Dung-tempered Clay

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Cow manure was added to clay and fired in an electric kiln to examine its effect on the plasticity and firing ability of the clay. Two firing temperatures were tried. The experiment and the results are reported here. Dung was used, and continues to be used, as a tempering material and additive to increase plasticity in pottery around the world.

Introduction

The inclusion of dung in ancient pottery has been suggested by several authorities on the ceramics of the ancient Near East and elsewhere. F. R. Matson, in his study of the ceramics from Gözlü Kule, modern Tarsus, in Turkey, mentioned it as a possibility,[1] as has Halbaek in his work on the pottery from 'Amuq, Syria,[2] and Lachish, in Israel.[3] Kalsbeek has also commented on the possibility regarding pottery from Deir 'Alla, in Jordan.[4] Matson identified ". . . a small amount of fine organic material . . . " and, although it was too insignificant in quantity to have served as an effective tempering material, he assumed it would have been sufficient to have increased the clay's plasticity.[5] Its particularly fine nature led him to infer that it was not chaff taken directly from the threshing floor.[6] In certain Iron Age wares from Deir 'Alla, impressions and voids in the shape of seeds and grasses, prompted Kalsbeek to postulate that dung had been added to the clay.[7] In a later work, Matson also referred to the presence of voids shaped like seeds, indicating the use of dung.[8]

1. F. R. Matson, "Techniques of the Early Bronze Potters at Tarsus," Appendix in Hetty Goldman, *Excavations at Gözlü Kule, Tarsus* II (Princeton 1956) 35.

2. Cited by Matson, ibid. 35.

3. O. Tufnell et al., *Lachish IV: The Bronze Age* (London 1958) 137.

4. H. J. Franken and J. Kalsbeek, *Excavations at Tell Deir 'Alla I. A Stratigraphical and Analytical Study of the Early Iron Age Pottery* (Leiden 1969) 77.

5. Matson, op. cit. (in note 1) 35.

6. F. R. Matson, "Specialized Ceramic Studies and Radioactive-Carbon Techniques" in R. Braidwood and B. Howe, *Prehistoric Investigations in Iraqi Kurdistan* (Chicago 1960) 68.

7. Franken and Kalsbeek, op. cit. (in note 4) 77.

8. F. R. Matson, "Ceramic Studies," in *The Minnesota Messenia Expedition. Reconstructing a Bronze Age Regional Environment*, W. A. McDonald and G. R. Rapp Jr., eds. (Minneapolis 1972) 210.

To examine the feasibility of tempering clay with dung and to test its usefulness, a series of experiments was conducted at the Institute of Palestinian Archaeology, Rijksuniversiteit, Leiden. Clay was mixed with cow manure and fired in a small electric kiln. By controlling the amount of manure in each sample, we were able to study its effect on the workability of the clay. Learning to recognize its presence and to assess the possibility of determining the original proportion were also studied. It is usually assumed that the presence of a gray core area indicates incomplete carbon burn-out, but we felt that this might also be a factor of the duration of firing, the temperature, or the presence and quantity of carbonaceous matter in the clay.

Raw Materials

A red-firing, factory-mixed clay of European blend, tempered with quartz dust and very fine lime, fairly dense and suitable for throwing, was selected. It was mixed with cattle dung prepared by drying, pounding with a wooden mallet, trampling with wooden shoes, and then being seived through a strainer with holes 2 mm. square. Pieces as long as one cm. were able to slip through, although these were probably infrequent. A little water was sprayed on the fine, needle-like material to moisten it and increase adhesion between tempering material and clay. Moist particles of all types are more easily added to wet clay.

Procedure

Six pieces of clay each weighing 100 grams were prepared. One was set aside as a control sample to be fired without dung. Five graduated quantities of moistened dung, 2–40 grams, were added to the others and each was individually kneaded by Jan Kalsbeek. The dung was mixed thoroughly and evenly throughout the clay. The numerical ordering of the samples did not coincide with the increasing amounts of dung. This procedure was followed to prevent the imposition of our own bias.

Each sample was then roughly divided in half and shaped into two sets: one of thick rolls (2 cm. × 2 cm. × 5 cm.) and the other into thin, coin-like forms (5–8 mm. thick and 4 cm. in diameter). They were left to dry in Kalsbeek's studio on a painted hard-board, non-porous surface. Weights were measured four times: before and after the manure was added; after the 100°C pre-fire drying in the kiln, which lasted 30 minutes; and after firing (TABLE 1). The purpose of the pre-fire drying was to eliminate the non-chemically bound water. Clay is never drier than the air around it from which it readily reabsorbs moisture—even after a pre-fire kiln drying.

These experiments were conducted during the damp, cool months of August and September, 1977. The firing was done immediately following the 100°C drying. Each sample was broken in half, and each half exposed to a different firing test, i.e., a thick and thin piece fired in two batches.

Firing

The samples were fired in the kiln under two firing conditions. For the first set, to simulate an open fire, i.e., not a built kiln, the temperature was quickly brought up to 700°C. The kiln was set on 100% and 700°C was achieved in approximately 40 minutes. The peak was maintained for 15 minutes. Cooling in the kiln lasted several hours.

For the second set, the thermostat was set to climb up to 900°C over a period of two hours and the peak was held for 15 minutes. Cooling lasted overnight.

Results

The two firings produced strikingly different results. All control samples fired completely orange, thus implying that the clay oxidizes quickly. There is no core, which we define as the inner portion of fired clay, the color of which differs from the outer surface. Dung-tempered clay, on the other hand, appeared as described below. The Munsell Soil Chart was used; where two color names are listed with one Munsell number, the first is my identification and the second, is the Munsell name.

700°C

Carbon burn-out here was minimal with a resultant thick, dark gray core. The size and coloring of the core in the thick and thin samples containing 5–40 grams of dung hardly varied. On the other hand, within the thick group, the visual difference between the sample containing 2 grams and that with 5 grams was enormous. In the former, the discolored core area was slightly smaller than in all the others, and its coloring, light brown (7.5 YR 6/4) with a few small, darker specks, was unique. The thin piece with 2% dung also fired differently than all others: it alone fired orange throughout, but this result may be by accident since it was 2 mm. thinner than the rest.

All samples with 5–40 grams, both thick and thin, fired at 700°C, had an orange (light red 2.5 YR 6/8) exterior under which is a thin, light tan (yellow 10 YR 7/6) layer enclosing a thick, very dark gray (10 YR 3/1) core. The thinner series did not fire faster nor was oxidation more complete than in the thicker series, although there was a tendency for the outer margin to grow in the thinner pieces. Thin samples with 20 and 40% (weightwise) dung are identical to their thicker counterparts.

900°C

In this set, oxidation was more complete. Surfaces fired orange (2.5 YR 6/8) as in the first group, but the interior

Table 1. Measurements of weight. Note that in samples 1, 2, 5, and 6 extra water was added to help mix the dung through the clay, resulting in an extra decrease in weight after kneading. The water caused the clay to stick to the kneader's hands. Much was lost, especially in sample 4, because of the difficulty in adding a negligible 2 grams of dung. The control sample shows a 15% weight loss and by adding the dung, this figure rose to 26.5% in sample 6. To begin with, 140 grams of water was sprayed onto 300 grams of dry dung. 100 cc. dry manure = 45 grams (well packed in a glass flask); 100 cc. moistened manure = 70 grams (packing is easier with wet material).

Sample no.	*Dung gr.*	*Wt. after kneading*	*Wt. after prefire*	*Loss gr.*	*Wt. after firing*	*Loss gr.*	*Total loss*	*Total % loss*
3	0	100	91.0	9.0	85.0	6.0	15.0	15.0
4	2	100	80.5	19.5	74.2	6.3	25.8	25.8
2	5	105	86.9	18.1	79.8	7.1	25.2	24.0
1	10	110	94.3	15.7	85.9	8.4	24.1	21.9
5	20	120	101.0	19.0	91.7	9.3	28.3	23.5
6	40	135	112.4	22.6	99.1	13.3	35.9	26.6

Table 2. Firing pattern illustrating the colors and relative thickness of each zone and type of transition between them: sharp = xxxxxx; less clearly defined = oooooo. Colors are those of the *Munsell Soil Color Charts* (Baltimore 1954).

700°C	Thick samples		Thin samples	
	Dung: 5–40%	2%	5–40%	2%
outer margin	2.5 YR 6/8	2.5 YR 6/8	2.5 YR 6/8	2.5 YR 6/8
transition	xxxxxx		xxxxxx	
middle zone	10 YR 7/6	oooooo	10 YR 7/6	
transition	xxxxxx		xxxxxx	
central core	10 YR 3/1	7.5 YR 6/4	10 YR 3/1	

900°C	Thick samples		Thin samples	
	Dung: 5–40%	2%	5–40%	2%
outer margin	2.5 YR 6/8	2.5 YR 6/8	2.5 YR 6/8	2.5 YR 6/8
transition	xxxxxx			
middle zone	2.5 YR 6/4			
transition	oooooo	xxxxoo	oooooo	oooooo
central core	7.5 YR 7/4	7.5 YR 7/4	7.5 YR 7/4	7.5 YR 7/4

pattern differs radically. No gray cores were found, yet most samples showed two inner zones. In the thick series, the narrow, sharply differentiated outer margin covers a wider, light reddish brown (2.5 YR 6/4) layer which gradually fades into a wide tan core (pink 7.5 YR 7/4). The centers of the 5% and 10% samples consisted of tan and pink patches, unlike the clear zonal division in the 20% and 40% pieces. The thick 2% sample as well as all thinner samples had an outer orange margin and a thin tan core; the reddish brown layer is absent.

Analysis

Color and Zonal Division

Table 2 illustrates color variation and zonal divisions. The exterior surfaces at both temperatures measure the same on the Munsell chart, but the hue of the 900°C set is brighter. Also, the outer margin is twice the thickness of the 700°C set, suggesting that the degree of firing is more a factor of temperature than anything else at this low temperature. The thickness of the clay did not influence the coloring since in the 700°C firing, thick and thin samples turned out similarly and the same large gray core occupies most of the thickness whether a mere 5 grams or as much as 40 grams of dung were used. In the 900°C set, the disparity between the thick and thin pieces is much more pronounced with the thicker exhibiting a three-color interior whereas the thinner pieces have two only. Here thickness of the clay did play a role in the coloring (FIG. 1).

At 900°C, the thick series show a sharp edge separating the outer margin from the middle zone, yet the transition to the central core is gradual. In the thinner samples, the color transition is fluid. For the 700°C set, the three-tone color variation is prominent in samples with 5–40 grams of dung, but the transition from one color to the next is less explicit than at 900°C. The 2% sample especially exhibits a hazy demarcation.

The reason for the sharp delineation of color zones as opposed to a gradual transition between them has not been fully determined. Matson experimented on employing a

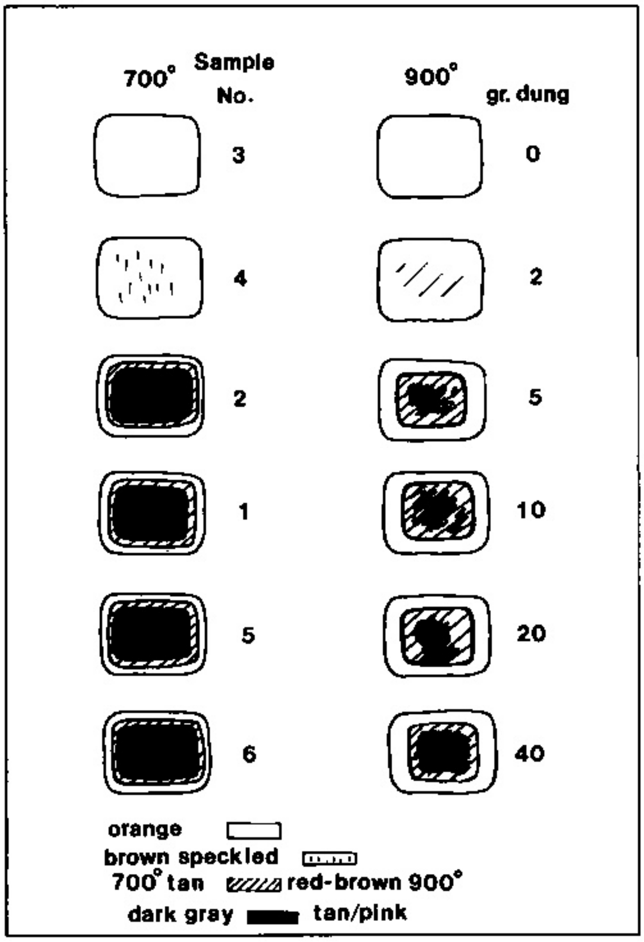

Figure 1. Thick samples drawn to scale showing the interior zoning and color arrangement.

fine- and then a coarse-grained tempering material in order to compare the effects of two sizes of inclusions on the firing. In the fine-grained samples, a sharper distinction between core and margin was produced.[9] Hodges states that ". rapid burn-out of short duration ." may result in sharp outlines,[10] but what precisely is meant by 'rapid' and 'short'? In our sample, the higher firing temperature resulted in sharper margins, but the situation may be more complicated than is suggested. The individual nature of clays for example, remains to be considered, a point that Shepard stresses throughout her writings.[11]

In a further series of experiments, we fired samples of the same clay now tempered with sand, river gravel, crushed pottery, and crushed sea shell at 50°C intervals between 700° and 1000°C. The only set to show a thick gray core was the 700°C set. Other samples in which a core was present have a relatively thin, brown or gray (750°C) core that gradually blends with the outer margin. No darkened core area exists in the 950° and 1000°C tests, although the presence or absence of cores in the 800° and 900°C sets depends on temper size and type. In all these tests, the kiln was set to climb slowly to the desired temperature over the course of several hours.

9. F. R. Matson, "Some Aspects of Ceramic Technology," *Science in Archaeology*, D. Brothwell and E. Higgs, eds. (London 1963) Pl. XXIV.

10. H. Hodges, *Artifacts* (London 1968) 197.

11. A. O. Shepard, *Ceramics for the Archaeologist. Carnegie Institution of Washington*. Pub. 609 (Washington 1954) 105, 222.

Texture and Voids

A fresh break across the width clearly illustrates the effect of temper quantity on the texture. The 2% samples are dense and compact. Those with 20 and 40 grams of dung show more voids than those with 5% and 10%, but the difference between these two groups is minimal. To the naked eye, the 40% sample is unique: it has a spongy or bone-like structure. This feature results from the large quantity of organic tempering present in proportion to the clay and was recognized by A. Glock who brought it to our attention. Our maximum of 40 grams of dung to 100 grams of clay represents a considerable ratio of dung to the more compact, wet clay. Kalsbeek felt that more dung could have been added without causing problems.

The use of carbonaceous matter was more easily recognized in clay of the 700°C set, which had a gray core, than in the 900°C set, which did not. In both sets, very fine holes are in abundance, although the 20% and 40% samples show elongated voids, which again lead one to infer the use of organic tempering materials. The dung voids are oriented lengthwise and parallel to the long side of the thick rolls. Some organic material was still visible. No seed-shaped voids were seen and it is unlikely that seeds would have fit through the sieve.

As for quantification of the voids, controlling the amount of dung used did not enable the application of terms commonly used to quantify inclusions, such as abundant, common, sparse, and rare. The sample with a mere 5 grams of dung appears completely overcrowded with voids.

Hardness

It was easier to break the samples in the 700°C set containing 5–40 grams dung, than those of the higher firing set. None was crumbly. Samples without dung and the 2% samples in the lower set are harder, suggesting that the hardness of pottery is in part influenced by the quantity of organic matter as well as the firing temperature.

The summary of our analysis is as follows.

1. Carbonaceous matter in clay inhibits oxidation and results in the presence of a darkened core area.

2. In the samples with over 5 grams of dung/100 grams of clay, the precise quantity of organic material exerted little influence on core color and size.

3. Core color varies with temperature more than with the amount of dung used.

4. Thick and thin samples in the 700°C test fired similarly, but not so in the 900°C test.

5. Plasticity is activated as Matson and more recently Picon[12] have stated. The effect was first felt once 10 grams of dung were used per 100 grams of clay.

6. A spongy, open texture was produced by using large amounts of dung (40 grams/100 grams clay) which then burned away.

7. Unintentional orientation of the dung occurred from rolling the samples briefly.

8. No bloom is present. The natural salts in the manure are not visible on the surface, but in none of our experiments with this clay did the white salt deposit appear.

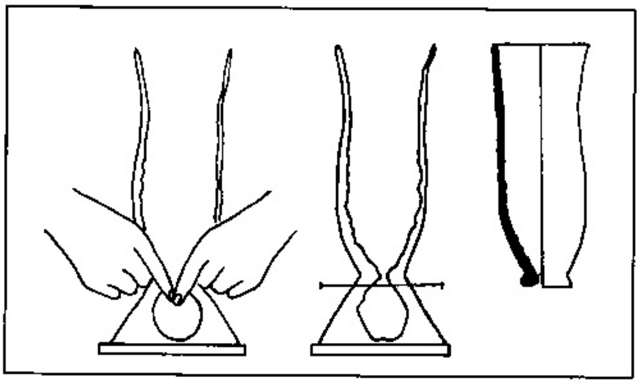

Figure 2. Pot shaped from a lump of clay and cut off too high with a string, thereby leaving a hole in the base. This problem was regularly solved by inserting a lump of clay heavily tempered with organic material. The plug fired a slightly different color than the pot. Drawing courtesy of the Department of Pottery Technology, Leiden.

Usefulness of Dung and Other Organic Matter As Tempering Material and To Increase Plasticity in Clay

One usually associates organic tempering material with poorly made and poorly fired ceramics alone. The usefulness and advantages of this temper are seldom considered. Its most obvious advantage is in manufacturing an "open-walled" (i.e., porous) pot, intended for storing water in a hot climate. Such a jar keeps its contents cool by allowing slow evaporation through its porous walls: the results of using a carbonaceous tempering material. Several authors list examples of these jars from Nubia, Greece,[13] and in Israel today, local potters fabricate the *'abrik* (a spouted, one handled jug) which is used by archaeologists during summer excavations to keep their drinking water cool. Such containers are far more effective than metal or plastic water bottles.

In working the clay, practical uses for organic material can be found in almost every stage of pottery fabrication, as follows.

Preparing the clay

Kelso and Thorley mention the use of animal refuse to sour clay, i.e., to hasten the break down of particle size which produces a better clay.[14] In dung, alone of all the organic tempering materials, the presence of gel-forming hydrated organic polymers increases the clay's plasticity (P. Leavens, personal communication). For this reason, manure would have been preferable at times.

Manufacture

Organic material can be added to clay used for accessory pieces and for any part of the vessel joined after the basic form has been completed. Clay with organic additives is used for accessories mainly to alleviate drying problems, as in the jars from Ed-Deir in Iraq, in the collection of the University of Leiden. With kind permission of H.J. Franken, an illustration of the manufacturing technique has been included here (FIG. 2). These slender pots were made right-side-up on some type of rotating work surface, from which they were then cut off. The tool occasionally cut too high and made a hole in the base, which was later 'plugged up' with a clay heavily tempered with large-sized organic material. Thus to solve the problem of the hole and to enable the plug—which was considerably thicker than the vessel wall—to dry and fire evenly with the rest of the pot, organic tempering material was introduced to 'open' the clay to enable easy evaporation.

Drying

Another use of organic material in clay is to alleviate the problems caused by differential drying rates throughout a vessel during the various stages of fabrication and especially at the stage of adding accessory parts. It has been mentioned

12. M. Picon, *Introduction á l'étude technique des céramiques sigillées de Lezoux, Centre de Recherches sur les Techniques Gréco-Romaines*, No. 2, (Dijon 1973).

13. F. C. Lister, *Ceramic Studies of the Historic Periods in Ancient Nubia*. *University of Utah, Department of Anthropology. Anthropological Papers* No. 86 (Salt Lake City 1967) 16, fig. 33a; S. Casson, "The Modern Pottery Trade in the Aegean," *Antiquity* 48 (1938) 471.

14. J. L. Kelso and J. P. Thorley, "The Potter's Technique at Tell Beit Mirsim, Particularly in Stratum A," in W. F. Albright, "The Excavation of Tell Beit Mirsim III. The Iron Age," *Annual of the American Schools of Oriental Research* XXI–XXII (1943) 93.

above that accessory pieces affixed to a pot that has been set aside to dry must be able to dry as quickly as the rest of the pot. Extra temper serves this purpose by 'opening' the clay to enable faster evaporation of water from the added pieces. If the latter dries too slowly, it will fall away from the body, a frequent problem with handles. Certain accessories, therefore, are tempered with an organic substance, although the rest of the pot is not. For this reason, mineralogical analysis of handles can be troublesome. Examples of the use of an organic material in handles (from Israel[15]), necks (from Nubia[16]), bases (from Iraq: the work of Franken and Kalsbeek mentioned above), and plastic decoration (from Israel[17]), are fairly common. Frequently handles have a darkened core area which is absent in the vessel body. This apparently is the result of the inclusion of organic material in the handle alone. It is not merely a factor of handle thickness in contrast to a thinner body wall. Confirmation of this comes from our thick and thin samples, which fired similarly irregardless of thickness.

Firing

Also in the firing stage, the openness of the wall aids the thicker pieces to fire. In addition, such ". pottery needs little special care in the firing, since the heat is equally distributed in the clay and firing can be short."[18] In most of our thick samples the surface alone has oxidized and the core is large. The surface, however, is sufficiently hard to be used and to resist weathering. Thus without complete oxidation, fuel is saved and the resultant porous ware is well suited for containing water.[19]

Decorating the surface

Another advantage is that a porous wall can absorb an added wet layer of clay in the form of a slip. Wares heavily tempered with mineral inclusions may not absorb a slip evenly all over the surface because the minerals are not porous. The inclusions will be visible on the surface in such cases, as in the so-called Late Bronze Age 'Midianite' ware from Saudi Arabia which is shale tempered.[20] Organic material, however, tends to open the surface and unless a slip layer is applied, the pot may appear coarse and rough, especially if the tempering material is large. There is perhaps a connection between the use of combustible tempering and the application of decorative slips and paint. At Jericho, the Neolithic pottery falls into five temper groups, of which the four with organic tempering are the most frequently painted.[21] Only Group I, without vegetal inclusions, is never painted and vessel form and function do not play a role. This circumstance does not imply that all pottery with organic tempering will be painted, but there may exist a connection.[22] The question remains whether the rough, open surface necessitated the decoration or the porous ware was especially selected or prepared for decorating in certain societies.

Summary

Several factors may have induced ancient potters to use dung as a tempering material in place both of other organic substances and mineral and rock particles. Dung is available year round, whereas other organic materials are frequently confined to certain seasons of the year. It is minimal in cost and preparation, and there are numerous other uses of dung. It can be used as heating fuel or as fuel for firing finished pots in an open fire. Tufnell mentions the use of camel dung for firing pots in southern Arabia; Reina records the similar employment of cow dung in Guatemala; and Miller cites its use for the same purpose among American Indians. Once the pots are fired, horse manure is used by the well-known San Ildefonso potters to make the fire smolder, thereby producing the famous black color.[23] The Papago Indians of southern Arizona are said to use horse manure to temper clay.[24] There are other uses for dung, including medicinal. In India it is mixed with clay and used to plaster walls.[25] Dung-tempered wares may be more common than we think. As a tempering material and as an activating agent to in-

15. A. Glock, "Homo Faber: The Pot and the Potter at Taanach," *BASOR* 219 (1975) 18; O. Tufnell, et al., *Lachish II: The Fosse Temple* (London 1940) 81.

16. Lister, op. cit. (in note 13) 39.

17. Tufnell, op. cit. (in note 15) 81.

18. Franken and Kalsbeek, op. cit. (in note 4) 77.

19. H. J. Franken, *In Search of the Jericho Potters, Ceramics from the Iron Age and from the Neolithicum*. North Holland Ceramic Studies in Archaeology. Vol. I (Amsterdam 1974) 65.

20. J. Kalsbeek and G. London, "A Late Second Millennium B. C. Potting Puzzle," *BASOR* 232 (1978) 52.

21. Franken, op. cit. (in note 19) 210 and chart I.

22. Similarly, Professor Weinberg kindly informs me that the ware on which paint and slip appear in the Early Neolithic pottery of Greece is a spongy fabric rather than the more compact wares. Again, the open-walled fabric received an extra coating. S. S. Weinberg, "The Stone Age in the Aegean," *CAH* Vol. I, Part I (1970) 584.

23. O. Tufnell, " 'These were the Potters .' Notes on the Craft in Southern Arabia," *The Annual of Leeds University Oriental Society*, J. MacDonald, ed., Vol. II (1959–61) 30; R. E. Reina, *The Law of the Saints: A Pokoman Pueblo and Its Community Culture* (Indianapolis and New York 1966) 54; M. Miller, *Indian Arts and Crafts* (Los Angeles 1972) 95 and 96.

24. B. L. Fontana, Wm. J. Robinson, Ch. W. Cormack and E. E. Leavitt, Jr., *Papago Indian Pottery* (Seattle 1962) 57.

25. C. H. Childers, "Banjaras," in *Pastoralists and Nomads in South Asia*, L. Leshnik and G. Sontheimer, eds. *(Weisbaden 1975)* 254.

crease plasticity, dung appears to have been used with full knowledge of its properties and was of some value to the potter's craft.

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