table 2.
Basic characteristics of important (groups of) minerals.

mineral (group)		colour	streak colour	lustre	cleavage	fracture	hardness	crystal habit	special features
quartz		colourless to variable	white	vitreous to greasy	indistinct	conchoidal	7	prismatic	
feldspar group	alkali feldspars	colourless or white, pink or red	white	vitreous to pearly	good	conchoidal to uneven	6	prismatic tabular blocky	
	plagioclase group	colourless white, grey greenish	white	vitreous to pearly	good	conchoidal to uneven	6	prismatic tabular blocky	
carbonate group	calcite	white, pink red, violet	white	vitreous to dull	perfect	conchoidal to brittle	3	rhombohedral prismatic tabular	rhombohedral cleavage; reacts strongly with diluted HCl
	dolomite	white pink reddish	white	vitreous	perfect	conchoidal	3.5 4	rhombohedral with curved surfaces	rhombohedral cleavage; reacts slowly with diluted HCl
mica group		light and dark types	white	vitreous pearly submetallic	perfect	brittle sheet	2.5 3	tabular or sheets with hexagonal outline	perfect cleavage in sheets
pyroxene group		dark green, brownish green, black	greyish green	vitreous	good	conchoidal	5 6.5	often short columnar	
amphibole group		brownish or greenish black	greenish grey, grey-brown	vitreous	good, perfect	uneven	5 6	often long columnar	

carried out by a mineralogist, or by the archaeologist after further training in mineralogical identification.

Absolute mineralogical identification falls outside the scope of the present paper. Table 2, nevertheless, summarizes the basic characteristics of eight monomineral (groups) which normally constitute the bulk of the macro-grains in ancient pottery.

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EXPERIMENTS WITH STONE "POTTERY WHEEL" BEARINGS - NOTES ON THE USE OF ROTATION IN THE PRODUCTION OF ANCIENT POTTERY

Introduction

Potters have used rotation as a part of the pottery making process since very early times. Rotation, however, can be employed in different ways. In spite of the very necessary and useful attempts of some archaeologists in order to attain a standard terminology with respect to pottery manufacture techniques, in general there is no question of an unambigeous terminology in the archaeological descriptions of the various rotation techniques employed in antiquity. This applies also to the pottery descriptions as found in the archaeological literature with respect to Palestine. In this article an attempt is made to more specifically define a number of these ambiguous terms as used in the Palestinian archaeological literature. The immediate reason for this were two series of experiments with stone "pottery wheel" bearings, executed in order to establish the (im)possibilities for pottery manufacture of such an apparatus, of which some have been excavated in Palestine and elsewhere. The results of these experiments are described in this article. In an appendix a sequence of rotation techniques used by potters is given.

Terminology

A number of words need defining if we wish to discuss the forming of pots by rotation:

1. Throwing
2. Wheel-made
3. Hand-built
4. Hand-formed
5. Hand-made

6. Turning
7. Trimming
8. Scraping
9. Finishing
10. Smoothing

The definitions that are proposed are:

1. "Hand-building" or "hand-forming" is the building or forming of a pot by any means, but without the use of centrifugal force.
2. "Throwing" a pottery vessel is the forming of that vessel on a wheel which rotated at sufficient speed to allow the potter to employ centrifugal force as an active agent in the formation and shaping of the vessel (ie. approx. 50+ revolutions per minute).
3. "Trimming" is the process of paring clay from any part of a pottery vessel by the blade of a knife, or any other convenient tool whilst the pot is either stationary or being rotated. Centrifugal force is not necessary in this process.
4. It is proposed that the terms "wheel-made", "hand-made", "turning", all be used with extreme care. Terms such as "scraping", "finishing" and "smoothing" are considered to be quite acceptable as descriptive terms in this type of discussion.

First series of experiments

In the first series of experiments we set out to see whether it was possible to form a small pot from a cone of clay attached to the upper half of the wheel bearing while it was rotated rapidly (Fig. 1). For this experiment, a wooden wheel-head approximately 30 centimeters in diameter was attached to the upper bearing with the aid of a large cake of clay.

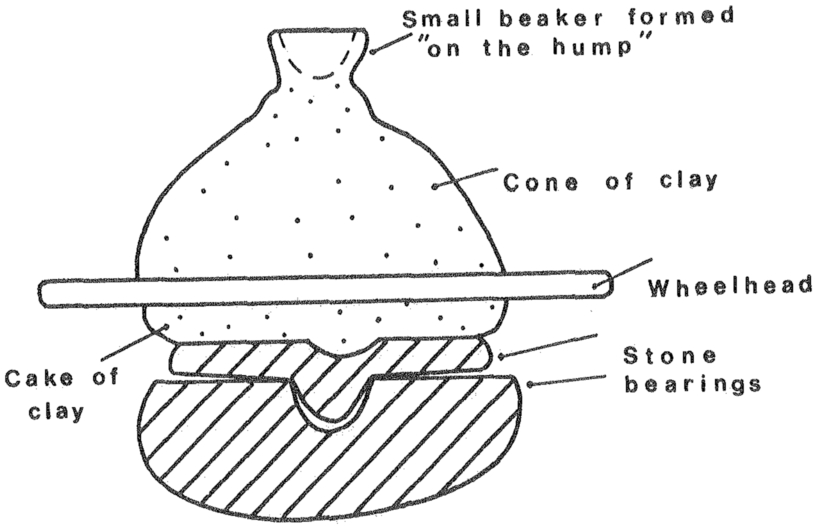

Fig. 1. Experiments with stone "pottery wheel" bearings.

A seven kilogram cone of clay was attached to the wheel-head in a central position. The wheel-head was then spun by hand. The wheel did not rotate freely. On inspection, it was noticed that some water had got between the two bearings. The bearing surfaces were dried and graphite from a soft pencil was rubbed on the bearing surfaces. This permitted the wheel to revolve more readily. However, we could not get the wheel to rotate more than one and a half revolutions. A little machine oil was introduced between the bearings but only a marginal difference was noticed.

If the definition of "throwing" is the use of centrifugal force in the forming and shaping of the vessel being "thrown" then clearly no pottery vessel could be "thrown" using a wheel which relied only on this type of bearing.

A second experiment was carried out in which one person continuously rotated the pottery wheel with two hands at a slow steady speed (approximately 15-20 revolutions per minute) while the second person attempted to form a small beaker from the clay at the apex of the cone. The friction that was developed by this pot-forming process made the continuous turning of the wheel difficult, however a small beaker was formed.

The experiments showed that:

1. It is impractical to "throw" using this type of apparatus as the friction developed at the bearing surfaces prevents continuous, rapid rotation of sufficient speed to develop centrifugal force which the potter can use. (i.e. approx. 50+ r.p.m.).
2. It shows that this type of apparatus would have been quite practical for the forming and smoothing of necks and rims on hand-built pottery vessels such as those from Iktanu and Jericho in the E.B./M.B. period and for forming small beakers similar to one found at Teleilat Ghassul with a string cut base.

<u>Second Series of experiments with the stone "pottery wheel" bearings</u>

We increased the size of the wheel-head to 40 cms in diameter. This did give the wheel-head slightly increased momentum and greater stability, as well as making it more convenient for the assistant to turn, however, adding a thick coil of clay (4 kgs) around the perimeter of the wheel-head did not appreciably increase the number of revolutions per "hand induced spin".

With the assistant rotating the wheel-head manually at approx. 15-20 r.p.m. " the potter" formed a depression in the cone of clay and then formed the equivalent of the neck of a pot. Although this was a little uneven, it was possible to trim and smooth it during rotation.

These experiments confirmed that it was possible to form small bowls and the rims of hand built pots by this method.

However some characteristics do mark this type of forming process:

a. Heavy finger rilling on the interior of the vessel is a feature of this type of pot forming on a slow wheel (tournette) with a tell-tale internal spiral torsion twist in the wall of the vessel.

b. When hand-built pots have been rotated on a slow wheel in order to form a rim or neck there is an obvious transition area from the finger marks made during hand-forming on the lower pot walls, to the rilling marks left by the fingers during rotation and the forming of the rim of the vessel.

These further experiments showed that:

1. A wider wheel-head did increase the momentum developed by the wheel but that this was still insufficient due to the friction of the stone bearings to allow centrifugal force to be developed. Hence pots could be formed by rotation but not "thrown" on this type of machanism.

2. The wheel-head could be "spun" for 1½ revolutions before it stopped under its own weight (this took 3 secs). The average turning speed possible by an assistant rotating the wheel during forming by the potter was in the order of 15-20 r.p.m..

Appendix

A rough sequence can be observed in the way potters used rotation, although in later periods some of the earlier and simpler techniques were used alongside other more sophisticated techniques.

A sequence of rotation techniques used by potters:

1. Pots built on mats (Chalcolithic Period, Teleilat Ghassul) or on pottery discs (Bronze Age, Cyprus). This technique allowed the pot to be turned slowly and

intermittently during the making process. Pots with mat impressions on their bases are usually light in weight, even in wall thickness and very symmetrical (Proto-tournette).

2. Pots built using a small bowl-like pottery mould which allowed the pot to be slowly and intermittently rotated during the making process but at the same time supported the lower section of the pot, particularly at the junction of the base and the wall thus preventing slumping in this vital area, eg. E.B. Iktanu and Jericho (Proto-tournette).

3. Pots made by the coiling technique either on or off an intermittently rotated, slowly turned wheel (commonly termed a tournette), and then forming and finishing the necks of these pots by continuous, slow but steady rotation of the wheel-head. Presumably the wheel-head would have been rotated by an assistant sitting opposite to the potter during the operation but a modified, smoothing of the rim procedure can be roughly accomplished by the potter smoothing with one hand and rotating the wheel with the other.

4. Using the tournette or slowly turned wheel for a variety of tasks eg. smoothing and finishing, trimming or shaving excess clay from pots. It is proposed that the tournette referred to here would be similar to the paired stone axle bearings proposed for pottery wheels by Amiran. However, a fired clay disc of approximately 20 cms in diameter which was rotated on a peg located on a flat smooth surface would have been suitable (Fara).

5. Pots formed on a tournette or slow wheel, by slow (15-20 r.p.m.) but continuous rotation. An assistant almost certainly would have been needed. Pots formed in this manner usually show the strong clear marks of heavy finger pressure (rilling) on the interior of the base and the walls, and tend to show a spiral torsion twist

in the walls. This type of pot making on a tournette could be regarded as being in the proto-tournage stage because it is using the basic throwing techniques of the later fast wheel or tournage, on a slowly turned mass of clay. Experiments of this type, when combined with the achievement of faster wheel rotation, the development of momentum in the wheel-head and the decreasing of friction at the bearing surfaces together with the resulting development of centrifugal force, would have enabled potters to truly "throw" pots, i.e. use centrifugal force as the positive shaping force in pot making.

6. "Thrown" pottery is defined as ware formed on a fast wheel or "tournage" by a potter as he harnesses the developed centrifugal force in the shaping of his pottery forms.

M. Beatrice Annis
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ETHNOARCHAEOLOGICAL RESEARCH - POTTERY PRODUCTION IN ORISTANO (SARDINIA). RELATIONSHIPS BETWEEN RAW MATERIALS, MANUFACTURING TECHNIQUES AND ARTIFACTS

M. Beatrice Annis

Introduction

The traditional potters of Oristano in Sardinia (Fig. 1) distinguish three different clays which they blend. The basic clay is the clay "from the heart", i.e. from the centre of the sediment, which, when of good quality, can also be used alone. The clay called "wild" or "sweet" is fatter than the clay "from the heart" and lies above the latter in the sediment with the "sandy" clay lying below (Fig. 2). The quality of the basic clay determines how much "wild" or "sandy" clay must be added in order to obtain the most suitable blends for the different artifacts as a fatter blend is needed to throw, for instance, water jars than to make a basin. This implies that when the basic clay is not "good enough" to throw water jars - the product 'par excellence' of Oristano - the potters have to blend it with the "wild" clay which on the one hand makes the work on the wheel easier ("sweet"), but on the other may cause problems when it comes to drying and firing the vessels ("wild" means impossible to tame). These limitations imposed on the potters by the raw material have consequences as regards both the size and the shape of the pots. Moreover, when at the end of the 1940's the clay pits were exhausted and the potters had to move to another area where the suitable clay was scarce and of poor quality, they had to drastically reduce the capacity of the vessels. Now that the quarries are almost abandoned and the clay is usually supplied by firms digging wells for the building industry, the craftsmen often have difficulty procuring the raw material and no longer have

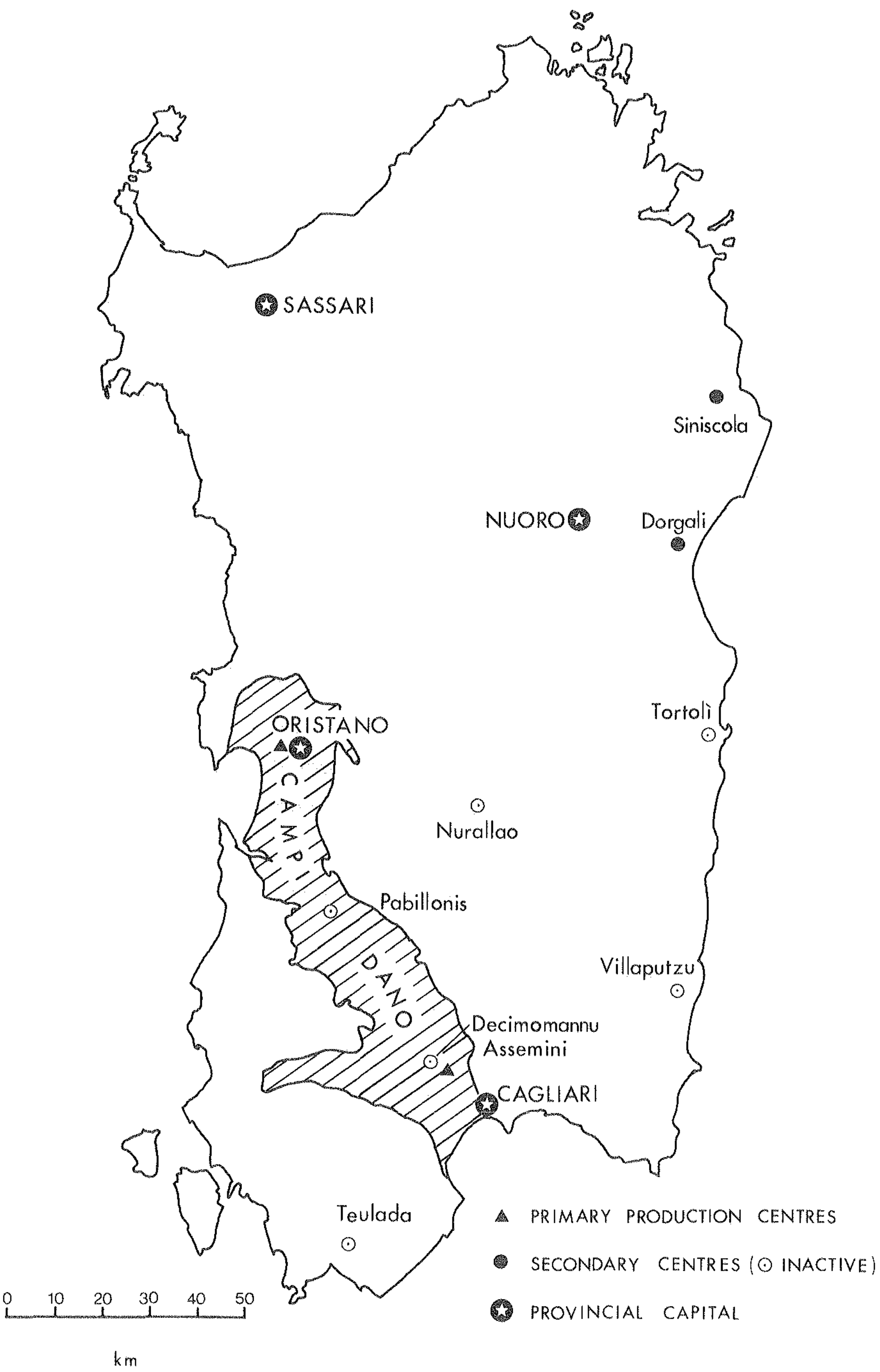


Fig. 1. Map of Sardinia.

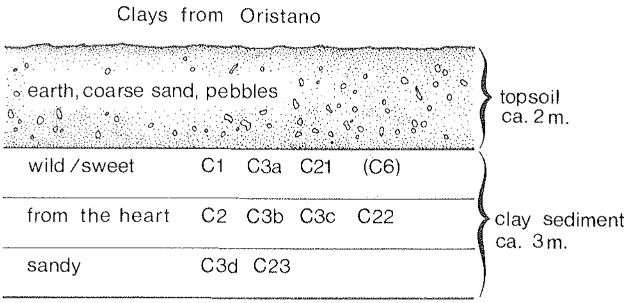


Fig. 2. Clay samples from Oristano.

sufficient control over the quality of the clay. Consequently, the production of large pots has become economically unattractive and is therefore gradually coming to an end (Annis 1984, 1985 a; 1985 b).

Having obtained this information, I wondered whether the properties of the Oristaneian clays as indicated by their names and as described by the potters could also be defined by means of laboratory analyses like those carried out at this Institute (Franken and Kalsbeek 1975; Jacobs 1983; Van As 1984; Van As and Jacobs 1985). I also wondered whether in the same way a relationship could be established between raw materials, manufacturing techniques and final product. For this purpose I collected some clay samples from different workshops dug both from the quarries and from wells.

The collected samples are:

C1, C3a, C21 — wild/sweet clays

C2, C3b, C3c, C22 — clays from the heart

C3d, C23 — sandy clays

C1, C2, C3a, C3b, C3c, C3d — dug from wells

C21, C22, C23 — dug from quarries

Other samples are:

C6: clay from the area to the north of the town where, according to the potters, only a very "wild" clay is availabe which is not at all suitable for pottery making.

C4: clay-body obtained by blending clays dug out of wells and ground mechanically by means of a grinding machine. This is a blend suitable for water jars.

C5: clay-body obtained by blending clays dug from the quarries and prepared by hand and foot. This is a blend suitable for basins.

C8a, C8b: Engobes from the village of Nurallao (about 50 km east of Oristano) used by Oristaneian potters under the lead glaze to prevent the green and brown pigments added to the glaze from becoming too dark through direct contact with the red clay. C8a is said to be less suitable for coating the Oristaneian clay-bodies than C8b.

L. Jacobs

Technological investigation into the clays from Oristano

The Atterberg test

The point at which a clay becomes workable is dependent on its capacity to absorb water. This can be determined by slowly adding water to a certain amount of dry clay powder and then measuring the weight of the minumum amount of water that has to be added to the clay powder to enable coils to be rolled from it. If less water is added, the clay will crumble. The weight of the minimum amount of water that causes the clay to become liquid when vibrated marks that clay's point of water saturation. Atterberg discovered that the greater the distance between the point at which a particular clay becomes workable and its point of saturation, the more plastic that clay will be. The test therefore in fact indicates the capacity to absorb water of the clays under review. Usually there is a positive correlation between the plasticity of the clay and the distance between the point at which it becomes workable and its point of water saturation. Although this connection does not exist for all clays, the values obtained in the Atterberg test do provide a possibility for expressing the plasticity of a clay in figures. The further apart these two points lie, the longer a clay can be worked on the wheel before becoming saturated. The values in the diagram are the grammes of water required for ten grammes of clay powder to reach the respective limits (1).

As regards the capacity to absorb water, C6 and C21 differ from the other clays in a positive sense, but they cannot be used by themselves on account of their shrinkage and poor behaviour in firing. C3a, C1 and C2 also have a slightly higher water absorbing capacity than the other clays (Fig. 3A). The Atterberg values provide information on the behaviour of the clay when worked on the wheel. Since clays with a high plasticity generally contain more water than less plastic clays, they also shrink more, which makes it interesting to compare the Atterberg values with the shrinkage behaviour of the investigated clays. It then appears that clays C1, C2, C3a, C6 and C21 have both favourable and unfavourable properties (Figs. 3A; 4). This is why the Oristaneian potters blended their different clays to take advantage of their favourable properties and to more or less reduce the unfavourable shrinkage and poor firing behaviour. The composition of the clay blends used by these potters is therefore partly determined by a compromise between the behaviour of the clay when worked on the wheel and its behaviour when fired.

<u>pH test</u>

The acidity of a clay is determined by the soluble substances present in that clay. A high concentration of sub-

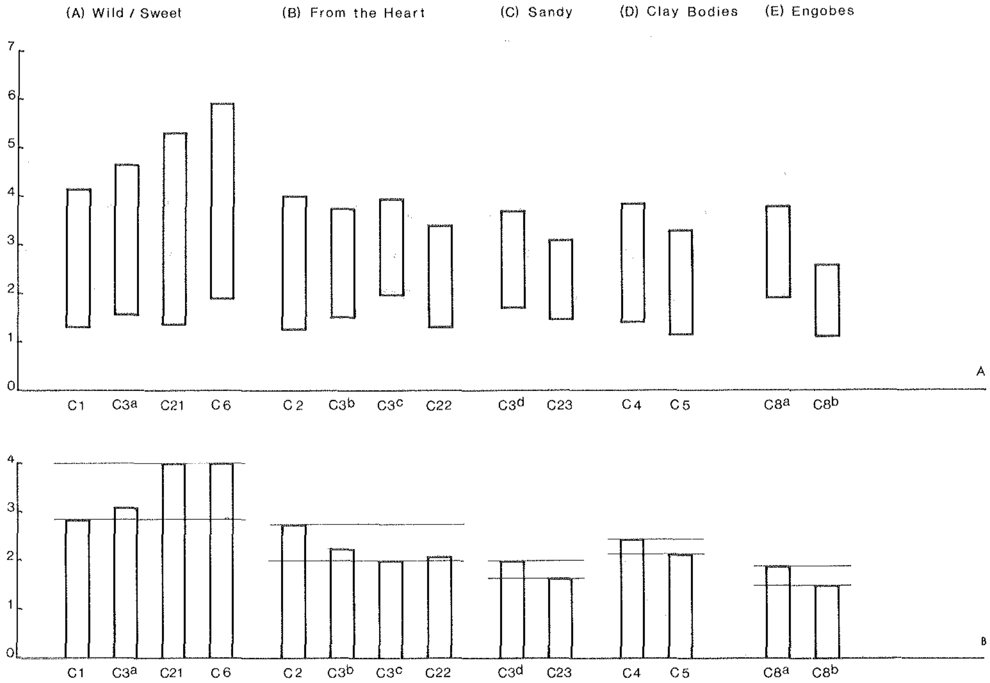


Fig. 3. A: Atterberg test values.
B: Relative duration of the workability of the clays and the formation of groups.

stances that lower the melting point may make the clays less acid, since these substances are alkaline. Such substances are, for instance, Na_2O, K_2O, Li_2O, but also CaO, which may occur in the clays in a more or less soluble form, for example as carbonates. The acidity of clay C4 can be explained in this respect. The acidity was determined according to the following scale: 6.0, 6.4, 6.8, 7.0, 7.2, 7.6, 8.0, in which 7.0 is neutral and 6.0 and 8.0 are acidic and alkaline, respectively. In extreme cases the acidity has a great influence on the clay's capacity to absorb water. Clays with a very high concentration of alkaline substances can absorb much less water. In other words, they become liquid sooner. A clay that contains a considerable amount of calcium can absorb less water and is therefore less plastic. However, a comparison between the acidity and the Atterberg values shows that the Oristaneian clays do not contain sufficient alkaline substances to permit such conclusions (Table I p. 69). All of the clays of Oristano tend to sinter rapidly around 950 °C, as appears both from the shrinkage graph and the porosity figures (Figs. 4; 5). On the other hand, the sherd retains its shape

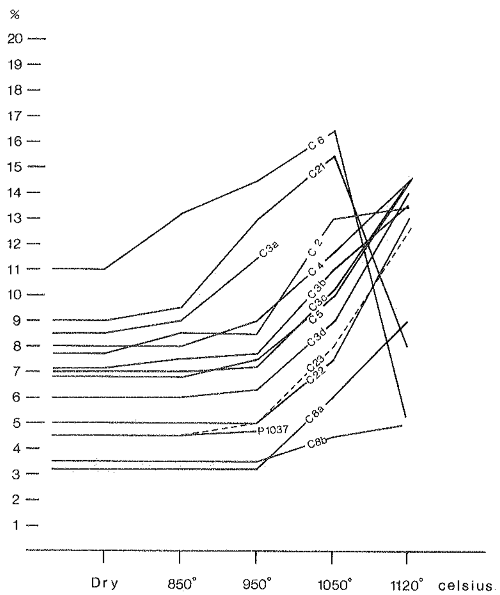


Fig. 4. Shrinkage percentages.

up to 1120 °C, which would imply that the clays do not contain many alkaline substances.

An interesting aspect is that the "wild" clays C6 and C21 as well as, to a lesser extent, C3a bloat at approximately 1100 °C. This means that these clays contain a substance that becomes partly volatile on firing between 1050 °C and 1120 °C in an oxidizing atmosphere. The following mineral substances are to be considered here:

$SrCO_3$ strontium carbonate (1075 °C)

$MgSO_4$ magnesium sulphate (1127 °C)

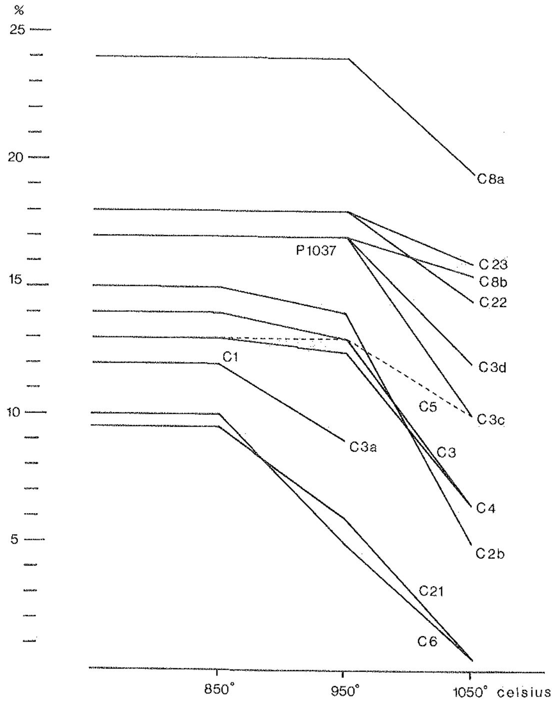


Fig. 5. Apparent porosity percentages.

LiAlFPO4 amblygonite (1100 °C)

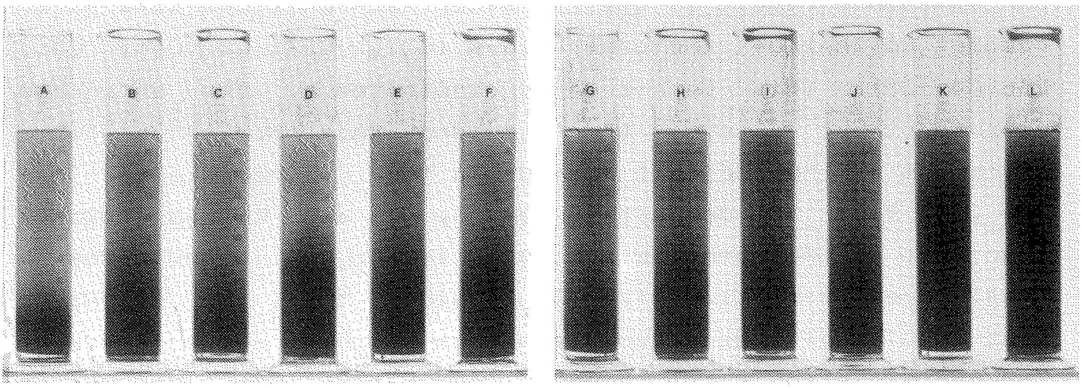
This prevents the clays in question from shrinking any further, but causes them to expand and lose weight instead.

The surface of the other clays becomes slightly glossy at 1100 °C, which is a result of continuous sintering. The same does not apply to C8a and C8b. These clays, which (particularly C8b) may be regarded as stoneware (2), also show a different shrinkage behaviour (Figs. 4; 11).

Sedimentation test

The purpose of the sedimentation test is to compare the sedimentation behaviour of different clays. The sedimentation behaviour of a particular clay may also be compared with that of a clay whose working properties are known (in this case P 1037). These are the favourable and less favourable qualities of a clay which become apparent when the mass is shaped into vessels by a potter. The sedimentation test may provide explanations for certain properties of the clays under review. On the whole, it takes longer for the fine, flat clay particles of which fat clays are composed to be deposited than the coarser particles constituting short clays. The rate of sedimentation is a fairly accurate means for determining such relations. In practice, however, comparing different clays as regards their rate of sedimentation is a somewhat more complicated matter because clays are often composed of differently sized particles including minerals that are the non-plastic components. On account of their shape, the latter tend to be deposited sooner than the clay particles. Plasticity depends on such factors as the size and the shape of the clay particles,as well as the concentration of true clay particles. In sedimentation the particles separate according to size and weight. The deposit formed by clay particles in a transparent cylinder gives a good impression of how the clay is composed. Although the exact ratios cannot be determined in this way, a direct relation can be established with the workability of a clay. It is very difficult to numerically compare the different clays with one another because the sedimentation behaviour of a clay is affected by at least five factors, of which the most important are the size, the shape and the weight of the clay particles. Apart from this, we are usually dealing with a blend in which different particles may occur and, finally, electrical properties may affect the sedimentation behaviour of the particles. It is therefore impossible to predict how the investigated clays will behave when worked on the wheel on the basis of the results of a sedimentation test. However, the sedimentation behaviour of a clay may serve to explain its workability especially when the results of the sedimentation test are related to data regarding other properties like shrinkage, porosity, capacity to absorb water and acidity. For example, two of the clays that the Oristaneian potters call "wild" (C21 and C6) do not appear to be deposited much slower than the other clays. The high shrinkage of these clays (approximately 15 %), which undoubtedly explains why the Oristaneian potters hold these clays in little esteem, is in our opinion a result of their smaller mean particle size with respect to that of the other clays (C22, C23, C2, C3b, C3c, C3d,C4, C5). This is not only indicated by the shrinkage behaviour, but also by the Atterberg test results and the thickness of the deposit formed in the cylinders after one hour. In fact the deposit formed by C21 and C6 was thicker than that of the other clays of Oristano, which indicates a smaller mean particle size (3). Besides this, the Atterberg test results of these two clays are slightly above average. The sedimentation rate, however, shows that these clays are not deposited any slower than the other clays (i.e. after 14 and 18 minutes, respectively). C21 was even deposited first (Fig. 6). In our opinion these data show that the mean particle size of C21 and C6 is indeed smaller compared to that of the other Oristaneian clays, but that the shape of these particles is predominantly granular rather than flat. Even if they are small, particles of such shape do not result in a very plastic clay. A fair amount of water must therefore be added to these clays before they become workable, the result being that they are always on the verge of saturation when worked on the wheel. A clay that contains a large amount of water will lose the same amount of water during drying and firing and will consequently shrink considerably. Such properties do not make these clays very suitable to be used as a raw material for a shaping technique requiring the continuous addition of water (throwing on the wheel). In practice this means that these clays soon become sticky, that a product shaped from them will easily collapse under its own weight, that the wall of the vessel tends to tear when pulled and that

Sedimentation
after
14 minutes:



Sedimentation
after
18 minutes:

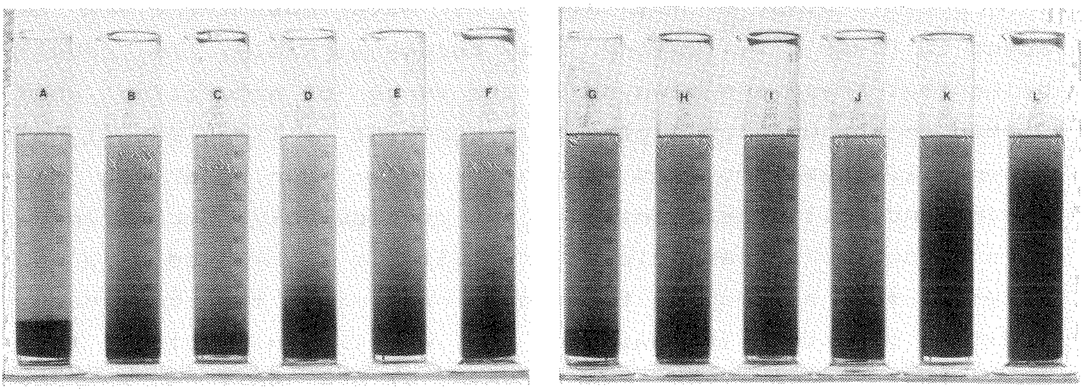
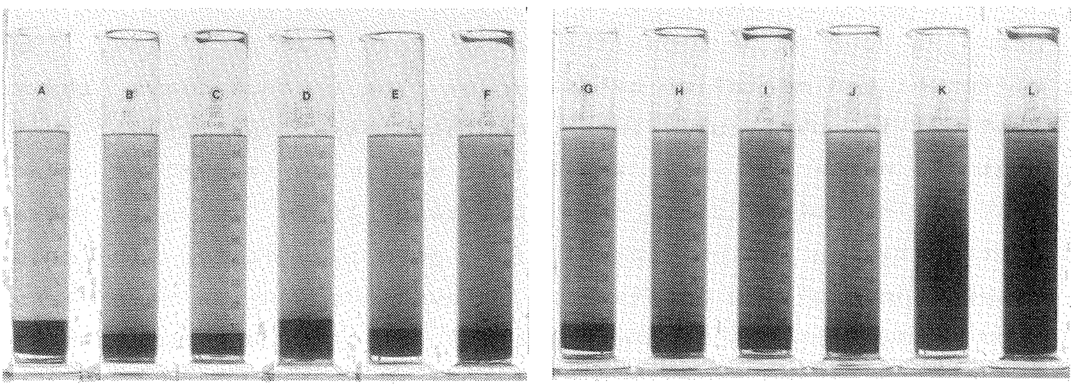
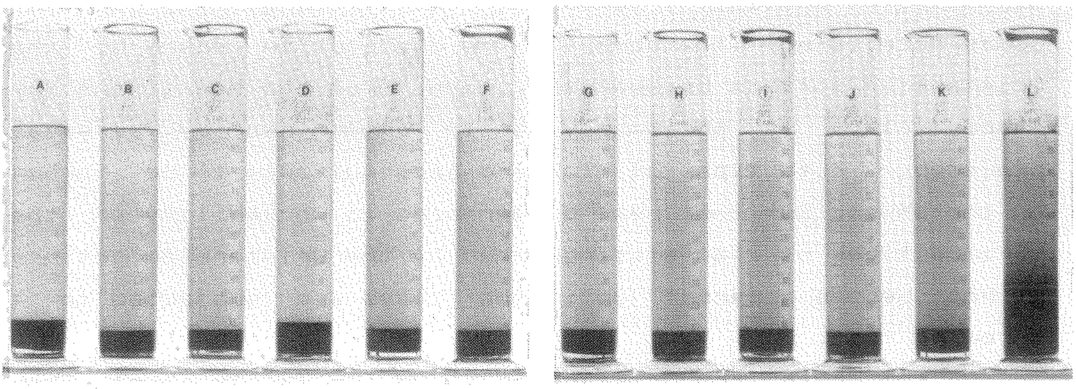


Fig. 6. Sedimentation test: A=C21; B=C22; C=C23; D=C6;
E=C2; F=C3b; G=C4; H=C3c;
I=C5; J=C3d; K=C8b; L=P1037.

Sedimentation
after
22 minutes:



Sedimentation
after
60 minutes:



any successfully finished products will almost definitely crack in drying. All this explains the combined occurrence of paradoxical properties like high shrinkage alongside relatively low plasticity and a high sedimentation rate. The connection between the last two properties is more obvious because granules tend to be deposited sooner than flat particles. The different sedimentation behaviour of the various clays shows that C21 in particular indeed contains small particles, but that the number of very small flat particles is smaller than that of the other clays from Oristano. It is in fact these flat particles which account for good plasticity. In this respect none of the Oristaneian clays under review have very good properties, as becomes apparent when they are compared to the sedimentation behaviour of P 1037 (Fig. 6). Clays C21 and C6 differ from the other clays in a negative sense. The differences between the various clays belonging to the other groups are much less. The classifications "from the heart" and "sandy" indicate differences on another level. The shrinkage behaviour of C22, for example, is quite similar to that of C23 and yet the Oristaneian potters call C23 sandy. The sedimentation test shows that C22 indeed contains particles that are deposited at a slightly lower rate than those of C23, but the difference is not that great. The distinction drawn by the Oristaneian potters between the clays "from the heart" and the "sandy" clays is presumably partly determined by personal preference. Both types of clay are less suitable to be thrown on the wheel. But the real differences in workability of the various types of clay distinguished by the Oristaneian potters do not become apparent until the clays are subjected to a throwing test.

On the whole, the Oristaneian clays are fairly short. They were all deposited almost completely within one hour. In general, a clay that is deposited within 2 hours is considered not suitable for throwing because it is not plastic enough. This indicates the absence of small or colloidal particles.

Table I

Atterberg test results and the acidity of clays from Oristano

clay	point at which it becomes workable	point of water saturation	acidity
C1	1.30	4.15	6.0
C2	1.25	4.00	6.0
C3a	1.55	4.65	7.6
C3b	1.50	3.75	6.0
C3c	1.95	3.95	6.8
C3d	1.70	3.70	8.0
C4	1.40	3.85	8.0 !
C5	1.15	3.30	8.0
C6	1.90	5.90	7.2
C8a	1.90	3.80	6.0
C8b	1.10	2.60	7.6
C21	1.35	5.30	7.6
C22	1.30	3.40	7.6
C23	1.45	3.10	7.2

Table II

Shrinkage of the clays from Oristano at 1120 °C

Clay	%	Clay	%
C1	–	C5	13.5
C2	13.5	C6	5 !
C3a	11 !	C8a	9
C3b	13.5	C8b	5
C3c	14.5	C21	8 !
C3d	14	C22	13
C4	14.5	C23	12.5

Table III

Apparent porosity percentages of the clays from Oristano

Clay	850 °C	950 °C	1050 °C
C1	12	-	-
C2	15	14	5
C3a	12	9	-
C3b	14	13	6.5
C3c	17	17	10
C3d	17	17	12
C4	13	12.5	6.5
C5	13	13	10
C6	10	5	0.5
C8a	24	24	19.5
C8b	17	17	15.5
C21	9.5	6	0.5
C22	18	18	14.5
C23	18	18	16
P1037	-	16.5	-

The Oristaneian clays are fairly sandy clays, largely composed of non-plastic minerals, which explains why they can not be easily shaped on the wheel and accounts for their low water absorbing capacity. Because of these last properties these clays can or rather must be thrown rapidly, which will in some form be apparent in the final product.

Oristano throwing test

The aim of this test was to obtain an impression of the properties of a clay-body when worked on the wheel. The sample used was a clay-body for throwing water jars prepared by one of the Oristaneian potters. As to the shape and the dimensions of the vessels, it is to be noted that the tested clay-body - providing it is thrown in a particular way and by a skilled potter - does not impose very severe limitations. The clay is short, that is, it does not stretch very much and soon becomes saturated with water. However, another characteristic of short clays is that they are readily shaped, which means that they can, and in this case must, be thrown rapidly. What's more, the excellent lubricant effect of the tested clay-body prevented the clay from becoming saturated too soon, thus losing its cohesion and tearing. If the clay is therefore thrown as required, it can be said to have reasonable working properties.

This clay must be thrown as rapidly as possible. Therefore the pot is given its required total height at an early stage. While being thrown, the clay must be pressed between the finger tips or the knuckles to increase the height and the width of the vessel. The clay is therefore pushed up rather than pulled. If the clay is pulled, in which case, in the cylinder phase, the hand inside the pot has to be placed higher than that outside, there is a great risk of the clay tearing as a result of a sudden upward movement.

The belly of the vessel may not be too wide, but must remain rather restricted. The belly is shaped in one or at most two movements, which, particularly if done quickly, will result in an increase in the width and the height of the pot. At the end of this phase a kind of biconical grenade-shaped vessel is obtained, with more or less the required total height (Fig. 7a; 8a,b).

If the neck is pulled up any further, the clay will tear. Therefore, the normal procedure cannot be followed to obtain a shoulder and a narrow neck.

By placing both hands round the rim of the vessel, the opening is narrowed until the hand no longer fits through. A few fingers are then placed in the opening as a form of support and the wall is pressed down with the help of the rib to produce a shoulder and neck (Fig. 7b; 8c,d).

Although the rims of pots shaped from the clays under review do not tend to warp during the narrowing of the open-

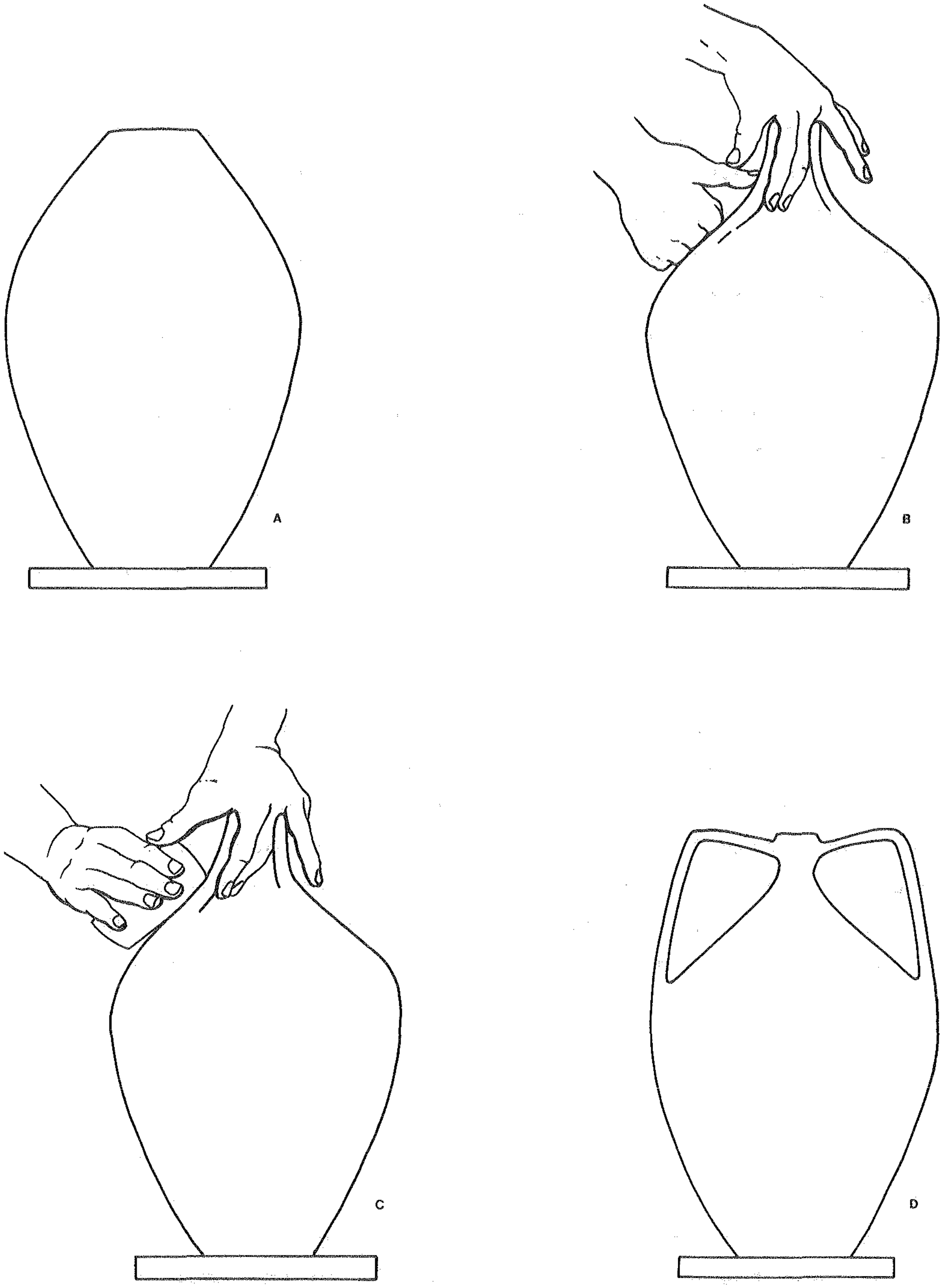


Fig. 7. Reconstruction of the throwing technique of a water jar from Oristano (a,b,c,d).

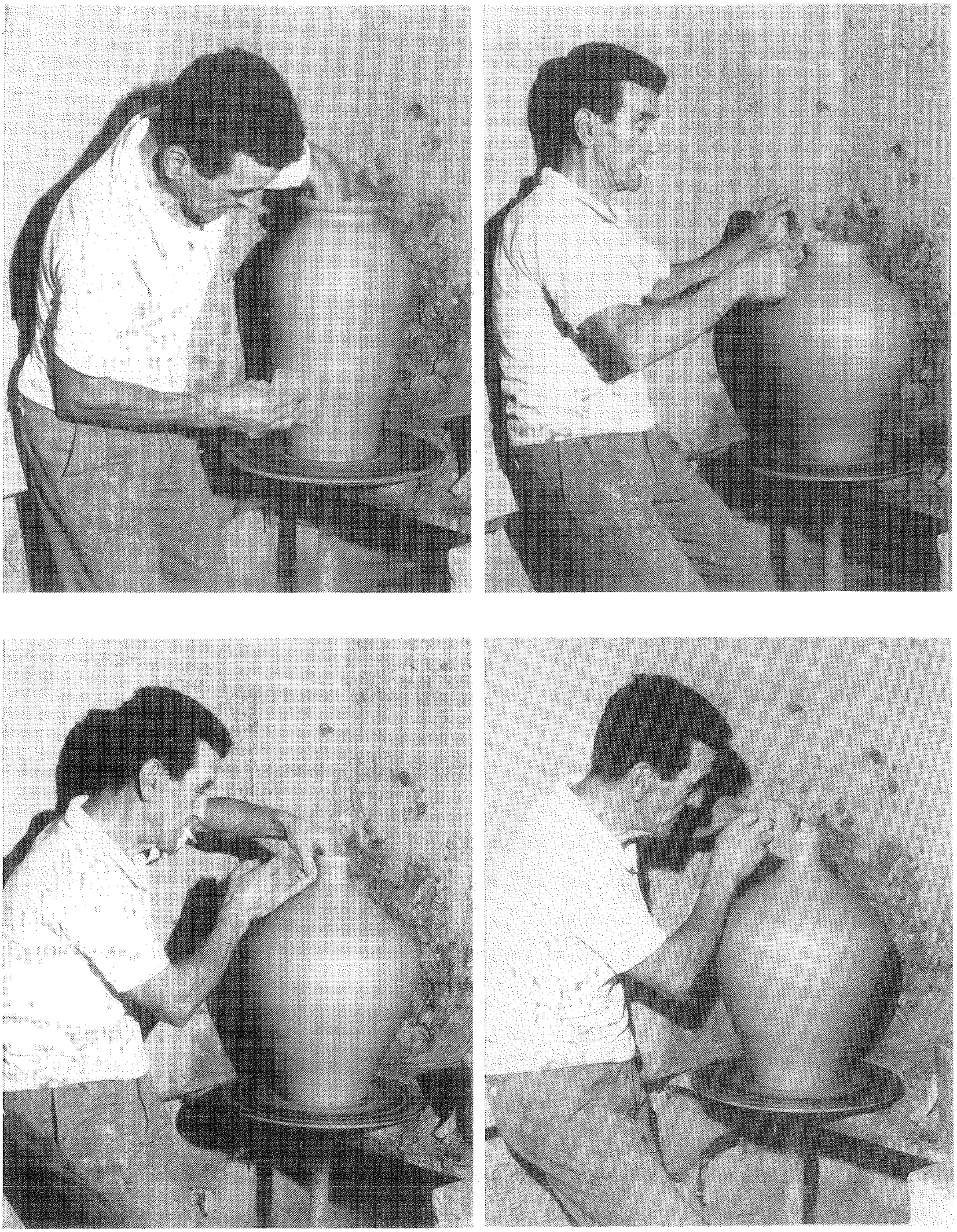


Fig. 8. Oristaneian potter throwing a water jar (a,b,c,d).

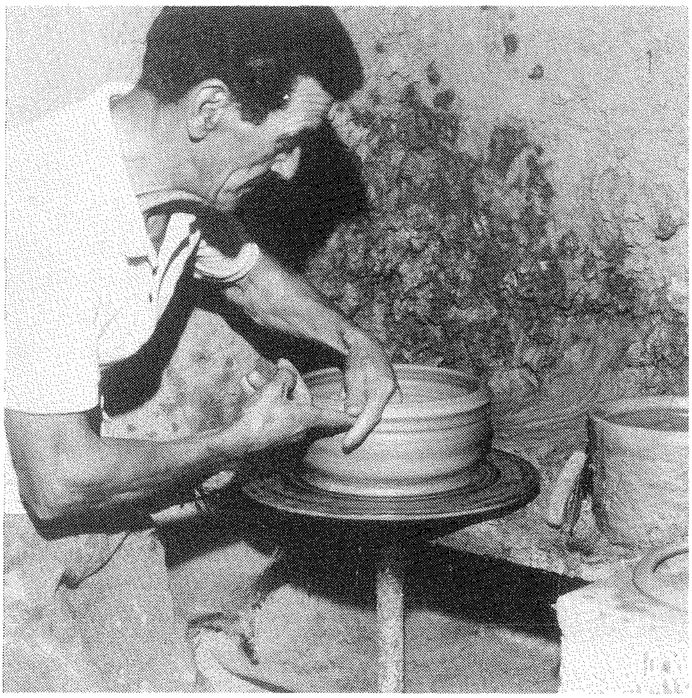


Fig. 9. Oristaneian potter throwing the handles.

ing, this will be prevented, where necessary, by the fingers placed inside the rim.

The advantage of this technique is that the clay does not have to be stretched again for the modelling of the neck. Finally, the rim is shaped.

The handles are thrown because the clay is too short for them to be pulled (Fig. 9).

The size and the shape of the handles is not only determined by the size and the function of the pot, the potter's artisanal sense and tradition, but also by the way in which they are made. The length of a handle is half or a quarter of the circumference of the cylinder that is thrown specially for that purpose. Technically, the length of the handles therefore poses no problems; in fact, the handles of the Oristaneian pots tend to be too long rather than too short (Fig. 7d).

There are "individual" differences in the way in which the handles are attached to the pots and these must be taken into consideration when classifying the vessels (Fig. 10). The same

Fig. 10. Oristaneian potter attaching the handles.

applies to the shape of the curve marking the transition from neck to shoulder, since this is determined by the shape of the rib used.

In the different stages of throwing the clay reacts as follows:

kneading : the clay tends to stick to the surface it is kneaded on (is not very coherent).

centering : excellently, that is, centering does not take long because the clay is easily mod-

		elled and has an excellent lubricant effect. This prevents it from becoming saturated too soon because the clay has a low water absorbing capacity.
opening	:	lumps of soft clay easily tear away from the body when the pot is opened on account of its lack of cohesion.
pulling	:	moderately to well. If gripped too tightly, the clay will react as above. cylinder - well shaping inwards - well belly - moderately to well, providing it is not too wide (otherwise it will tear and collapse)
manipulating	:	moderately to poorly. If the modelling takes too long (for example when shaping the neck), the clay will easily tear and collapse because of its lack of elasticity and cohesion.
scraping	:	if the finished pot is scraped when leather-hard, the grains contained in the clay cause ugly skratches and grooves in the surface. But no scraping takes place in the manufacturing technique of these vessels.

Oristano slip and glaze

A leather-hard water jar, thrown according to the method still practised in Oristano today, was coated with a slip made of C8b clay. Before being applied to the pot, the sample of C8b had to be diluted into a slip and sieved to remove excessively coarse grains of sand. Clay C8b shrinks much less than the clay used to throw the pot (Fig. 4). It is therefore not only practical, but also necessary to allow the finished vessel to dry to the air for some time before applying the slip coating. If the latter is applied at exactly the right moment, the subsequent shrinkage of the two clays will be almost equal (Fig. 4). Nevertheless, a thick coating of slip is to be avoided, since the slip does not adhere to the body very well. In this case the pressure on a thick layer of slip will exceed the tensile stress, which may cause the coat to chip, particularly around the rim. The Oristaneian potters therefore apply the slip coating in fairly liquid condition which results in a very thin film. This is done by dipping the rim and the neck into a slip bath.

As fas as shrinkage and expansion are concerned, the lead glaze used is quite suitable to be applied over the above type of clay and slip coating. In this combination, the adhesion between the body and the slip often poses problems. The shrinkage of the glaze used may therefore not differ much from that of the clay used for the pot. A property of lead glaze that is favourable in this respect is its relatively great elasticity. Wat's more, on account of its low viscosity, the liquid glaze partly penetrates the slip layer, providing the latter is very thin. This results in a better adhesion between the coating and the body of the pot. The most effective way of quickly applying a thin, even coating of slip is to dip the vessels into a bath, as is indeed done in Oristano today. The purpose of the film of slip is to ensure that the glaze remains bright green. If the transparent glaze is applied directly over the red iron-containing clay-body, the result is a brownish colour. The glaze is applied when the vessel is completely dry. A glaze applied at this stage may not shrink too much and this is why the type of glaze used in Oristano contains no clay. A binding agent consisting of flour is added to the glaze to ensure that it can be handled when dry. Usually, organic binding agents cause the glaze paste to rot when stored for some time. The bacteria responsible for such rotting processes are presumably unable to develop in this lead glaze prepared with flour, since no rotting processes were observed in the paste after a given period of time. Since the glaze lacks clay, it contains almost no aluminium oxide, which is why it melts into a smooth coating at low temperatures. A disadvantage of the lack of aluminium oxide is that the glaze is less durable. In addition to this, the melt is less viscous, which may cause the glaze to drip at high temperatures or if it is applied too thickly. Because of this, there are limits to the melting range. In the case of vessels whose rims only are glazed, this is no disadvantage. The experimental vessels were fired at 800 °C to 850 °C in an oxidizing to neutral atmosphere.

According to the potters' information, engobe C8a is less suitable than C8b. This is not simply due to the different shrinkage of the clays, since this is almost the same in the temperature range concerned (Fig. 4). However, the Atterberg test results show that C8b reaches its point of water saturation much sooner than C8a (Fig. 3a). In fact, C8b has the lowest point of saturation of all the investigated clays, which makes clay C8b quite suitable to be used as engobe because less water has to be added to C8b than to C8a in order to turn the clay into a slip suitable for application as engobe. In other words, a slip of C8a with a consistency equal to that of C8b contains more water and will therefore shrink more when applied as engobe. The reason why engobe C8a is referred to as "less suitable" is probably that it tends to shrink too much. In contrast with C8a, clay C8b is clearly alkaline (see Table I, p. 69), which explains its low point of water saturation. Clay C8b contains traces of iron, whereas C8a remains pure white.

M. Beatrice Annis

Some comments on the results of the technological investigation and a conclusion

Atterberg test

The diagram of the Atterberg test (Fig. 3a) indicates:

1. at which point a clay becomes workable on addition of water;
2. at which higher point a clay becomes liquid, thus losing its workability.

The diagram I have drawn using the data collected by L. Jacobs indicates:
how long the individual clays remain workable on addition of water (Fig. 3b).
The diagram shows the formation of groups:
Group A = wild/sweet clays
Group B = clays from the heart
Group C = sandy clays
Group D = clay bodies
Group E = engobes
This formation of groups matches the Oristaneian potters' information regarding the working properties of the various types of clay. The wild/sweet clay cannot be used by itself on account of its high shrinkage. According to the potters, it is, however, required for obtaining a blend that can be easier thrown and pulled, which is of particular importance in manufacturing water jars. This appears to be correct because the clays of group A have a higher water absorbing capacity and can therefore be worked on the wheel longer before becoming saturated. In some cases the clays from the heart can be used by themselves. One of these cases may be that of our C2. It is also significant that the lowest level of water absorbing capacity within group A (wild/sweet) corresponds to the highest level of group B (from the heart), while the lowest

level of group B corresponds to the highest level of group C (sandy). Group D, the clay bodies, comes within the limits of group B and the blend for water jars (C4) shows slightly higher values than the blend for basins (C5).

Shrinkage (Fig. 11)

The clays of group A (wild/sweet) have a high percentage of drying shrinkage which increases in firing to 850 °C and becomes considerable from 850 °C to 950 °C, particularly in the case of C6, the clay from the beds lying to the north of the town (4).

The clays of groups B and D (from the heart; clay-bodies) hardly shrink at all from dry to 950 °C. Group C (sandy clays) appears to shrink even less than B and D, but apart from that the clays of this group behave like B and D. Group D remains entirely stable up to 850 °C and the same applies to C3c and C22 of group C. C22 of group C remains entirely stable up to 950 °C. From 850 °C to 950 °C the clays of group D appear to shrink more than the clays of groups B and C.

Group E (engobes) shows a very low shrinkage percentage and remains entirely stable up to 950 °C. Sample C8b does not shrink much above that temperature either.

These observations confirm the potters' information that the clays of group A as well as the clays from the area to the north of the town cannot be used by themselves on account of their high degree of shrinkage. Furthermore, the fact that the clay-bodies (group D) show a higher shrinkage percentage than the clays of groups B and C, may be due to the presence of the wild clay (group A) in the blend.

Porosity (Fig. 12)

The apparent porosity percentages of the clays in firing from 850 °C to 1050 °C, shown in the form of a diagram here, are relative:

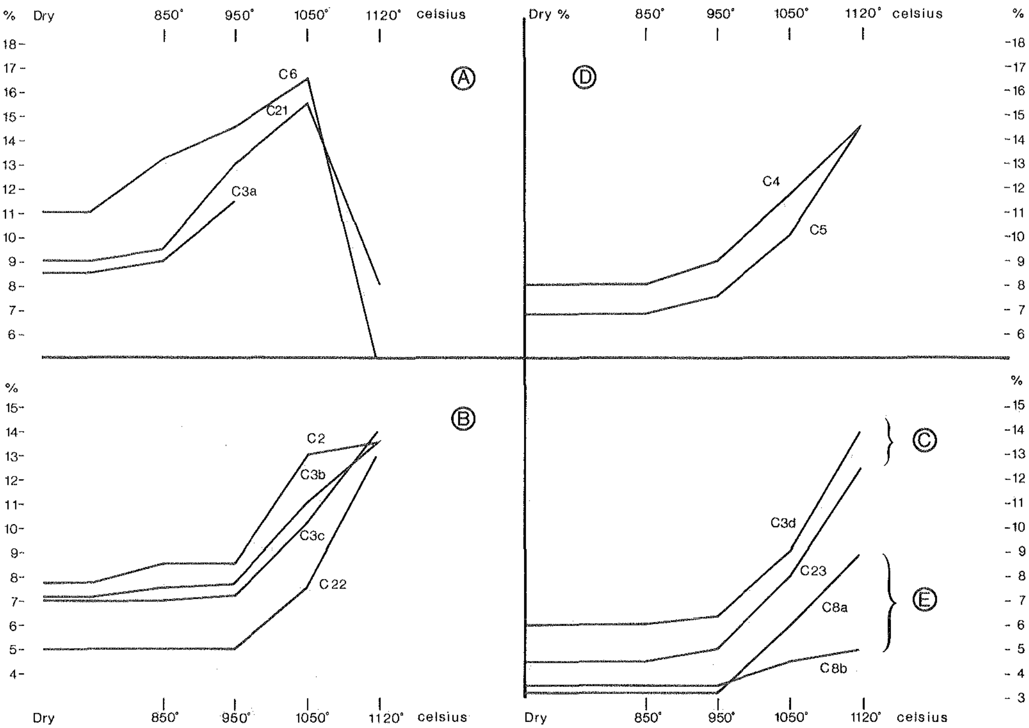


Fig. 11. Shrinkages of the different groups in drying and firing.

very high: 24 %

high : 17-18 %

average : 13-15 %

low : 12 %

very low: 9-12 %

The porosity values at 850 °C - indicated as (a) - and the behaviour of the clays from 850 °C to 950 °C - indicated as (b) - can be combined as follows:

Group A (wild/sweet) : (a) = low (C1; C3a)
very low (C21; C6)
(b) = considerable decrease

Group B (from the heart) : (a) = average C2; C3b
(b) = slight decrease
(a) = high C3c; C21
(b) = stable

Group C (sandy) : (a) = high
(b) = stable
Group D (clay-bodies) : (a) = average
(b) = stable (C5)
slight decrease (C4)
Group E (engobes) : (a) = high (C8b)
very high (C8a)
(b) = stable

According to the potters, one of the purposes for which the wild/sweet clay was used was to reduce the porosity of the clay from the heart and of the sandy clays. This was of particular importance with respect to water jars which are required to be permeable, though not to such an extent as to allow the water to leak through the wall of the vessel. The diagram appears to confirm this.

A comparison between the diagrams of the Atterberg test (Fig. 3b) and the apparent porosity percentage test (Fig. 12)

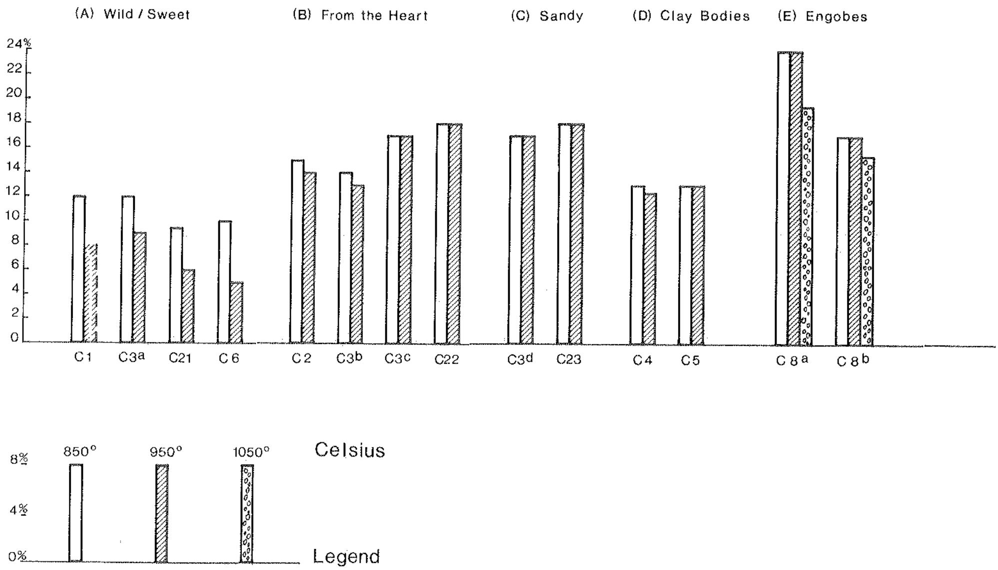


Fig. 12. Diagrams of apparent porosity percentages at different temperatures.

gives the following results:

Atterberg values (water absorbing capacity of the clay)		Porosity percentages (apparent porosity of the sherd)
very low	________________	very high
low	________________	high
average	________________	average
high	________________	low
very high	________________	very low

To sum up, as Loe Jacobs has above pointed out, the Oristaneian clay has a number of properties rendering it far from ideal to be thrown on the wheel. This inconvenience can be met to a certain extent by blending, but, as we have already seen, there are limits to this which become apparent during drying and firing. Therefore, within the Oristaneian pottery making tradition the main criteria for qualifying a craftsman as a "master potter" and for evaluating a potter's skill and productivity are both the ability to assess the quality of the raw material and to prepare the appropriate blends and the ability to throw a jar with a large capacity at a high speed.

The traces of this situation that are visible in the products are to be found in the absence of both particularly large vessels - a capacity of 18-20 l. is exceptional - and of pots with a truly globular belly. The water jar, for instance, has a biconical body with a gradual and restricted widening of the belly and a rather short neck which are counterbalanced by the wideness of the handles. The latter are thrown (Fig. 9) because they cannot be pulled (Annis 1985a; 1985b).

The causes of the above-mentioned traces, that is, the limitations imposed on the potter by the raw material, can be identified archaeologically by analyzing the throwing techniques which show how the craftsman adapted himself to those limitations. By means of archaeological methods it is also possible to determine, to some extent, the behaviour of a fabric under different firing conditions.

The analysis of the artifacts alone, however, will not be sufficient for establishing the inversely proportional relation between the workability on the wheel and the behaviour of the clay in firing, not to mention several other technical aspects described above which are also significant in the technology of this tradition. In fact, only through an appropriate analysis of both artifacts and raw material may the archaeological reconstruction of the technology approach reality.

Notes

1. In fact, the Atterberg test results do not indicate the plasticity of the clays, but the water content above and beneath which the clay is unsuitable to be thrown according to any method involving the plastic properties of the clay.

   Although the Atterberg test method contains a subjective element, it is frequently applied in comparative tests.
2. Stoneware is the name given to pottery which matures in the temperature range of about 1200 °- 1300 °C.
3. The particles are surrounded by an extremely thin film of water. The smaller the particles, the greater the amount of space occupied by this film of water and the thicker the deposit will therefore be.
4. According to the potters, the temperature in the traditional kilns range from 820 °C to 870 °C.

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