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Dedication

This book is dedicated to the late Martin Levey. Doctor Levey, a noted historian of science, was the organizer of two previous symposia on archaeological chemistry sponsored by the American Chemical Society. It was also he who initially suggested that the 1968 symposium, the one presented in this book, be held. Doctor Levey was an outstanding philologist, an historian, a mathematician, and a chemist. It was the combination of these diverse qualifications, unique perhaps in him, which accounts for his accomplishments in the history of science and medicine. Although his work met the most exacting standards of scholarship, there always lay behind it an unpretentious attitude and an insight into the ways of human beings—both those of the past and those of the present.

R.H.B.

Chapter 4

A Study of Temperatures Used in Firing Ancient Mesopotamian Pottery

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Introduction

Fragments of pottery and sometimes of figurines are found in abundance at most archaeological sites in the Near East occupied after about 6000 B.C. The variation in the color of such potsherds and figurines can indicate the range in temperatures to which they were fired, provided that one undertakes the color sortings with a background knowledge of the color changes that can take place when the local clays of the region are fired. (See Plate VI.) An adequate sample is needed, so such sortings should preferably be done at the excavation camp after the sherds have been washed and before any of the materials have been discarded. If this cannot be done, the nature of the samples studied must be well-considered when interpreting the results.

Data are presented in this paper showing the changes in some physical properties of a Tigris River clay as it was fired to successively higher temperatures. The color changes of this high lime clay serve as indicators for estimating the degree of firing of ceramic products in ancient Mesopotamia. Color sortings of sherds and figurines can then provide information on technological aspects of the culture producing the ware. Most of the laboratory work was completed some years ago, and the conclusions then reached but not published are modified here in the light of additional field work and visits with potters working today in Near Eastern villages. In a concluding section I should like to sketch broadly my present impression of the variation in firing temperatures used in pottery manufacture by the successive cultures in wide areas of the Near East where the clays are rich in lime. These interpretations will surely be modified or refined as additional ceramic materials become available at well-excavated, stratified sites.

Much of the data presented here has been available on microfilm for many years (Reference 6). I should now like to use it to provide information that may be of help to those concerned with the uses of pottery in the study of man's technological development.

In 1936–1937, I was privileged to be a member of the field party excavating at Seleucia-on-the-Tigris during the sixth and final season of the University of Michigan's work at that site. I am most grateful for the training and academic stimulation that I received from Professor Clark Hopkins, Director, and Dr. Robert H. McDowell, Field Director. Seleucia is now a complex of mounds twenty miles south of present-day Baghdad on the west bank of the Tigris River. It had been the capital city of the Seleucid Empire and a major city during Parthian times but sharply declined in importance when the Sassanians established their capital immediately across the river at Ctesiphon. The four major occupation levels at Seleucia represented a span of five centuries, from 295 B.C. to A.D. 216. My major assignment at the site was to excavate a temple area with the aid of 140 Arab workmen. I also had the opportunity to become acquainted with all of the pottery excavated in several parts of the city during the last season and to collect clay samples at many sites in Iraq. During the next two years, as a part of the work for my doctoral dissertation, I made extensive laboratory tests and studies of the clay samples and sherds and had available for examination all of the ceramic material from Seleucia allocated to the University of Michigan.

Firing Changes in the Physical Properties of the Seleucia Clay

The clay used in these studies came from an undisturbed stratum immediately below the lower level of the temple which I was excavating. Thus it was clay that was at, or quite near, the surface at the time that the site was occupied. It all passed through a 120-mesh sieve and was a good plastic clay with which to work. An X-ray diffraction study showed that the principal clay mineral was illite. The differential thermal analysis was inconclusive. The chief mineral inclusions in the clay were calcite, quartz, flint, gypsum, magnetite, biotite, and sericite. Accessory minerals were chlorite, sillimanite, red iron-stained lumps, serpentine, diallage, and actinolite.

The chemical composition of the Seleucia clay was determined by Miss Mildred Parrish in the Research Laboratories of the Armstrong Cork Company, and is shown in Table 4.1. The low alumina and high calcium oxide content are explained by the presence of calcite and gypsum in the clay. A separate analysis of acid-treated clay, in which the amount of calcium present was determined by titration with

Table 4.1
The Chemical Composition of Two Tigris River Clays

	Seleucia (%)	Samarra (%)
SiO_2	40.28	39.90
Al_2O_3, TiO_2	9.52	20.07 (with a little oxide of iron)
Fe_2O_3	6.36	
CaO	16.43	16.75
MgO	4.20	Trace
BaO	0	
Na_2O	0.58	
K_2O	1.41	
SO_3	0.78	
Loss on Ign.	19.36	23.49
Total	98.92	100.21

$KMnO_4$, showed that it contained about 30 percent $CaCO_3$. A similar lime-rich Tigris River clay underlying the conglomerate at Samarra, about 70 miles northwest of Baghdad, was reported by Willcocks (Reference 18, p. 93, analysis by A. Lucas). It, too, is shown in Table 4.1.

Soluble salts present in clays can have an important role in the development of colors when pottery or brick are fired. In the ancient city area of Seleucia, there is a salt encrustation on the surface of the ground at the beginning of the dry season that breaks as one walks over it. The village and desert Arabs use washed salts from some areas as flavoring for their food. In one spot near Seleucia, the surface salts were so rich in nitrates that they were said to have been used in making crude gun powder. The improvement of Iraqi agricultural yields is greatly hindered by the difficulties encountered in effectively reducing the salt content of the soil. A qualitative analysis of soluble salts extracted from the Seleucia clay showed the presence of small amounts of chlorides and phosphates and a significant amount of sulfate, doubtless from the gypsum present in the clay. The salt content of the clay is because of the saline waters of the Tigris which include the effluent from sulfur and naphtha springs. One must keep in mind the effect of the variable salt content of the Mesopotamian clays when discussing color developments during firing.

Clays rich in lime that also contain sufficient iron to be an important factor in color development are frequently used in the brick industry. Both Ries (Reference 11) and Salmang (Reference 12) have summarized some of the studies of the roles of lime and iron in the progressive color changes in such clays when they are fired. Shepard (Reference 13, pp. 213–224) has provided an excellent discussion of the firing of pottery, particularly of wares such as those of the American Southwest where kilns were not used. High lime clays containing iron were not important raw materials for the Indian potters she studied.

The final stages in the color development during the firing of the lime and iron bearing clays so widely available in the Near East will be briefly outlined:

1. *Black to gray*. The organic materials present in many clays will cause the bodies to darken during the initial stages of firing. Gradually the surface and finally the core lighten, the rate depending on the amount and form of the organic material present, its bond relation to the surfaces of the clay particles, the porosity of the body, and the time-temperature-atmosphere conditions of firing. Many surface clays, particularly in arid regions, are very low in organic materials, so surface and body darkening caused by the presence of carbon may not appear. Then the lack of a black surface or core in sherds may not indicate higher temperatures or longer firings. The Seleucia clay, however, which was taken from a deposit two meters below the present land surface, showed progressive loss of the carbon black. The appearance of the Seleucia test pieces has been discussed and illustrated (Reference 7, pp. 34–35; Reference 8, pp. 492–493, Pl.XXIV). The deposition of grease or soot on and near the surfaces of cooking ware or on vessels trapped in the char and ash of burning buildings must also be considered.

An additional aspect of the dark coloration aided by the presence of carbon and carbon monoxide can be the reduction of the iron present to Fe_3O_4 which is black in color. Further reduction to FeO provides iron in the state of an active flux which will react chemically with the clay. Dark-colored silicates thus formed will not reoxidize at higher temperatures if the kiln atmosphere remains generally reducing in nature, and permanent dark cores can develop which are not indicative of low firing temperatures for the ware.

2. *Pale brown to pink*. When the clay is fired to increasingly higher temperatures up to about 1000°C under oxidizing conditions, the iron present has a chance to become fully oxidized and exert its strong coloring effect. When conditions are less oxidizing, gray-browns may develop. The length of time at which a temperature is maintained influences the color development, and the rate of cooling has a strong influence on color development. If the cooling is too rapid in parts of poorly sealed or cracked kilns, the optimum color will not appear. The form and grain size of the particles in which iron is present in the clay body as well as the total amount of iron will have a strong influence on the fired color.

3. *White skin on pink body*. The soluble salts in the clay will tend to concentrate on the surface of the ware as it dries, having migrated there in the water which evaporates from the unblocked surfaces. Salts, particularly chlorides, will react with the iron present to form $FeCl_3$ which volatilizes readily at about 800°C. This leaves an iron-free surface that has the appearance of a white slip (and has too often been mistakenly called a slip by archaeologists). I have discussed this phenomenon together with other color changes elsewhere (References 5 and 6).

4. *White body*. The lime in the clay becomes an active coloring agent once the $CaCO_3$ has decomposed. Paler shades and finally white colors start to develop above about 850°C as the CaO begins to react effectively with the clay, particularly under reducing conditions. Gypsum, too, decomposes under reducing conditions in this temperature range (Reference 16). This complex series of reactions is familiar to ceramic engineers who have to deal with the color problems relating to the scumming of brick. Brownell (Reference 2) has provided a good summary statement of the nature of scumming. Clays rich in lime, particularly those also containing soluble salts, develop pale pinks and then whites in the general temperature range of 850° to 1000°C, the exact temperature depending on many factors such as chemical composition of the clay and the time-temperature-atmosphere. Frequently one will find sherds with pink cores and white surface zones.

5. *Pale yellow*. Above about 1000°C as vitrification approaches, the calcium-ferro-silicates that have been developing in the clay appear pale yellow in color and at times even olive. The temperature at which this occurs will be strongly affected by the fluxing action of iron in a reducing kiln atmosphere and by the salt content of the clay. Pieces of pottery may become warped as the body softens, and some vessels may stick together if they have been in contact in a very hot zone of the kiln.

In this brief survey of color changes, temperatures have been intentionally mentioned in an imprecise manner so as to emphasize the fact that many variables are involved. Temperature zones rather than precise degree markers are most useful for archaeological studies. The color terms are those used with the Munsell Soil Color Charts (Reference 10).

The test briquettes made from the Seleucia clay were fired in an electric furnace heated by means of SiC resistance rods. The furnace atmosphere could be established through the introduction of air, natural gas, or air-gas mixtures by means of gas and air manifold controls. Three types of firings with differing kiln atmospheres, here termed R, O, and R-O, were used. The R represents the reducing atmosphere firing in which the kiln was brought up to the desired temperature and held there for 30 minutes in a strongly reducing atmosphere. The briquettes were then removed from the kiln and quickly placed in a box of sand so that they might cool with little air being present. An analysis of the reducing atmosphere by means of an Orsat apparatus showed that it was CO, 16.0 percent; CO_2, 4.0 percent; and O_2, 0.8 percent. Sixteen percent CO is about the maximum that can be maintained in a kiln without producing too much smoke and having carbon deposition. The O signified the oxidizing atmosphere which was also held for 30 minutes at the maximum temperature of the run. The briquettes were cooled to about 350°C in the kiln and were then placed in a dessicator for the final cooling. In the R-O firing, after the atmosphere had been reducing for 30 minutes at the maximum temperature, it was changed to oxidizing and the temperature was held for another 30 minutes. This procedure introduced as a variable a longer time of firing, but it demonstrated the color changes that could be produced in a kiln such as those used in many Mediterranean and Near Eastern villages today in which strongly reducing atmospheres are produced when fresh fuel is added. At the higher temperatures when the interior of the kiln becomes incandescent the atmosphere is oxidizing for the time intervals between the introduction of additional straw, brush, or wood, etc., as fuel.

When the color changes of the Seleucia clay briquettes with increasing firing temperatures under three different kiln atmospheres were first determined, the Ridgway color system was used. This is now obsolete, and the Ridgway manual is unobtainable. Therefore, in the present restudy for publication, the colors were redetermined using the Munsell Soil Color Charts (Reference 10). Since the Munsell system has frequently been described and discussed, it will be noted here only that one can think of colors grouped in the shape of a sphere with an irregular surface. The *Hues*—red, yellow-red, yellow, etc.—vary around the circumference of the sphere in the order of the spectrum and may be thought of as segments of an orange. The vertical axis of the sphere shows gradations in gray, with black at the base and white at the top, the *Value* or lightness of the color is then indicated numerically from 1 (black) to 10 (white). The strength of the color, its position between neutral gray and its maximum brightness at the same numerical value (in a horizontal plane from the axis to the surface) is termed the *Chroma*. The Chroma increases in numerical value from 1 (gray) to 8 on the Soil Color Charts which are published in a loose-leaf handbook. The directions for the use of the charts and the notes on the determination of soil color provide all the information needed for the effective use of the Munsell system. Shepard's discussion (Reference 13, pp. 107–113) contains useful suggestions for archaeologists who are describing the colors of sherds. (I find that partly closing one's eyes helps when making the final color match.) Broader aspects of color descriptions and measurements are discussed in the two symposia organized by the American Ceramic Society in 1941 and 1947 with Weyl and Balinkin as the chairmen (see References 1 and 17).

A series of color names appears opposite the Munsell Soil Color Charts. These non-exotic simple names were selected after much consultation and compilation as basic color terms. Many of the names are applied to a cluster of two to four colors on the charts, so are not precise, but are simply classificatory. Color descriptions of pottery should make use of these terms despite one's personal predilections, for extremely precise color descriptions are inappropriate, even irrelevant. Colors often vary in shade on different parts of the surface of one vessel, and certainly among vessels from one firing. Therefore, if one wishes to describe pottery colors in a useful way it is best to avoid false precision.

The color descriptions for the Seleucia briquettes appear in Table 4.2. To simplify the summary of the color analysis, the Munsell color notations are used in the left-hand portion of the table, and the color names for the same series are listed separately on the right side.

In the R-series fired in a reducing atmosphere and cooled in a box of sand, a gray core first appears at 500°C and continues to be present throughout the series with little variation in color. Beginning at 850°C, a lighter surface skin appears that is related to the action of the soluble salts, as has already been discussed, and possibly to a slight oxidation of the surfaces as the briquettes cool quickly in the sand. Water quenching might have been a better way to cool these briquettes. Above 950°, the surface color is paler, and at 1100°, it acquires a pale olive gray Hue to the eye although it is still termed white in the Munsell system. These shades of color frequently occur on Near Eastern pottery. The light gray cores of sherds in contrast to the surfaces are best seen on freshly fractured or saw cut edges, and they are intensified when the cross sections are moistened with water. Since flames can play directly on some of the ware in simple up-draft kilns such as those used in the Near East, it is quite possible to have some strongly reduced ware that was stacked near the hearth in the kiln, while more oxidized pieces are produced in most of the kiln-load from the same firing. By 1170°, the clay has melted into a gray slag and is useless.

In the O-series the color changes from very pale brown to pink with increasing temperatures, and becomes noticeably lighter in Value at 900°. At 1100°, a pale yellow surface and body have developed.

In the R-O series the gray cores have been entirely eliminated by the 30 minute final period of firing in an oxidizing atmosphere, but there is still a difference in color Value between the core and surface. It has been found when refiring sherds that it is seldom possible to eliminate completely the effect of the reducing period on the core color because some fluxing has usually occurred. The colors developed in the R-O firings are the same as those of the O-series through 800°. Above this temperature the R-O briquettes are less pink, and the color differences between the two series are clearly seen above 950°. At 1100°, the color is lower in Value, approaching a pale olive.

The test briquettes whose color changes have just been discussed were tempered with distilled water in accordance with good laboratory practice when they were prepared. The colors developed were, therefore, influenced only by salts already present in the clay. However, the Tigris River water has a bitter taste, and the Arabs working in the excavations at Seleucia preferred to get their drinking water from irrigation canals whose water came from the Euphrates River, some 18 miles to the southwest. Thus additional salts may have been included in the potter's plastic clay through the tempering water or because surface clays including the salt crust were used for the production of pottery and figurines.

As a first check on the effect of salted tempering water on fired color development, sodium chloride and plaster of Paris were boiled in water and the filtrate was used to temper the clay. The fired briquettes of this salted series showed the same color developments through 850° as the basic series under the three atmospheric conditions. At higher temperatures they were more strongly bleached with shades in the range of the Munsell "white," being well developed by 950°. These colors are commonly seen on Mesopotamian vessels and sherds.

In the past four years we have been systematically adding salts under controlled conditions to a series of Near Eastern clays. The results of these studies will be discussed in another paper, but they confirm and enrich the data of these first studies. They strikingly show that salts in lime-rich ferruginous clays accelerate the development of white bodies at firing temperatures above about 900°C. The white surface skin on brown to pink clay ware, often mistakenly termed a slip, appears in the 800°–900°C temperature zone. This white surface indeed looks like a slip when first seen, but if one examines freshly fractured edges of sherds with a hand lens, no differentiation in the fracture pattern will be seen at the color interface. If doubt persists, thin sections of sherds should be prepared. When they are examined under a petrographic microscope at high magnification the presence or absence of a surface coating can quickly be determined. There are indeed slips applied to some ware, but the term should not be indiscriminately used for white-surfaced pottery.

Ten figurine fragments were refired to 1000°C for 30 minutes under oxidizing conditions to determine the changes in their color. The series consisted of three that were pink to reddish yellow in surface color (using the Munsell terminology) with pinkish gray cores; three with a white sur-

Table 4.2
Firing Changes in Color of the Seleucia Clay

Temp (°C)		Furnace Atmosphere*			Furnace Atmosphere		
		R	O	R-O	R	O	R-O
		(Munsell Color Notation)			(Munsell Soil Color Names)		
Unfired		10YR 7/2	10YR 7/2	10YR 7/2	Light Gray	Light Gray	Light Gray
300°	Surface	—	10YR 7/3	—	—	Very Pale Brown	—
	Core	—	10YR 7/3	—	—	Very Pale Brown	—
400°	Surface	10YR 7/3	10YR 7/3	—	Very Pale Brown	Very Pale Brown	—
	Core	10YR 7/2	10YR 7/3	—	Light Gray	Very Pale Brown	—
500°	Surface	—	7.5YR 7/4	—	—	Pink	—
	Core	—	7.5YR 7/4	—	—	Pink	—
600°	Surface	10YR 5/1	7.5YR 7/4	7.5YR 7/4	Gray	Pink	Pink
	Core	2.5Y 7/0	7.5YR 7/4	7.5YR 7/4	Light Gray	Pink	Pink
700°	Surface	10YR 7/2	—	7.5YR 8/4	Light Gray	—	Pink
	Core	2.5Y 7/0	—	7.5YR 7/4	Light Gray	—	Pink
800°	Surface	2.5Y 5/0	7.5YR 7/5	7.5YR 7/5	Gray	Pink	Pink
	Core	2.5Y 7/0	7.5YR 7/4	7.5YR 7/4	Light Gray	Pink	Pink
850°	Surface	2.5Y 8/2	5YR 7/5	7.5YR 8/4	White	Pink	Pink
	Core	10YR 8/1	5YR 7/6	7.5YR 7/4	White	Reddish Yellow	Pink
900°	Surface	2.5Y 8/2	5YR 8/4	7.5YR 8/4	White	Pink	Pink
	Core	2.5Y 7/0	5YR 8/4	7.5YR 8/4	Light Gray	Pink	Pink
950°	Surface	5Y 8/1	5YR 8/4	7.5YR 8/4	White	Pink	Pink
	Core	5Y 8/1	5YR 8/4	7.5YR 7/5	White	Pink	Pink
1000°	Surface	2.5Y 8/2	5YR 8/4	10YR 8/4	White	Pink	Very Pale Brown
	Core	2.5Y 7/0	5YR 8/4	10YR 8/5	Light Gray	Pink	Very Pale Brown
1050°	Surface	5Y 8/1	—	2.5Y 8/4	White	—	Pale Yellow
	Core	2.5Y 8/0	—	2.5Y 8/4	White	—	Pale Yellow
1100°	Surface	5Y 8/2	2.5Y 8/4	5Y 7/4	White	Pale Yellow	Pale Yellow
	Core	5Y 7/1	2.5Y 8/4	5Y 7/4	Light Gray	Pale Yellow	Pale Yellow
1170°	Surface	10YR 5/1	—	—	Gray	—	—
	Core	2.5Y 5/0	—	—	Gray	—	—

* Note: Furnace Atmosphere: R, Reducing throughout the firing; maintained for 30 minutes at the highest temperature. O, Oxidizing throughout the firing; maintained for 30 minutes at the highest temperature. R-O, Same as R, but followed by 30 minutes in an oxidizing atmosphere at the highest temperature.

4.1
A fired brick pavement of neo-Babylonian times at Ur. The low-fired brick have disintegrated.

face over a pink to very pale brown core; two that were white throughout; and two with a grayish-green tinge, although they are classed as white in Munsell's terms. They all fired to 2.5YR 8/4 or 7/4, both termed pale yellow. There were, however, reddish yellow to red stains on some ancient fractured and original surfaces. It would appear that materials absorbed by the fired ware while it remained buried at Seleucia for almost 2000 years had an influence on the refired colors. This is a phenomenon well-known to brick manufacturers. They term it "flashing" when a surface coloring effect is developed because of the chemothermal reactions of volatile fluxing and coloring ingredients that are on the brick surfaces. The formation of $FeSO_4$ could account for this discoloration.

The tests so far reported in this paper have established a basis for estimating firing temperatures of ware made from a Tigris River clay, and by extension to similar clays. Color sortings of Seleucia pottery, lamps, and figurines will be discussed shortly, but mention should first be made of the results of the measurements of some of the other physical properties of the briquettes insofar as they might be of use in determining firing temperatures.

The hardness of pottery is reported in some archaeological papers. Presumably the hardness will increase with the higher firing temperatures, particularly as the vitrification stage is approached. The measurement is made by attempting to scratch the test surface with a series of ten minerals ranging from talc to diamond. This is, of course, Mohs' mineral-hardness scale so commonly used by mineralogists. The scratch hardness is really a measure of abrasion resistance, so the grain size distribution of the ingredients in the clay body, the effective packing of the particles, the bonding strength of the clay, and the force with which the test scratching is done can all affect the results. Shepard (Reference 13, pp. 113–117) has useful comments on hardness testing. Mohs' scale with the refinements suggested by March (Reference 4, p. 20) was used to test the fired Seleucia briquettes, and the scratches were all examined with a hand lens so as to increase the accuracy of this subjective measurement.

The results, summarized in Table 4.3, suggest that in the usual firing range of Mesopotamian pottery, 600°–1000°C, differences in scratch hardness are not of diagnostic value in estimating firing temperatures. Small changes occur at temperatures known from the color shifts to be critical. They can first be recognized in the surface hardness, then at the next higher temperature in the core. Thus knowledge of the variations in hardness can help characterize pottery. For example, Seleucia ware exposed to a reducing atmosphere

Table 4.3
Scratch Hardness of the Seleucia Clay

Temp. (°C)		Furnace Atmosphere R	O	R-O
Unfired		2.5	2.5	2.5
500°			2.5	
600°	Surface	2.5–3	2.5+	2.5–3
	Core			2.5
700°	S	3		3
800°	S,C	3	2.5+	3
850°	S,C	3	3	3
900°	S,C	3	3	3
950°	S	3.5	3	3.5+
	C	3	3	3
1000°	S	3.5	3.5	3.5+
	C	3.5	3	3.5
1050°	S	3.5–4	3.5	3.5–4
	C	3.5	3.5	3.5
1100°	S	5	5	5.5
	C	5	3.5–4	5.5
1170°	Slag	5.5		

during some stage of its firing may be slightly harder than that fired under oxidizing conditions, possibly because of the fluxing action of FeO. This difference in hardness was noticeable when the test briquettes were sectioned with a diamond-embedded saw blade. Low-temperature ware will be less abrasion-resistant, and can break or disintegrate readily. The fired brick pavement of Neo-Babylonian times at Ur that is seen in Figure 4.1 illustrates this point. The brown brick in the foreground have crumbled, while the higher-fired white brick with greater bond strength are intact. Undoubtedly the crystallization of salts in porous pottery and brick during the dry season accelerates the disintegration of those pieces with low-fired bodies.

Hardness measurements of potsherds can be of use to help resolve specific problems, and they certainly should be made on the test pieces when studying the firing behavior of local clay. However, they are of little diagnostic value when studying the range in firing temperatures.

It is encouraging to report that Wright has recently published extensive tabulations of hardness and color measurements of the sherds found in the excavation of an Early Dynastic Mesopotamian town near Ur (Reference 19, Appendix I). He says (p. 123), "This appendix should encourage more detailed comparisons between Early Dynastic ceramic assemblages than has been usual. It should also provide data for the rapidly developing field of mathematical topology."

The percent loss of weight upon firing is another physical measurement that might be of use in determining the firing temperatures of ancient pottery. When clays such as that from Seleucia are fired, they lose weight below about 600°C because of the volatilization of the chemically com-

Table 4.4
Percent Loss of Weight of the Seleucia Clay

Temp. (°C)	Furnace Atmosphere R	O	R-O
600°	3.1%	3.2%	3.2%
700°	7.4	—	8.4
800°	12.5	10.4	12.4
850°	17.1	16.2	17.3
900°	17.9	17.5	17.5
950°	18.2	17.5	17.5
1000°	18.1	17.5	17.9
1050°	18.2	17.6	17.9
1100°	18.3	17.6	18.0

bined water present in the clay, plus a small amount of water from the gypsum, chlorite, and biotite that occurred in the clay deposit. Between about 600° and 900°C, the thermal decomposition of calcite from the limestone and possibly of gypsum will cause significant weight loss. (West and Sutton, Reference 16, have shown that gypsum in the presence of carbon and under reducing conditions can decompose in this temperature range.) The calcined limestone present in fired pottery will rehydrate and gradually revert to the carbonate form if the ware has not been fired high enough, usually about 900°C, so that the CaO can react with the clay and form part of a complex silicate structure. Therefore, loss of weight studies of potsherds and figurines, refiring them at successively higher temperatures, may not always give reliable results if there was much limestone present in the potter's clay. A test series of figurines, however, gave surprisingly good results.

The loss of weight of the Seleucia clay briquettes measured in this series of firing experiments is reported in Table 4.4. The percent loss is expressed in terms of the unfired dry weight so that there will be a common base for comparison. Below 600°C, there was a small loss in weight, but the great loss occurred between 600° and 850° in the zone of calcite decomposition. Above 900°, there was no further significant loss. It is noticeable that the R and R-O series lost weight more rapidly than those briquettes fired under oxidizing conditions and that the reactions were almost completed at 850°. In the O-series it was not until 900° that the weight became constant, and the total weight loss by 1100° was less than that for the briquettes which had been subjected to reducing atmospheres. These

notes indicate trends but should be confirmed by further testing of several samples at each temperature. This experiment does indicate, as did the color changes, that clays rich in both lime and iron are sensitively influenced in their chemothermal reactions by the kiln atmosphere.

The ten figurines selected for special study have already been characterized in terms of their colors. They were first refired to 400°C in an oxidizing atmosphere for 30 minutes to establish base weights, for they might contain some partially hydrated material after burial for almost 2000 years. They lost 1–2 percent in weight. In the second refiring they were held at 1000°C in an oxidizing atmosphere for 30 minutes. The results are shown in Table 4.5a where it can be seen that the weight losses agree well with the color indications of low, medium and high fired wares.

The data in Table 4.4 were used to calculate the approximate weight losses of the Seleucia test briquettes were they to be refired to 1000°C. The difference in weight between the 1000° firing and that at 600°, 700°, 800°, and 850° was expressed as the percent based on each of these lower temperatures. (Calculations were not made for the firings above 850° because the weight losses were so small.) The results are shown in Table 4.5b aligned with the appropriate figurine groups of Table 4.5a.

The percent loss of weight of the refired figurines agrees in rank order of color indications with the calculated data for the briquettes but not closely enough by 100° to use this approach for actual temperature estimates. The amount of lime originally present in the figurines compared with that in the test briquettes as well as the degree to which it had reverted to the carbonate form would be affected by the ever-present factors of the time-temperature-kiln atmosphere when the figurines were originally fired. The correlation is surprisingly good when one considers the effect of these variables upon the results. Percent loss of weight upon refiring could serve as a useful check procedure in the study of specific problems.

The true specific gravity of the Seleucia clay and of a series of figurine fragments

Table 4.5
(a) Percent Loss of Weight of Seleucia Figurines Refired to 1000°C; (b) Percent Loss of Weight of Seleucia Test Briquettes Refired to 1000°C. (calculated).

(a)

Figurine Color Group	% Wt. Loss
Pink surface, pinkish gray cores	12.1, 11.3, 9.1
White surface skin, pink cores	8.7, 6.2, 5.0
White	2.4, 1.0
White with olive-gray tinge	0.1, 0.04

(b)

Orig. Firing Temp. (°C)	% Wt. Loss at 1000°C
Unfired	17.5
600°	14.9
700°	10.1
800°	6.0
850°	0.5

Table 4.6
True Specific Gravity of the Seleucia Clay

Firing Temp. (°C)	Furnace Atmosphere R	O	R-O
Unfired	2.75	2.75	2.75
800°	2.85	2.79	2.84
900°	2.90	2.93	2.89
1050°	2.93	2.94	2.94
1100°	2.97	2.95	2.97
1170° (slag)	3.00		

was accurately measured using calibrated pyncnometers for the tests. Selected results, those at the temperatures where significant changes occurred, are shown in Table 4.6 with the values rounded off to two significant figures. As in the other tests, the briquettes fired under oxidizing conditions showed less chemical reaction resulting in increase in true specific gravity by 800° than did those under reducing atmospheres, and their final approach toward vitrification may have been a little less complete by 1100°.

Fragments of six figurines from the selected color series were powdered and their true specific gravities were determined. The moderately fired pieces were found to have values of 2.75, 2.80, and 2.88; the highest fired, to judge from their color, had results of 2.96, 3.03, and 3.03. The comparison between these figures and those in Table 4.6 is in good agreement, even though the composition of the figurines and the briquettes may have differed somewhat. Therefore, it would be possible to measure the true specific gravity of carefully selected samples for the estimation of the ancient firing temperatures, but the amount of work involved in these time-consuming measurements would rarely be justified. The fired colors of the ware can usually provide the information with sufficient accuracy.

The firing shrinkage of most clays used by potters is not great nor progressively uniform. It will be influenced by the amount and grain size of any sand present in the body that occurs naturally or has been added as tempering material by the potter. Some clays are washed to remove sand from them. The volume firing shrinkages of the fine textured Seleucia clay briquettes were measured, and the data were then recalculated to express the values as percent linear firing shrinkage. Warping would thus not influence the shrinkage measurements. The detailed results will not be presented as they are not useful for the estimation of firing temperatures. In general the clay had a linear expansion of 0.2–0.4 percent at 600° and 700°C, followed by less than 3 percent shrinkage through 1050°, and 4–7 percent shrinkage between 1050° and 1100° as incipient vitrification began. It is possible to measure the additional shrinkage of sherds and figurines that have been refired in the laboratory, but the results do not justify the effort. For highly siliceous bodies such as those of special types of glazed Islamic pottery studied by Kiefer and referred to later, shrinkage measurements can give an indication of the original firing temperatures.

A decrease in porosity might be an indication of increased firing temperature as the clay body begins to shrink but before the overfired vesicular structure develops. (The porosity of a ceramic body is expressed as the percent water absorbed under standard test conditions per unit of volume of the test piece.) The results of the porosity measurements of the briquettes, ranging from 28 percent to 40 percent, did not show any clear trends save at the highest temperatures. The small size of the pieces tested and the small number of examples would in part explain this. There was a marked decrease in porosity between 1050° and 1100° caused by incipient vitrification. There was also a slight tendency for the R-O series (with 60 minutes at the highest firing temperature) to be lower in porosity than those of the R and the O series which had but 30 minutes at the highest firing temperature. A series of 43 figurine fragments selected to represent the major color differences indicative of degree of firing were tested for their porosity, but the results, ranging from 24 percent to 44 percent, gave no useful correlation with fired clay color. It would therefore seem that the firing temperature, save for very high temperature overfiring, had no important influence on the porosity of the ceramic products.

The study of thin sections of the fired briquettes, some figurines, and many sherds from Seleucia under the petrographic microscope confirms the temperature indications provided by the color of the fired products. Changes in the birefringence of the clay, the alteration of the calcite, and the appearance of ferruginous inclusions are temperature indicators. Such detailed studies, however, are made for other purposes and cannot be considered a primary means of estimating firing temperatures, although they can provide confirmation. Shepard (Reference 13, pp. 27–31) has useful comments on the effects of heat on nonplastics.

This survey of the results of some of the physical measurements made on Seleucia clay briquettes and figurines indicates that changes in color because of firing temperature and atmosphere can serve as the most useful and simple guide for the estimation of the original firing temperatures. The percent loss of weight on refiring may at times be useful; hardness and true specific gravity determinations have limited application.

The Firing Temperatures of Seleucia's Ceramic Products

The large quantity of figurines, clay lamps, and almost complete pieces of pottery from the six seasons of excavations at Seleucia that was available at the University of Michigan made it possible to study firing temperatures in terms of clay colors on stratigraphically controlled large samples. Selected materials from this extensive study will be presented to illustrate some of the results. Five arbitrary color categories were established based on Munsell's soil color names. It might be well to comment on the terms selected. *Brown* indicates at least the surface color of the objects, and often their core color as well, although this may shade into grays. This arbitrary color range includes Munsell's pinks as well. *White on brown* is used for the objects that have a white surface skin with a brown body beneath it. *White* includes the pale colors, some of which observers not oriented toward the Munsell terminology might call pale pink to yellow. Villagers in Greece and the Near East today term a wide range of shades as white and do not differentiate between them when discussing pottery. *Olive* includes the higher fired white wares that are verging on yellow-green shades of color. It includes the colors grouped on Munsell's Hue 5Y plate. The term yellow might have been used, but it is too close to white for useful distinctions to be made in large sortings. The category used for the pieces that cannot be classified into the other groups is *X*. They may vary greatly in surface color, have been discolored by burial in hearth debris or in burned buildings, or have been made of clays which developed a different series of colors when fired. Consistent results are best obtained when one person or two people working together make the classification. In the Seleucia studies all of the color groupings were determined by one person under reasonably uniform lighting conditions. The results of several color sortings of the Seleucia ceramic materials are presented in Table 4.7.

The large number of almost whole pieces of pottery available (969) made it unnecessary to use sherds in this study. Since several sherds could have come from one vessel, it was thought best not to group them with the pottery. Most of the pottery (70 percent) fired white, and very little showed evidence of overfiring. The low percentages of white on brown and of brown point to a good ceramic tradition of kiln firing in which the ware had an opportunity to mature at 900° to 1000°C before the firing ended. The kiln temperature probably dropped quite rapidly after the firing ceased, judging from the pale neutral color of the ware. The pottery from the sixth season constituted about one-third of the sample. Since the excavations in the last season included some new areas, this group was compared with the materials from the other seasons and the color distributions were found to be almost identical. This would suggest that there was a long-established tradition of pottery manufacture at Seleucia that was consistent in the several parts of the large city in terms of degree of firing of the wares.

Small lamps are found in large quantities in excavations of the Hellenistic and Parthian periods and show little variation in shape or design. The 97 lamps brought back to the University of Michigan after the last season were sorted as to color distribution. The distribution was about the same as that for the pottery, with fewer low fired pieces and several more that were quite high fired. This parallel distribution would indicate that the small lamps were fired in the same kilns with the pottery. Today the Greek and Near Eastern potters fill the interstices in the kiln load with small vessels. It is likely that lamps were placed in the voids between vessels when the Seleucia kilns were loaded.

Table 4.7
Color Distribution of the Pottery, Lamps, and Figurines Found at Seleucia.

	No. of Test Pieces	Brown	White on Brown	White	Olive	*X*
(a)						
Pottery	969	14.24%	9.60%	70.38%	1.55%	4.23%
Lamps	97	11.34	7.22	70.10	8.25	3.09
Figurines, Total Series	2927	32.83	30.92	27.37	4.20	4.68
(b)						
Figurines, Block G-6 (by Levels)						
I (120 A.D.–216 A.D.)	200	42.5%	25.5%	23.0%	3.5%	5.5%
II (70 A.D.–120 A.D.)	336	36.3	34.5	20.8	4.5	3.9
III (143 B.C.–70 A.D.)	686	34.4	36.9	22.6	3.3	2.8
IV (295 B.C.–143 B.C.)	79	22.8	46.8	22.8	6.3	1.3
(c)						
Figurines, Block G-6						
Late III (Postrevolt)	291	39.9%	32.6%	19.9%	4.8%	2.7%
Early III (Prerevolt)	367	29.2	40.6	25.9	1.9	2.5

Almost 3000 figurines were available for color sorting. Their distribution is quite unlike that for the pottery and lamps, and indicates a different tradition of firing. The colors are distributed about equally among low-, medium-, and high-fired groups. This would suggest that a different type of kiln was used, probably with less uniform heat distribution. It is likely that the duration of the firings was also less. We will return to this discussion later after having looked at some subgroups of the figurines and examined Dr. Van Buren's figurine color distribution.

One of the areas excavated at Seleucia for several seasons was G-6, a large residential block with small shops facing the streets around its periphery. Three major levels of occupation in this city block had been excavated through a depth of over 30 feet of deposits below the surface during the earlier field seasons. In the last campaign a start was made on the excavation of Level IV. The color distribution of the 1301 figurines that were sorted from Block G-6 in terms of their levels is shown in Table 4.7b. The earliest materials (but by far the smallest sample) were the best fired. The latest materials were the lowest fired although the increase in the brown figurines was only six percent. Grouping together the brown plus the white on brown, one finds that the percentage is about the same as in the earlier levels. Other factors such as the size and shape of the figurines and variations in the amount of soluble salts in the clay should also be considered when assessing the meaning of the slight increase in lower-fired figurines. Level I covers a final century of unrest for the city of Seleucia, a time when it was sacked by three Roman generals—Trajan, Verus, and Septimius Severus—so a decline in production standards or in the availability of fuel might not be surprising.

A further test was made by sortings of the G-6 figurines. After Seleucia was conquered by the Parthians, it remained an autonomous Hellenistic city in culture and architecture, paying tribute to the new overlords but living for the most part in its old ways. During a seven-year period, A.D. 36–43, the city experienced great unrest with severe power struggles going on with varying success between the native party and the aristocratic party. The latter eventually won but had been so weakened that, according to McDowell, it had to request royal domination. McDowell (Reference 9, pp. 225–226) has described and interpreted this struggle in terms of the series of coins that were minted during this period of unrest. As a result of these disturbed years, the loss by Seleucia of autonomy in government, and the development of a strong native party that was frequently in power, there was a marked change in the cultural life of the city, judging from the archaeological evidence. Hellenistic types of architecture, figurines, pottery, etc. that had still been common in early Level III, were replaced by types characteristic of the oriental culture of the Parthians. These new types continued through Levels II and I.

It was possible to select 658 figurines from Level III that could be approximately divided into the prerevolt and the postrevolt periods. The color sortings in Table 4.7c clearly show a change for the worse in the manner of firing the figurines after the time of the revolt. They were fired at lower temperatures, and there was less experienced control of the kilns; for there was a marked increase in the number of overfired pieces. It is easy to speculate on the reasons for this decline in the degree of firing of the figurines. Without elaborating on them, a few ideas can be suggested: Fuel may have become scarcer or more expensive to obtain, there may have been a decline in standards of craftmanship because of untrained assistants or added responsibilities in the homes (if women made the figurines) with the shift in cultural orientation toward the East, and probably there was a depression. It is interesting to note that the color distribution of postrevolt Level III is almost identical with that of Level II.

A postscript can be added to these color distribution studies of some of the ceramic products from Seleucia. In the spring of 1955, I was able to return to the site at the suggestion of and with the help of the late Dr. Naji al Asil, then Director General of Antiquites for Iraq. The Tigris River had changed its course near Seleucia as a result of severe floods in 1938, and parts of the city, including the temple I had excavated, were irretrievably under water. As I walked about the extensive site, I was surprised to note the large number of brown sherds that lay on the ground. My recollection, based in part on the pottery sortings in which 70 percent of the vessels were white, was that brown materials were scarce. I examined the surface sherds and realized that the materials lying on the ground to a large part represented soft low-fired vessels that had broken easily in antiquity. Few of these would be among the restorable pots that would have been saved by the excavators. Many would have crumbled due to the crystallization of salts in the porous bodies, a destructive process of low-fired ware that is illustrated in Figure 4.1. Spalling or disintegration in less than a year after the vessels were fired would occur for those pieces containing coarse grains of limestone that had been calcined during firing if the CaO had not reacted with the clay to form a calcium silicate but was free to hydrate.

It is a good idea to observe the sherd detritus on the surface of a site and on

Table 4.8
Color Distribution of the Van Buren Figurines

Site	No. of Figurines	Brown	White on Brown	White	White plus White on Brown	Olive	Miscellaneous
Total Van Buren Series	750	30.8%	11.5%	40.7%	52.2%	11.9%	4.1
Seleucia	2927	32.8	30.9	27.4	58.3	4.2	4.7
Assur	41	31.7	14.6	36.6	51.2	7.3	9.8
Babylon	39	33.3	10.2	30.8	41.0	12.8	12.9
Kish	77	28.6	13.0	50.7	63.7		7.7
Nippur	103	27.2	13.6	42.7	56.3	8.7	7.8
Tello	34	32.3	8.8	26.4	35.2	29.4	3.1
Warka	34	17.7	2.9	50.0	52.9	20.6	8.8
Ur	109	14.7	20.2	40.4	60.6	21.1	3.6
Susa	28	17.8	3.6	50.0	53.6	14.3	14.3

the dumps from the excavations to judge whether the sample one collects for color distribution studies truly reflects the range of products coming from the kilns. Figure 4.2 shows such a sherd-strewn surface in southern Iraq at Tell Uqair. Much high-fired Ubaid pottery had been obtained at this excavation, but it was amazing to see the large number of chips of low-fired ware intermingled with the white sherds.

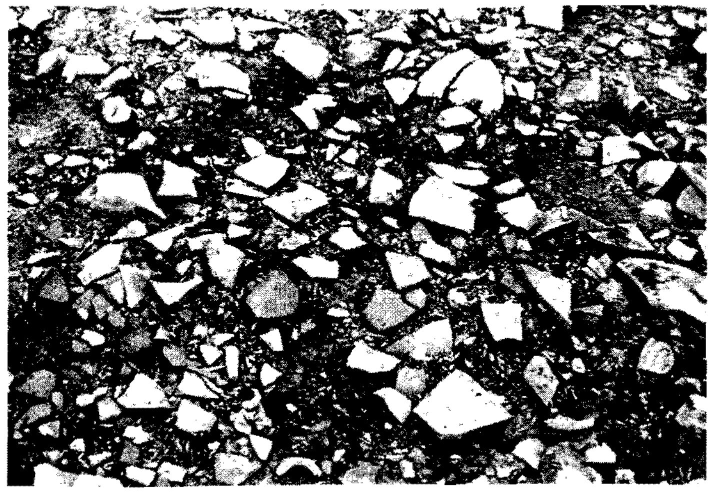
While this paper was in press, Wright has published an extensive series of Munsell color identifications for both paste and surface color of Early Dynastic sherds excavated near Ur (Reference 19, Appendix I). It would be interesting to group them for comparison into the five categories used in this report.

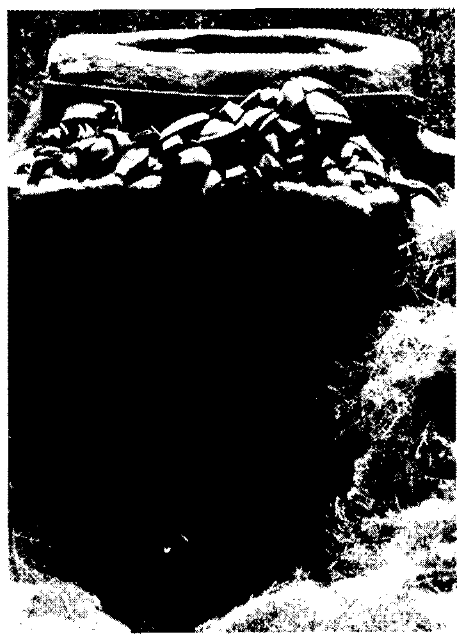
Van Buren Figurine Colors

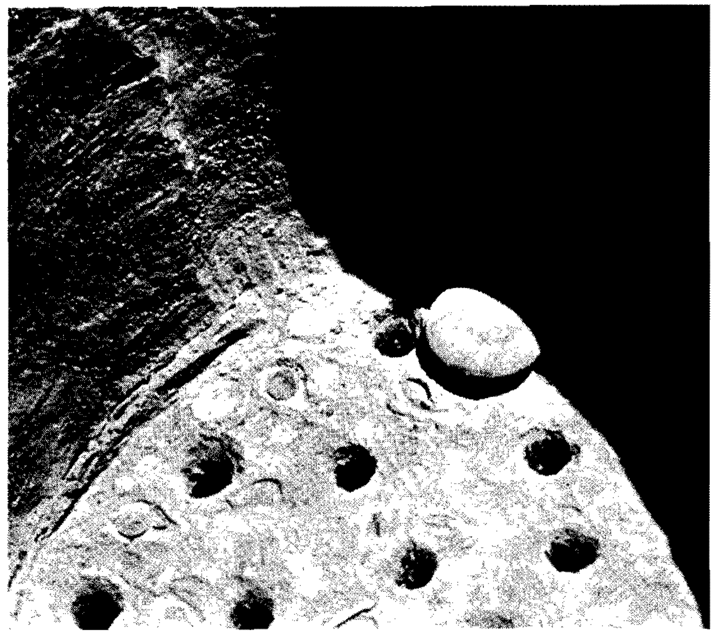
One of the few early publications in which the color of the clay objects is consistently given is that of the helpful and energetic late Elizabeth Douglas Van Buren (Reference 15). In her study *The Clay Figurines of Babylonia and Assyria* many terms were used to describe the colors. I have attempted to group them into five categories using Munsell soil color names, so that her data can be compared with color distributions for the Seleucia figurines. Some of the Van Buren color designations had to be arbitrarily squeezed into this simple classification. The results appear in Table 4.8. The white on brown category is very low compared to that of the Seleucia figurines, and the white group is high. This is doubtless because the surface color often was used to characterize a piece without reference to its core color, which may not have been visible were some of the figurines complete. To compensate for this, an additional column has been added to the table in which these two categories are grouped together. With this addition the color distribution of Van Buren's series agrees well with that from Seleucia. The olive category seems high, but some pieces so termed might have been classified as white by another observer. One value of the Seleucia series is that the color sortings were all carried out by one person. The high percentage of olive figurines could also indicate that these high-fired and therefore durable pieces had good survival value.

Of the 750 figurines described by Van Buren, 62 percent of them came from but eight sites, and their color distributions are included in Table 4.8. Although the individual samples reported from these sites, 28 to 109 figurines, cannot be considered representative of all of the materials excavated, and they may have been made in widely different time periods, it is interesting to compare them for they show surprising consistencies. Assur, Babylon, Kish, and Nippur are sites in upper and central Mesopotamia, the region roughly between present-day Mosul and Diwaniya. Their color distributions are similar to those of the Seleucia figurines. Tello is to the southeast. If the color designations are accepted, there is a remarkably high number of olive pieces. One wonders about increased salt content of the clay or a difference in techniques of firing. It would be interesting to examine an extensive series of ceramic materials from Tello. Warka and Ur are southern sites, and in the sample reported, which certainly is but a tiny part of the materials from these great excavations, the pieces tend to be white to olive in color. Again, this may be due to increased salt content in the soil. Susa is in a different geological region, but its color distribution is like that of Warka, judging from the very small sample from both sites.

This analysis of the Van Buren color designations suggests what could be done with better samples. It would be interesting to examine large collections of figurine fragments from stratigraphically well-controlled excavations to see if differences in the degree of firing could be related to method of manufacture, workshops, types







4.2
Sherd-strewn surface in southern Iraq at Tell Uqair. The softer low-fired ware is broken into the smaller pieces.

4.3
Pottery fired on open hearth with dung cakes as fuel in Iraqi Kurdistan.

4.4
Kiln used in 1968 in village of Charikar in Afghanistan.

4.5
Hearth of kiln in Figure 4.4.

4.6
Early Dynastic III vessels from Ur.

of figurines, etc. The eight classes into which Van Buren divided the 750 figurines used in her study—male, female, gods, goddesses, divine couples, religion and magic, animals, and daily life—bore no relationship to the degree of firing.

The good agreement between the color distributions for the Van Buren and the Seleucia sortings certainly indicates a consistent tradition in the firing of the figurines, one different from that used in pottery manufacture. Speculation as to the type of kiln used when there is at present no archaeological evidence is rather fruitless, but one wonders if it was not small and more like a bread oven than a potter's kiln. A craft tradition different from that of the potters must be recognized for the manufacture of the figurines. Possibly it continued as a household art carried on by the women long after the potters had established separate working establishments.

Kilns and Firing Temperatures

Early pottery of the Near East in the time range 6000–4000 B.C. was fired on open hearths with dung cakes, straw, or brush as fuel. The tradition still continues today in remote villages. I have observed such firings in Kurdistan in northeastern Iraq at the village of Diyana which is near the Rowanduz gorge. A bed of ash served as a hearth, and dung cakes were used both as the fuel and as the kiln. They were stacked to form a vault above the nested vessels, as can be seen in Figure 4.3. This picture was made at the end of the firing as the ashed cakes crumbled and the vessels were ready for removal from the kiln to be decorated with painted lines and dots applied with tar. After the ware had cooled, it had a dull pale brown color similar to that of briquettes made from the same clay that had been fired in the laboratory for 30 minutes at temperatures of 600° and 700°. The ware is sufficiently durable to be used today as water jars and cooking pots. It had not been fired high enough to decompose much of the fine grained limestone in the clay, so disintegration of the vessels due to the rehydration of the lime was no problem. Shepard (Reference 13, pp. 83–84) inserted a thermocouple in the similar hearth loads of pottery as Pueblo women fired their wares. She found that the firing temperatures ranged from 625°–940°C. In Guthe's detailed study of the manufacturing processes of the potters at the Pueblo of San Ildefonso in New Mexico, the pioneer work in ethnographic ceramic studies, he described the simple ovens used to fire the pottery. He found that each firing took about half an hour, the end point being determined by the appearance of the progressively lighter surface color of the pottery. (Reference 20, p. 72.)

It is not yet possible to pinpoint the development of permanent kilns in the ancient Near East, but it was probably in the last half of the fifth millennium B.C. Scott has summarized the archaeological evidence for early kilns (Reference 21, pp. 391–397). Ubaid pottery was consistently high fired to white and often to olive colors (although low-fired ware also existed as the sherds in Figure 4.2 illustrate). Kilns were square or cylindrical tubular structures with a firing chamber at the base into which the fuel was intermittently placed. The perforated roof of this chamber formed the hearth of the kiln on which the ware was stacked. The flames and heat from the burning fuel rose through the hearth holes to fire the ware. The crown of the kiln, judging from present-day practices in villages, was often a temporary structure formed of fragments of fired pots that were placed over the top of the load of green ware. A kiln of this type in use in 1968 near the village of Charikar in Afghanistan is shown in Figure 4.4. One can see the pattern of sunlight that penetrated down through the hearth holes of the empty kiln into the firing chamber. A stack of sherds is waiting to be used to top the next load of unfired ware as a temporary crown for the kiln. The appearance of the hearth can be seen in Figure 4.5 as one looks down from the open top. One casserole from the previous firing still remains in place inverted between flue holes.

In kilns such as that just described there can be great variation in the final firing temperature from the hearth to the temporary crown and from the center of the load to the kiln walls. Drafts on windy days can wreak havoc with firings and cause much of the ware to be overfired. A series of Early Dynastic III vessels from Ur can be used to illustrate this point. They appear in Figure 4.6. A large series of such pots, identical in form, were stored in the Mustansarriyah in Baghdad, the supplementary storage area formerly used by the Iraq Museum. I was permitted to select the five pieces shown and place them in the courtyard to photograph them. They range in color from brown with a spot of surface white, seen on the left, through white on brown, white, very pale olive, and overfired olive. The smaller size of the last piece is probably not accidental; firing shrinkage has occurred.

Kiln design seems to have changed little in the Near East except for the building of permanent crowns on the kilns. But kiln control developed with experience. In general the firing range of 800°–1050° was standard in the simple structures, the end of the firing being determined by the appearance of the ware when viewed through a peep hole. Color changes under approximately black body conditions can be recognized by experienced potters. Thus they can terminate their firings in a consistent temperature pattern.

The development of glazes led to further problems of kiln control. I have suggested elsewhere (Reference 6, p. 91) that 800°–900°C was sufficient temperature to melt the glazes. I have the general impression but no statistical support for the observation that brown to white on brown bodies are characteristic of many of the glazed pieces of Islamic times, for the potter had to avoid the highest temperatures if he were to produce good glazed ware. Kiefer has published an excellent technological study of some glazed Anatolian ware whose body is a siliceous paste rather than clay, a body ineptly termed "faience" by archaeologists (Reference 3). From his analyses of the thermal expansion and contraction of his test pieces as they were fired to increasingly higher temperatures until they began to fuse, he was able to estimate the probable original firing temperatures of the wares. He found that many of them were in the range of 850°–900°C but that the total range was about 750°–1050°C.

In this report suggestions have been made as to some of the many factors that influence the firing temperatures of the pottery of the Near East and of their influences on the colors of the wares. No formal color chart has been developed based on the extensive laboratory experiments, as the intent is to emphasize the need for further studies of local clays and statistically significant samples of sherds, pottery, figurines, bricks, and lamps. As they appear, it will be possible to refine the general statements as to firing temperatures for specific plain, painted, and glazed wares, successive time periods, and regional differences.

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