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I. PLANO-CONVEX BRICKS AND THE METHODS OF THEIR EMPLOYMENT

II. THE TREATMENT OF CLAY TABLETS IN THE FIELD

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I. PLANO-CONVEX BRICKS AND THE METHODS OF THEIR EMPLOYMENT

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By P. DELOUGAZ

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FOREWORD

In the present volume Mr. Delougaz publishes the results of some research work which cannot well be embodied in an account of the excavations proper and which we believe nevertheless to be of value. His first essay deals with plano-convex bricks and the methods of their employment, the second with the treatment of tablets in the field.

PART I

Until a few years ago plano-convex bricks were regarded as the characteristic building material of early Sumerian times. But when Dr. Jordan published his discoveries from the archaic layers of Warka (Erech) in 1929–30, he drew attention to the very definite time to which the use of plano-convex bricks appeared to be limited. While, on the one hand, their use was discontinued a few generations before the rise of the dynasty of Akkad (in Lagash, for instance, by Entemena), they were, on the other hand, introduced at a time when flat oblong bricks had been in use in Mesopotamia for several centuries. Since plano-convex bricks are less appropriate for building purposes than the older type, Dr. Jordan concluded that their introduction was due to the arrival of new people from abroad.

It is clear that this argument elevates plano-convex bricks from a mere archeological curiosity to a phenomenon of some historical significance and that, in consequence, it is desirable to gain a clear insight into the peculiarities of this material and of its use in building. It is here that the Iraq Expedition has a contribution to make; for at Khafaje, on the east bank of the Diyala River, about fifteen miles from Baghdad, this expedition has been engaged for a couple of years in the task of disentangling the features of a number of successive buildings, all made of plano-convex bricks and denuded now down to their lowest courses. Mr. Delougaz, who is in charge of these excavations, is certainly well qualified to discuss the subject; for it is precisely a thorough understanding of the use of plano-convex bricks which has enabled him to succeed in recovering evidence which seemed completely lost. It is thus likely that his account will be of assistance to other excavators who have to deal with remains of the early dynastic or Lagash period. Furthermore, Mr. Delougaz here develops an argument in favor of a foreign origin of plano-convex bricks which seems to the writer to carry more weight than any of those hitherto advanced.

PART II

It is fortunate that baked clay tablets were abundant at the sites explored by the excavators of the nineteenth century, for tablets of unbaked clay present baffling problems when they are found. Yet at some sites—and Eshnunna is one of them—all the written documents consist of this very fragile material, which, moreover, is often found in a state of poor preservation.

We believe that Professor Chiera was the first to put into practice the idea of treating unbaked clay tablets in the field; the tablet kiln built at his request by Mr. Wilenski at Tarkhalan is the prototype of the apparatus now in use at Tell Asmar.

In the following pages a description is given of the method which Mr. Delougaz developed in co-operation with Dr. Thorkild Jacobsen in our work at Tell Asmar. It seems useful to publish an account of this method, as we have found that a considerable portion of our inscribed material could have been neither preserved nor, indeed, even excavated without it.

It is natural that some doubt should be felt as to the advisability of treating tablets in the field at all, since there is ample time and good equipment for such treatment in the museums in which the tablets are to be kept. The answer to this doubt is that some of the tablets found would never reach the museums at all under the circumstances, and others only after having suffered considerable damage in transport.

We are therefore convinced that the adoption, whenever unbaked tablets are found in a moist or salty soil, of the method of treatment described here will result in a substantial increase in the inscribed material which can be saved and thus made available for study.

H. FRANKFORT
Field Director, Iraq Expedition

LONDON
October, 1932

AUTHOR'S NOTE

The author wishes to acknowledge his sincere gratitude to Miss Mary Chubb for her untiring help in arranging the original typescript and reading the proofs, to Dr. H. Frankfort for his constant encouragement and many valuable suggestions, and to Dr. T. George Allen and the editorial staff of the Oriental Institute for their great care in the actual publication of the present volume. By their kind sacrifice of time and labor, this work has greatly profited.

P. Delougaz

Jerusalem
November, 1933

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I

PLANO-CONVEX BRICKS AND THE METHODS OF THEIR EMPLOYMENT

Plano-convex Bricks

DISTRIBUTION

Buildings of plano-convex bricks, both baked and sun-dried, were first discovered in Mesopotamia at the end of the last century by the French excavators at Telloh,[1] and almost at the same time by the Americans at Nippur.[2]

From the first discovery this special building material has been connected with a very early stage of Mesopotamian history, that of the pre-Sargonid or early Sumerian period. Later it was discovered at other sites as well, namely Fara,[3] Bismayah,[4] Warka,[5] Kish,[6] al-ᶜUbaid,[7] Ur,[8] and lately at Khafaje.[9]

There are a few more sites (not yet excavated) where buildings of this material are known to exist from bricks found on the surface. Similar buildings probably exist at other sites, but still remain unknown, since it is only natural that bricks of this remote period should in most cases be hidden deep under the surface. But even the sites

[1] De Sarzec, *Découvertes en Chaldée* I–II (Paris, 1884–1912); Gaston Cros, *Nouvelles fouilles de Tello* (Paris, 1910).

[2] Fisher, *Excavations at Nippur* (Philadelphia, 1905); Hilprecht, *Explorations in Bible Lands during the 19th Century* (Philadelphia, 1903).

[3] Heinrich and Andrae, *Fara* (Berlin, 1931).

[4] E. J. Banks, *Bismya* (New York, 1912).

[5] Jordan, *Die Ausgrabungen der Notgemeinschaft der deutschen Wissenschaft in Uruk 1930/31* (Berlin, 1931).

[6] Field Museum of Natural History, "Anthropology Memoirs" I, Part II (Chicago, 1929), by Ernest Mackay.

[7] Hall and Woolley, *Al-ᶜUbaid* (Oxford, 1927).

[8] Woolley in *Antiquaries Journal* VII (1928) 1–29, IX (1929) 305–39, X (1930) 315–43.

[9] Frankfort, Jacobsen, and Preusser, *Tell Asmar and Khafaje* ("Oriental Institute Communications," No. 13 [Chicago, 1932], hereafter referred to as *OIC* No. 13).

mentioned suffice to prove that plano-convex bricks were in common use over quite a large area of southern Mesopotamia before the rise of the first great Semitic dynasty. In all these excavated sites it was noted that this particular type of brick had disappeared approximately by the time of Sargon I; in fact, very often the term "pre-Sargonid" is applied to the whole period during which plano-convex bricks were used. This period is also often referred to as the "plano-convex period."[9a]

FORM AND SIZE

The name "plano-convex" is due to the peculiar shape of this type of brick. One of its sides projects to form a more or less convex surface and usually bears the impression of a finger and sometimes of the hand (cf. Fig. 6). Figure 1[10] shows one of the very few plano-convex bricks bearing an inscription.

All such bricks are oblong, the proportion between length and width varying considerably. Most of them are comparatively thin, at least at the edges. As regards size, it seems that no great care was taken to obtain a fixed standard. The limits between which their sizes vary are given in the table which follows.[11] In the first season at Khafaje Dr. Preusser observed that of twenty-two bricks the measurements of no two were identical.[12] The many thousands of bricks cleaned during our second season (1931/32) gave us limits of size between .18×.16 and .31×.22.[13] Within these limits almost all possible variations occurred. Originally the variations in size were probably even greater; it would seem that every brickmaker had his own par-

[9a] The absurdity of this term as well as of similar ones ("plano-convex builders," "plano-convex brickwork," etc.) from a literal point of view is obvious. However, for the sake of brevity they will be used below.

[10] De Sarzec, *op. cit.* I 407 and II, Plate 31, No. 1.

[11] The measurements given in the table are taken from the sources quoted on p. 1, nn. 1–9.

[12] *OIC* No. 13, p. 63.

[13] Frankfort, *Tell Asmar, Khafaje, and Khorsabad* ("Oriental Institute Communications," No. 16 [Chicago, 1933], hereafter referred to as *OIC* No. 16) p. 75. All our measurements are given in meters and their subdivisions, in accordance with the usage of the Oriental Institute, although the author feels that on many occasions the use of centimeters as a unit would be preferable.

ticular mold, and bricks of a certain standard size were produced only for such a length of time as his mold lasted.

FIG. 1.—A brick of Urnina from Telloh showing finger mark and turned-up edges.

MEASUREMENTS OF PLANO-CONVEX BRICKS AT VARIOUS SITES

Site	Length	Width	Thickness
Khafaje: smallest crude bricks	.18	.12	.025–.055
Telloh: below Urnina	.20	.13	.05
Bismayah: burnt bricks	.20	.13	....
Kish: semicircular buttress in court 6	.20	.13	.03 –.065
Kish: baked-brick pavement in room 51	.20	.135	.03 –.06
al-ᶜUbaid: burnt-brick wall	.203	.152	.04
Kish: stairway and wall in its vicinity	.205	.13	.035–.05
Kish: blocking of the fosse	.205	.13	.035–.06
Kish: later facing of the outer wall	.205	.13	.035–.06
Kish: walls of chamber 50	.205	.135	.04 –.065
Kish: outside buttress east of stairway	.205	.135	.035–.05

MEASUREMENTS OF PLANO-CONVEX BRICKS—*Continued*

Site	Length	Width	Thickness
Kish: sun-dried brick blocking of the passage at west end	.21	.135	.03 –.05
Kish: burnt-brick filling of the windowlike recesses in the buttress	.21	.14	.035–.05
Kish: pavement of pillared hall	.21	.14	.04 –.06
Kish: later addition in chamber 21	.21	.155	.045–.07
al-ᶜUbaid: burnt-brick platform, 1st dynasty	.21	.16	.04
Kish: walls of the ramp	.22	.14	.04 –.05
Nippur: staircase	.223	.153	.04 –.057
Kish: walls of the ramp	.225	.145	.04 –.05
Kish: platform in chamber 31	.23	.135	.04 –.06
Kish: pavement of pillared hall	.23	.14	.04 –.06
Kish: walls of the ramp	.23	.145	.05 –.06
Kish: burnt-brick walls of chamber 33	.23	.145	.045–.06
Kish: walls of the ramp	.23	.15	.04 –.05
Kish: pavement of chamber 31	.23	.15	.05 –.06
Kish: part of mud-brick column on east side of court	.23	.15	.04 –.07
Kish: pavement of pillared hall	.23	.16	.045–.05
Kish: pavement of chamber 30	.235	.14	.04 –.05
Kish: walls of the ramp	.235	.14	.05 –.06
Kish: baked-brick chamber 60	.24	.15	.04 –.06
Bismayah: burnt bricks	.24	.16	....
Kish: burnt-brick pavement in room 51	.24	.16	.035–.04
Kish: pavement of pillared hall	.24	.16	.05 –.07
Kish: sun-dried brick columns of the portico	.24	.14–.17	.035
Kish: baked-brick pavement in chamber 23	.245	.175	.04 –.045
Kish: baked-brick pavement of chamber 16	.25	.14	.03 –.05
Kish: pavement of chamber 30	.25	.15	.04 –.05
Kish	.26	.18	.064
Kish: burnt-brick pavement of the court	.27	.16	.05 –.06
Telloh: baked-brick construction of Urnina	.28	.15	.05
al-ᶜUbaid: mud-brick platform	.28	.18	.04 –.08
Nippur	.29	.18	.045
Telloh: baked bricks bearing name of Urnina	.29	.20	.07
al-ᶜUbaid: burnt-brick pavement(?)	.292	.203	.063
Telloh: well of Eannadu	.30	.20	.05
Nippur	.305	.195	.05
Fara: largest brick	.32	.16	....
Khafaje: largest unbaked brick	.32	.22	.07 –.11
al-ᶜUbaid: baked-brick patch of pavement	.30–.33	.21–.23	.04

THE MATERIAL

The material used for the making of plano-convex bricks, as we observed in Khafaje, was the alluvial soil of the plain. Since the soil was not carefully chosen, the bricks vary in quality as much as in size. Some of them are of very fine reddish clay, practically pure except for an occasional mixture of chaff, sand, or very fine gravel. Others, gray, almost black in color, contain all kinds of foreign matter including ashes, charcoal, bones, potsherds, fragments of stone, and sometimes even pieces of bronze. Obviously in the latter cases the soil used was taken from near living-quarters and probably from earlier ruins.

THE METHOD OF BRICKMAKING

By very close observation of the form, size, and material of the bricks we can get a fairly accurate idea of the way in which they were manufactured. This should be understood before we attempt to find an explanation for their peculiar shape. We have here one of the many instances where the craftsmanship of the modern inhabitants of the ancient site is so primitive that it illustrates perfectly that of the ancient world. This being so, it is well to devote some space to a description of modern brickmaking methods in southern Mesopotamia.

Modern brickmaking.—The presence of water is a decisive factor in the choice of a place for brickmaking. In southern Mesopotamia the only water supply derives from rivers and irrigation canals; therefore the actual brickmaking takes place in the cultivated fields alongside the water supply. The first step is to dig over such an area and to let in the water.

When the earth is thoroughly moist the mixing begins by a process of treading, done either by the workmen or by animals. Sometimes chaff or sand is added. After the clay has been prepared in this way, it is dug out and conveyed to the place where the bricks are made, a few paces distant. To avoid carrying the clay up from deep holes, but chiefly to prevent such holes being dug in cultivated fields, the brickmaker moves from place to place along the canal, so as to work over a large area of ground to a small depth rather than to go very deeply into a small area. This is easily done, as his equipment consists only of a light wooden frame, and, owing to climatic conditions, the bricks dry in the open air without any permanent shelter. Similar shifting of the place of operations for the same reasons accounts, I think, for the large variety in the consistency of the ancient bricks.

When the clay is put beside the brickmaker, he takes from the heap as much as he can hold in two hands and puts it on the ground in front of him. The ground is covered with fine sand or chaff. He then rolls the lump in the chaff into a convenient ball- or egg-shape, which is placed in a frame and rammed into the corners. The chaff prevents

FIG. 2.—Brickmaker removing surplus of clay projecting above frame

the clay from sticking to the frame. Usually the lump of clay is larger than the frame, so that a surplus projects above it. This surplus nowadays is removed by either smoothing the surface with the flat of the hand (see Fig. 2) or cutting it off with a piece of string or wire. The frame is then lifted and placed alongside the new brick, ready for the next. Brickmaking usually takes place in the spring after the last rains; but the actual building is carried out in the autumn, so that the bricks are left to dry all summer.

This brickmaking does not require any special technical knowledge, so that practically every villager does it occasionally. Each family, with all members taking a hand, usually constructs its own house. Of course there are some men in every village specially skilled in the making and handling of mud bricks; these usually go by the title of *ustādh* or *bannā*ʾ, meaning respectively "qualified craftsman" and "builder." It is interesting to note that, in almost all excavations I have known, the men who most easily acquired the knack of brick-cleaning and wall-tracing turned out to be *ustādhs* or *bannā*ʾ*s* in their own villages. Figure 2 shows a *bannā*ʾ who is one of our most highly skilled brick-cleaners. He has accomplished very delicate work at Khafaje in excavating the gate and other spots no less difficult, and his ability as an excavator is due to the training he received as a brickmaker. When he was

FIG. 3.—Unbaked plano-convex bricks of different sizes used in the same wall at Khafaje.

employed with other men in building our quarters, his bricks were the most regularly made, and he held a record for making almost three thousand a day. If we attribute approximately the same number to brickmakers of antiquity, we can understand why rather large sections of buildings are made of bricks of identical size, not through any intentional standardization of size, but simply because one brickmaker turned out thousands of bricks from his own particular frame. Therefore only in large buildings, where of necessity many brickmakers had to be employed, do we find that bricks of different sizes and proportions were used during the same period, as is the case at Khafaje (Fig. 3).

The ancient bricks.—Let us now study our ancient material in the light of modern methods of brickmaking. Figure 4 shows the cross-section of a typical plano-convex brick. We see the mass of the brick as a shell-like structure produced by rolling the lump before introducing it into the frame. The rough lower surface and the clay which escaped from under the frame at *AA* prove that the frame had no bottom. The edges at *BB* were dragged up by the lifting off of the frame. All these details have parallels in the modern brickmaking described above, and therefore that description can be applied to ancient bricks. The only difference is that in ancient times the surplus of clay instead

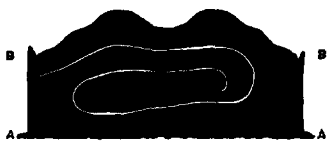

FIG. 4.—Cross-section of a typical plano-convex brick

of being taken off was left above the frame, thus forming the more or less convex upper surface.

The portions of clay (*AA* in Fig. 4) protruding from under the frame have sometimes given the impression that the frame was pushed into a layer of clay instead of the clay being put into the frame, but careful examination of the cases where such procedure was suspected has always revealed that they resulted either from the clay being pressed into the frames very tightly or from the unevenness of the ground below the frame.

I have gone into detail in describing the procedure of brickmaking because it explains, to my mind, the somewhat exceptional shape of this building material and at the same time makes it clear that this peculiar form was not made purposely to meet a special architectural need or even a particular technique of bricklaying. It came about naturally as a result of using a low frame varying from about .03 to .05 in height. Since flat bricks, so thin, would easily break if only sun-dried, there was good reason for leaving the surplus of clay, so that the brick was much thicker in the center. We cannot conclude from the height of the frame that the people in those times could not make deeper frames, for we actually found at Khafaje an indication that the carpenter's craft was well enough advanced to produce considerably wider planks. Figure 5 shows some flint sickles set in bitumen; under them one could distinguish quite clearly the impression of wood on the

FIG. 5.—Impression left in the soil by a wooden plank with nail holes, which once formed part of a box containing flint sickles.

soil, which even bore the marks of two wooden nails. This impression was bounded by two parallel lines, about .10 apart, which showed the width of the plank which had lain there.

As we have seen above, the size of the bricks varies between certain limits. I believe that these limits depend only on the amount or weight of clay which could be handled conveniently. The table which follows gives the measurements of bricks used today in various parts of the world.

USUAL MEASUREMENTS OF MODERN BRICKS*

Place	Length	Width	Thickness
Holland	.18	.086	.05
Belgium	.19	.09	.05
United States	.205	.10	.06
Marseilles	.215	.105	.05 –.07
Denmark	.22	.105	.052
Holland	.22	.105	.055
Paris	.22	.11	.06
Switzerland	.25	.12	.06
Staffordshire, Eng.	.25	.12	.06
Germany	.25	.12	.065
Italy	.25	.122	.05
South England	.254	.124	.076
Spain	.28	.14	.05
Austria	.29	.14	.065
Russia	.29	.14	.08
Austria	.30	.145	.07
Sweden and Norway	.30	.145	.075

* Taken from Albert Granger, *La céramique industrielle* (Paris, 1905) pp. 298–99.

The limits of these measurements are strikingly akin to those of plano-convex bricks.[13a] As it would be absurd to assert that the old Sumerian traditions survive in all these regions, one must admit that in both cases these limits result from a common and natural cause, namely the limits of size and strength of the human hand.

From this conclusion that the amount of clay used for each brick is more or less fixed it follows naturally that the bricks should become flatter when the frame increases in size, and we have observed that this is so. On an average, the frames used in the earlier layers of the ruins at Khafaje are smaller, and the bricks are of a more pronounced convexity which gradually disappears as their size increases. Figure 6 shows plano-convex bricks of various types; however, in all of them the surplus clay was not removed, but was pressed down with the hand.

[13a] Cf. table on pp. 3–4.

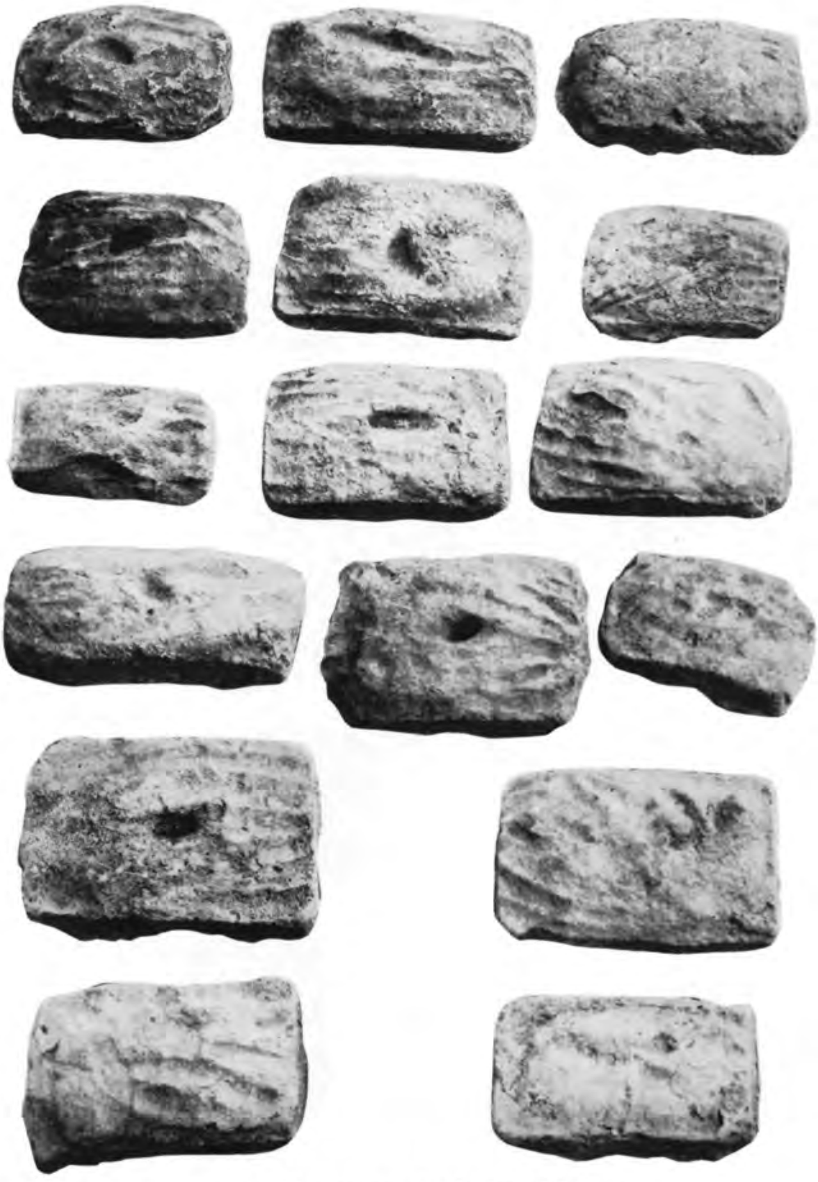

FIG. 6.—Plano-convex bricks from Khafaje

FIG. 7.—Flat and plano-concave bricks from Khafaje

FIG. 8.—Bricks from Khafaje illustrating the transition from plano-convex to flat shape.

Though such bricks are usually plano-convex, sometimes they are almost flat or even plano-concave (Fig. 7). Figures 8 and 9[14] show the transition from plano-convex to flat bricks; it is easy to observe that on the whole the flatter ones are larger. It is interesting to note that

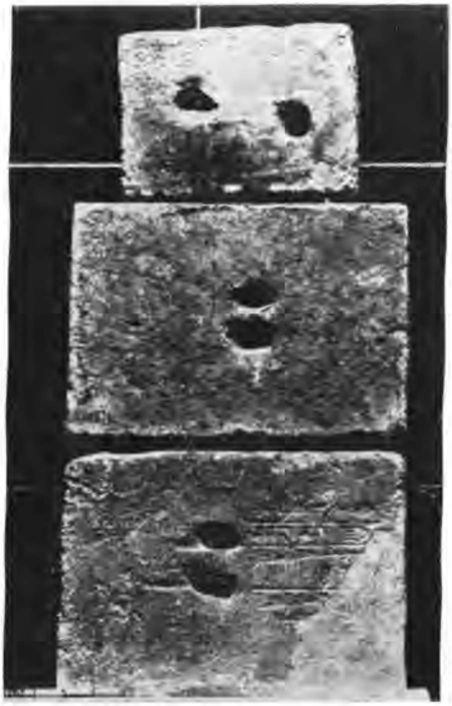

FIG. 9.—Bricks from al-ʿUbaid illustrating transition from plano-convex to flat shape. The lowest one shows an inscription of Dungi.

at this period certain special shapes, still showing the same characteristics, were already being made for special purposes (i.e., for circular structures; Figs. 10 and 11[15]).

PLANO-CONVEX BRICKWORK

Both baked and unbaked plano-convex bricks were used in building. At different sites the proportion between baked and unbaked

[14] Fig. 9 from Hall and Woolley, *op. cit.* Plate XII 7.

[15] Fig. 11 reproduced from Field Museum of Natural History, "Anthropology Memoirs" I, Plate XXXII 1 and 3.

bricks varies considerably. At al-ᶜUbaid, for instance, all the lower part of the big retaining wall is built of baked bricks (Fig. 12[16]); we find in Khafaje that baked bricks were used almost without exception in cases of absolute necessity such as for water basins, drains, etc., while the enormous majority of actual walls were built of sun-dried bricks throughout.

FIG. 10.—Plano-convex bricks from Khafaje shaped for use in circular buildings

THE MORTAR

The mortar used for ordinary building purposes was usually clay similar in consistency to the clay used for the bricks; but bitumen was used to obtain a water-tight structure, mostly in connection with baked bricks but sometimes also with crude bricks. Lime was found in use as mortar at Bismayah.[17] This material was often used as a plaster over the face of the bricks.

[16] Hall and Woolley, *op. cit.* Plate XXIV 1.

[17] Banks, *op. cit.* p. 244.

BONDING

Bricks laid flat.—When plano-convex bricks were laid flat, they were always put with the convex side upward. Their irregular shape and the variation in their proportions made bonding somewhat difficult. In fact, the common opinion of scholars until lately has been

FIG. 11.—Various types of plano-convex bricks and a brick column from Kish

that bonding was not attempted during the plano-convex period.[18] That view, however, is incorrect unless we limit the term "bonding" to modern methods, which are all founded on the proportions of modern bricks. In the latter the width is half the length, or a little less to allow for the mortar in the joints. But if we accept a wider definition and consider bonding as an attempt to lay bricks in such a manner as to avoid successive vertical joins, we find that it was widely and successfully used by the builders who worked with plano-convex bricks.

[18] E.g., W. Andrae, *Das Gotteshaus und die Urformen des Bauens im alten Orient* (Berlin, 1930) p. 87.

FIG. 12.—The corner of the retaining wall at al-ʿUbaid, built over a stone foundation and bonded by means of alternate headers and stretchers.

FIG. 13.—Buttressed drain at al-ʿUbaid showing bonded brickwork

FIG. 14.—Bonded brickwork (of unbaked bricks) in a wall at Khafaje

The excavators who were the first to discover remains of the plano-convex period had already noticed this. M. Heuzey reproduces

FIG. 15.—Bonded brickwork (of unbaked bricks) at the corner of a wall at Khafaje.

sketches from De Sarzec's notebook showing an attempt at bonding.[19] In almost all sites excavated later we find similar attempts made, especially with baked plano-convex bricks (e.g., at al-ᶜUbaid, Figs. 12–13[20]).

[19] Léon Heuzey, *Une villa royale chaldéenne* (Paris, 1900) p. 9.

[20] Hall and Woolley, *op. cit.* Plates XXIV 1 and XXV 1.

A new fact brought to light by the excavations at Khafaje is that quite effective bonding (according to the wider definition) has been

FIG. 16.—Typical brickwork (of unbaked bricks) at Khafaje, marking the outer face of the recessed towers (left) flanking the entrance and of the gateway and gate chamber (under measuring stick).

FIG. 17.—Sketch showing the difference in structure between an exterior quoin and an interior corner.

carried out with crude bricks (Figs. 14 and 15). In fact this flat bonding, especially in quoins and openings in the walls, was so commonly used that it has become a guiding factor for us in distinguishing quoins and doors in the enormous area of intermixed brickwork of different periods (Figs. 16 and 17).

Bricks set on edge.—The most characteristic method of laying bricks in the plano-convex period, a method common to all sites excavated so far, is placing them on edge instead of laying them flat; but it is interesting to observe that this method gradually disappears as the bricks develop into the flatter form.

FIG. 18.—Well of Eannadu at Telloh, showing herringbone pattern

In most cases when the bricks are laid on edge they are not perfectly vertical but slope at an angle. The rows may slope some to the right, others to the left, thus forming a "herringbone" pattern (Fig. 18[21]). The bricks are usually placed on their longer edge, the shorter edges forming the face of the wall. In all cases when the bricks slope they have the convex side upward.

Sometimes rows of bricks standing on edge alternate with rows of bricks laid flat. We can classify the resulting patterns generally as follows (Fig. 19):

a) All bricks standing on edge, the rows sloping alternately to right and left
b) Single row of bricks laid horizontally between single rows of bricks standing on edge

[21] De Sarzec, *op. cit.* II, Plate 57, No. 2.

c) Two rows of bricks laid flat between single rows of bricks on edge
d) One row of bricks laid flat between double rows of bricks on edge
e) Two rows of bricks laid flat between double rows of bricks on edge

The successive rows may slope the same way or in opposite directions, as in *d* and *e* respectively. In varying the number of rows set

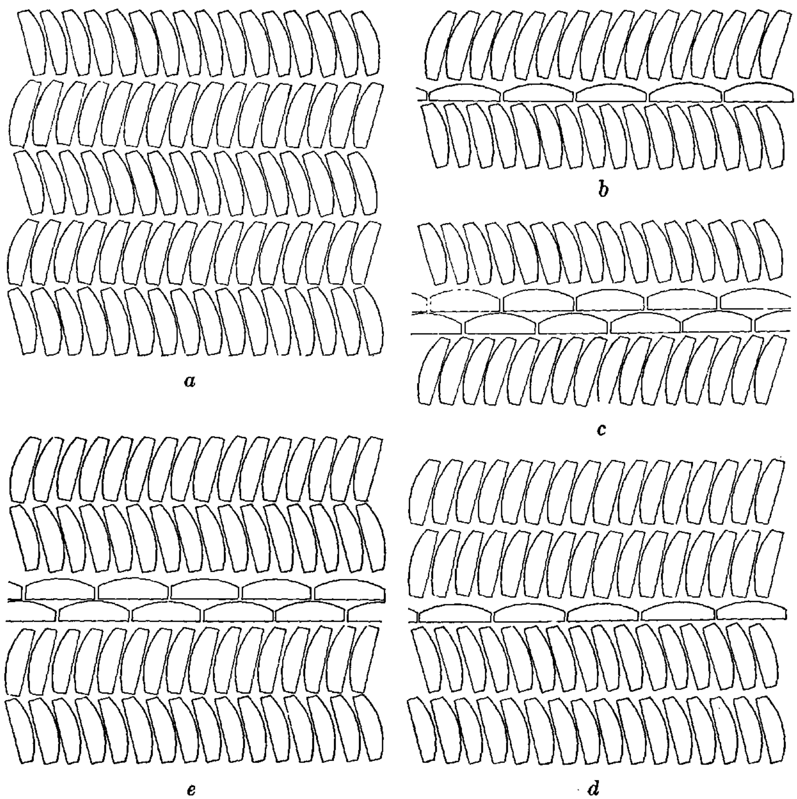

FIG. 19.—Herringbone patterns

on edge and laid flat, all possible combinations of the herringbone pattern can be obtained. This pattern could not have been used for decorative purposes, for in most cases it was covered with clay plaster. Figure 20 shows part of a wall after the plaster had been cleared away. To the right, the burnt plaster as it appeared originally all over the wall can be clearly distinguished.

Hilprecht has pointed out that the herringbone pattern should be of extremely early origin because the sign for bricks in the earliest script evidently represents it.[22] However, early as this technique of bricklaying may be, it is certain that horizontal brick bonding was used simul-

FIG. 20. Wall at Khafaje with plaster partly removed

taneously for specific purposes. The herringbone structure by itself would not allow any openings in the wall to exist, for it is certain that at doorways, for instance, herringbone brickwork could not withstand the pressure of superimposed walls. At such crucial points, therefore,

[22] *Op. cit.* p. 543.

we should expect to find a more solid structure to support the bricks standing on edge. Actually we do find in all such cases bonded bricks laid flat (Figs. 21 and 22). Now the fact that bonded bricks laid flat

FIG. 21.—A doorway of plano-convex brickwork at Khafaje

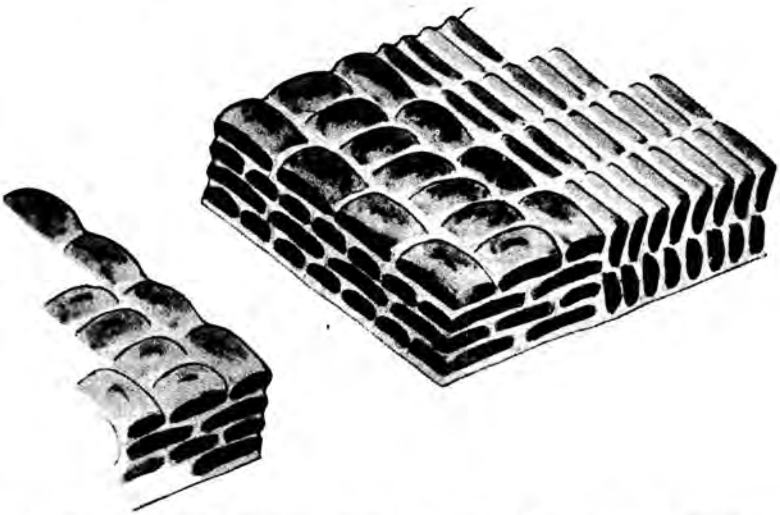

FIG. 22.—Schematic representation of a doorway in a wall of plano-convex brickwork.

are found in walls where the herringbone pattern also occurs is very significant. To my mind it serves as a clue to explain the cause of the herringbone structure, which until now has been more or less of a mystery.

We have good reason to believe that in most cases the plan of a building was marked out on the ground—with ropes or by similar means—before the building was erected, and naturally all openings were also marked. Moreover, since the flat-laid bricks served to support those standing on edge, it follows that the building of the quoins and doorways would have had to be kept slightly in advance, so that at any stage these parts would rise to a higher level.[23] Figure 23 shows a part of a wall between two openings in course of building. Now if the builder had to fill in this space, starting let us say from the left and placing his bricks on edge, he would naturally lean his first brick against the portion of the wall already built. Thus that brick would

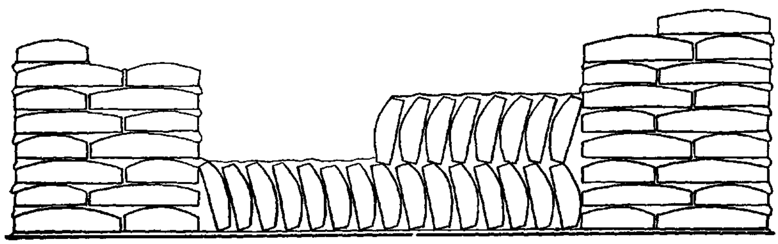

FIG. 23.—Diagram illustrating the way in which the herringbone pattern may have developed.

slant downward to the right (Fig. 23); and since all the bricks in the same row would be set parallel to the first one, the slant would be continued to the right end of the wall. Then instead of going back to his starting-point the mason would very likely begin at his present position for the row above, his first brick leaning against the right end of the wall. And so, working along backward and forward, he would produce *unintentionally* the well known herringbone pattern.

All the known forms of the herringbone pattern (see p. 21) can be explained in this way. Occasionally we find two or more rows of bricks standing on edge, all sloping in the same direction (see Figs. 19*d* and 27). This may have come about by having other masons follow the first one, all starting from the same point. When the upper surface became too uneven, a thick layer of clay mortar was placed over the

[23] A similar method is employed in modern building craft, especially in reinforced concrete and steel-framed buildings.

edges, then one or several rows of bricks were laid flat, and above them bricks were set on edge again.

After analyzing the way the bricks were made, we concluded that their peculiar form did not come about through any architectural or technical need, but merely as a result of rather primitive craftsmanship. A similar conclusion follows from our explanation of the origin of the herringbone pattern.

As we have seen on page 21, most of the walls built in this pattern were covered with plaster (see Fig. 20). Therefore the idea put forward by Professor Andrae in his remarkable work,[24] that this pattern is a survival from a mat or reed structure, does not seem to be in keeping with the facts; for it is unlikely that any people would take all the trouble to evolve a certain method of bricklaying in order to obtain an imitation of a certain decorative effect, and then plaster it over. Neither did it come about, on the other hand, as a result of using plano-convex bricks; for the herringbone pattern can be obtained as well if not better with perfectly regular flat bricks, and also, as we have seen, the plano-convex builders knew how to lay these bricks horizontally when necessity arose. We must therefore look for another reason to explain the use of bricks set on edge which leads to this particular pattern. The only explanation left, to my mind, is habit. If we look around in order to locate the places in which such a habit would be most likely to be formed, we turn naturally toward places where stone buildings are common; for indeed building with certain varieties of stone gives the same effect.

In places as far apart as the Anti-Lebanon, the northern districts of Mesopotamia round Mosul, and the south of France I have observed in modern stone buildings perfectly good examples of the herringbone pattern (Fig. 24). In each case this pattern results from the use of a certain kind of stone, such as limestone or alabaster, which is easily split. The flakes, being fairly regular in shape, are usually set on edge. A more careful investigation proved that the resemblance between plano-convex technique and this type of stone building is borne out in many other points. The use of more solid material or a more solid method of building at the corners and openings is almost universal in stone buildings (the expression "corner stone" for something

[24] *Op. cit.* p. 83.

specially solid survives to this day). As we have seen, all such points that we could observe in Khafaje are built more solidly than the rest of the wall, the material being necessarily the same throughout. But the resemblance goes still farther. In stone building the so-called "rubble technique," where the space between two regularly built wall faces is filled with pieces of stone irregularly laid in mortar, is widespread. In the first season at Khafaje, Dr. Preusser observed in several in-

FIG. 24.—Modern stone houses in northern Iraq showing herringbone pattern in the wall structure.

stances that the interior of the wall was very irregularly constructed. We constantly experienced the same thing in the second season, so much so that occasionally we were in doubt as to whether we had come upon a wall or simply a pile of collapsed brickwork. After careful cleaning of some such walls from the top we found that very often the faces of the wall were fairly regularly built, whereas the center gave the effect of stone-rubble technique (Fig. 25).

To avoid any misunderstanding it may be useful to say that this rubble technique, although quite common, is not the only one in use.

As a matter of fact, the majority of the walls, among them some of considerable thickness, are built regularly all through, which is only to be

FIG. 25.—A wall of crude bricks at Khafaje. Two rows of regularly laid bricks on each side with irregularly laid bricks between them. Note the difference in structure where this wall and the one in background meet.

expected when a regularly shaped material such as brick is used. Although the plano-convex bricks are somewhat irregular in shape and size in comparison with ordinary bricks, they are infinitely more regular than the rough stones used in rubble.

ARCHITECTURAL FEATURES

Oblique angles.—The number of excavated plano-convex brick buildings is as yet very limited, amounting to a few houses (struck by trenching) at Fara, House D at Khafaje,[25] the Sumerian palace of Mound A at Kish, the temple platform at al-ᶜUbaid, and oval inclosure walls at Khafaje, with a square building within them believed to be a temple platform.[25a] It is consequently not yet possible to form a complete picture of the architecture of this period. But one fact seems to be fairly certain, at least for the earlier part of the period. If we may judge from the outlines of two important buildings, the temple platform at al-ᶜUbaid and that at Khafaje, it would seem that the plano-convex brick builders did not have accurate methods of laying out right angles. In both cases the buildings were certainly of such proportions and of such importance that their outlines did not have to be accommodated to other buildings. Yet in both cases the corners are by no means right angles (Fig. 26).

Orientation.—Another point common to these two important buildings is that they are oriented with their angles to the cardinal points of the compass.[26] As the other buildings are well known from earlier publications, I reproduce here part of the plan of the Khafaje temple inclosure only (see Fig. 26). The oblong structure in the middle is what we believe to be the temple platform. The three kinds of hatching represent three building periods—solid black, the earliest period; vertical hatching, the second; and horizontal hatching, the latest. The three thick inclosure walls are similarly marked. This plan is described in more detail in the second preliminary report of the Iraq Expedition (*OIC* No. 16, pp. 63 ff.).

Buttresses.—Besides the interesting fact that the inclosure walls are oval in shape, it is worth noticing that only the two later complexes of the building are buttressed, but not the earlier one. Now buttresses are very common in later Babylonian architecture; and I think that

[25] *OIC* No. 13, pp. 89 ff.

[25a] The latter complex is still in process of excavation.

[26] I intentionally use the terms adopted by Mr. Woolley in the same case (see *Al-ᶜUbaid*, p. 65; his footnote on the same page can be applied to Khafaje also).

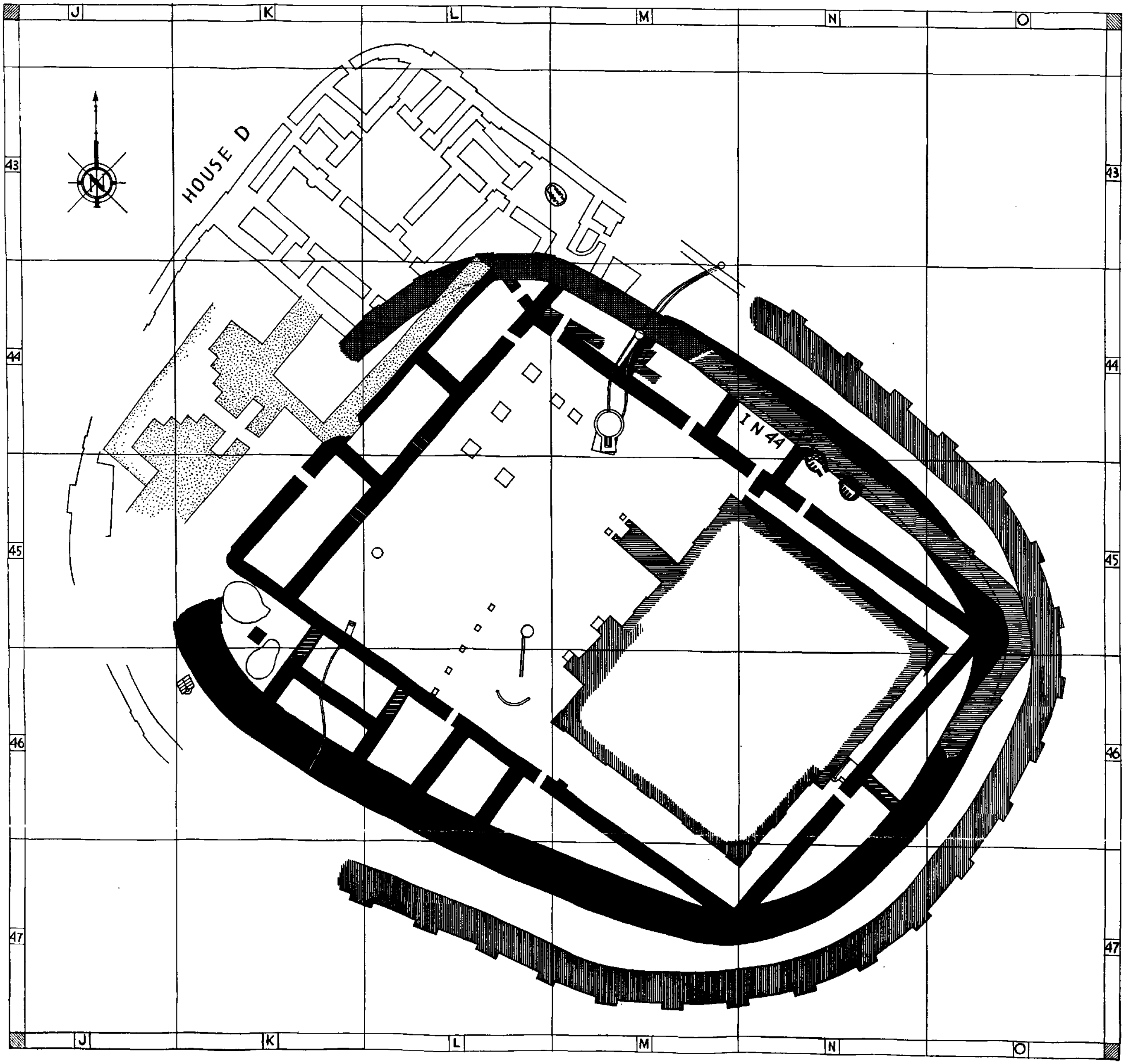

Fig. 26.—Plan of the Khafaje oval

the absence of this feature in the earlier building could be explained on the basis of the view put forward above as to the affinities of the builders. If the builders who first used plano-convex bricks at these sites preserved their traditional technique of building with small bowlders and flakes of stone, they would not be accustomed to buttressed walls. For these cannot be erected successfully with that material.

The introduction of buttresses necessarily increases the number of quoins considerably. As we have seen, all quoins require the use of bricks laid flat, so that this type of bricklaying becomes predominant in buttressed walls. In cases where the buttresses are small and frequent, as in the platform at al-ᶜUbaid, the abundance of quoins finally leads to the exclusive use of bricks laid flat (see Fig. 13).

From the evidence we possess up to date we cannot judge whether the buttressing was originally an invention of the plano-convex brick builders or whether they took it over from other inhabitants of the country, but in any case it does not seem to have occurred in the earliest stage of plano-convex building. Even if buttressing is a survival from or an imitation of archaic wood structures, as is supposed by some scholars,[27] it seems unlikely that the plano-convex builders were the people who carried down the tradition and applied it to brick building.

Stairways.—Of other architectural features it is worth while mentioning the stairways found in the palace at Kish and at al-ᶜUbaid. In Khafaje the two projections northwest of the platform (see Fig. 26) probably indicate the existence of stairways.

Columns.—The use of columns also was known, and specially made bricks were used for this purpose (see Figs. 10 and 11).[28] A series of square brick structures in front of the temple platform at Khafaje may be an indication of square pillars (see Fig. 26).

Round structures.—Round structures above the ground but of too great diameter to be columns are also quite common (Fig. 27). Others, in the form of wells or shafts, built of plano-convex bricks occur at Telloh, Fara, and Kish. Their diameters vary from 2 to 6 meters. Their function is not quite clear. Their form most naturally suggests

[27] Hall and Woolley, *op. cit.* pp. 68–69; Andrae, *op. cit.* p. 76.

[28] Field Museum of Natural History, "Anthropology Memoirs" I 108.

that they are wells, but some of them seem too wide and not deep enough for this purpose.[29] Most of them are executed in pure herring-bone pattern without horizontally bonded bricks, for naturally there are no quoins in a round structure.

FIG. 27.—Circular structure at Khafaje

Arches and vaults.—Vaulting (Fig. 28[30]), another very important architectural feature, was known in those early days. Vaulted drains built of plano-convex bricks have been found at most of the sites (Fig. 29). Some of them attained such a size as to suggest that their builders might have been able to span doorways or even rooms in this manner.[30a]

The Khafaje oval.—If we turn to the Khafaje plan (Fig. 26) we see that the inclosure walls of the three periods are not the same in shape. The two earlier walls are oval, whereas the later one, of which only a portion remains, is straight in its main length and only the rounded corner is left as a trace of the earlier tradition. The earlier, oval plan is unlikely to develop in a flat country, but arises naturally with the need for protecting buildings on top of a fairly regular hill, since the easiest way to build a wall of equal height round a hill is to follow one

[29] Cf. Heinrich and Andrae, *op. cit.* p. 4, where they are called "Rundkeller."

[30] De Sarzec, *op. cit.* II, Plate 57 *bis*, No. 1.

[30a] The correctness of this view was proved in the excavations at Tell Asmar during the third season's work (1932/33).—H.F.

FIG. 28.—A small vault at Telloh

FIG. 29.—A vaulted drain at Khafaje

of its level lines. Hence this type of fortification has been common in hilly countries all over the world from very early times. In high mountains or in a flat plain a straight wall is more likely to give the necessary protection.

In the later building period at Khafaje, when only the corner is rounded and the rest of the wall is built in a straight line, the number of bricks laid flat is increased, and at the same time the shape of the brick approaches the later flat type.

Elevations.—As regards the exterior appearance of the buildings, especially the façades, of course nothing definite can be concluded from the very few structures of this type now excavated.[31] But even in the case of later buildings, many of which have been found in much better preservation and some of them standing to a great height, one has to rely in reconstructing them mainly on pictorial representations found on sculptures and cylinder seals. Yet it seems unlikely that there is "every reason to think" that an early Sumerian building in the south of Mesopotamia should present the same features as an Assyrian palace pictured on a relief of about 700 B.C.[32] In using this method I believe we must depend on pictorial representations of buildings of the same or of a not very remote period.

As it happens, very few pictorial representations contemporaneous with this period are known. One of them, on a piece of a green stone vase found by Captain Cros in Telloh (Fig. 30[33]), has been much discussed. At first M. Heuzey believed that he found in it proof that the Sumerians were acquainted with the art of geometrical decoration.[34] Mr. Woolley in discussing the same piece concluded that it represents wood with all its characteristic features.[35] Afterward M. Legrain also discussed it in a very interesting article on Sumerian art,[36] and finally Professor Andrae has reproduced and discussed it in his remarkable work on temples and building forms of the ancient East.[37]

[31] Mr. Woolley's reconstruction of the façade at al-ʿUbaid does not apply, since he is mainly preoccupied with the superficial decoration.

[32] Field Museum of Natural History, "Anthropology Memoirs" I 84.

[33] Reproduced from Cros, *op. cit.* p. 41.

[34] *Loc. cit.* [35] *Al-ʿUbaid*, p. 69.

[36] University of Pennsylvania, *Museum Journal* XV (1924) 157.

[37] *Op. cit.* p. 76.

Since this piece was originally reproduced in a drawing and not in a photograph, and all other reproductions have been redrawn from that one, it is difficult to form any adequate opinion. However, the interpretation suggested by Mr. Woolley, that it represents a combination of reed and mat work combined with bricks, seems unlikely chiefly because the brick structure on top of the gate would have been supported by reed and mat work beneath against all laws of statics. It may of course represent a structure of reeds only, for such representations are very common on plaques and seals, and usually the realistic treat-

FIG. 30.—Straightened drawing of design on a fragment of a circular stone vase from Telloh.

ment is such that they leave no doubt as to what they intend to portray. This may be a reason for believing that this motive (see Fig. 30) represents the typical herringbone pattern in brick; if so, the vertical lines may indicate the buttresses, and the zigzag pattern in between them the herringbone structure. The meaning of the upper part of the drawing, where there is a downward semicircle, is still obscure.[37a] The Louvre possesses some complete stone vases bearing similar designs; there is a small fragment of a similar vase in the British Museum.[38] Another complete vase bearing a similar motive is reproduced by Contenau[39] and Andrae.[40] These fragments and vases from various sites, all bearing practically identical designs, certainly show that there was a

[37a] During his short visit to Khafaje in the winter of 1932, Prof. Andrae suggested a very ingenious explanation of this feature, which I hope he will find the opportunity to publish.

[38] B.M. 118275; reproduced by Mr. Woolley in *Al-ʿUbaid*, p. 69.

[39] *Manuel d'archéologie orientale* I (Paris, 1927) 276. [40] *Op. cit.* p. 62.

definite tradition for the representation of a building conceivably of plano-convex bricks, but in any case closely connected with the plano-convex period. Let us hope that further excavations will provide material for more positive conclusions on this problem.

DURATION OF THE PLANO-CONVEX BRICK PERIOD

The end of the period during which plano-convex bricks were used cannot be sharply defined, for the bricks gradually became flatter and the proportion of bricks laid flat gradually increased (see p. 20). We do know that when Sargon of Akkad came into power, square flat bricks bearing his name were used for public edifices. But this does not mean necessarily a new invention, for flat bricks were known before plano-convex bricks[41] and may have survived throughout this period. The beginning of the period was more sudden, for this type of brick can certainly not be considered as a form evolved from the earlier type of large flat bricks. We have no means of estimating the length of the period, even approximately, in years. However, judging from the fact that several periods of buildings and rebuilt houses use the same material, the tendency now is to allow a much longer time for this period than has been the case heretofore. According to the opinion of such an eminent scholar as Professor Langdon, the period lasted over a millennium in Kish.[42]

It is also difficult to draw sharp limits for any subdivisions in this period. However, from the point of view of the technique of building I think it is possible to divide it into at least two periods, the first being that in which all the traditions of stone building survive, while the second can be considered as a natural link between the old and the new brick technique. According to this subdivision, the first period is that of plain walls, herringbone technique, and bricks with a high camber; the second, that of buttressed walls, bonding, and flatter bricks.

It must be made clear that this distinction can be applied only to

[41] In both Warka and Ur the strata below the plano-convex bricks revealed buildings made of flat bricks. See Woolley, "Excavations at Ur," *Antiquaries Journal* X 333; and Jordan, *Dritter vorläufiger Bericht über . . . . Uruk . . . .* ("Abh. der Preuss. Akad. der Wiss.," 1932, Phil.-hist. Klasse, Nr. 2) p. 19.

[42] "A New Factor in the Problem of Sumerian Origins," *Journal of the Royal Asiatic Society*, 1931, p. 594.

important buildings, where buttresses are usual in later times, because private houses and buildings of minor importance have plain walls in any case. The two periods seem to be differentiated also by the style of

FIG. 31.—A green stone plaque from Khafaje

sculpture and reliefs. Two plaques found at Khafaje (Figs. 31 and 32) clearly show great differences in style. The first was found in connection with the first building period; the second, in House D, associated with the second period. A difference in script also seems to point to a

FIG. 32.—A plaque of alabaster from Khafaje, found in a later stratum

subdivision into two periods. It is a matter for observation in the future whether the same distinction holds good for household equipment, pottery, etc.

SUMMARY

Our main conclusions in the foregoing study were that the peculiar form of plano-convex bricks resulted from the brickmaking technique, and that the characteristic herringbone pattern was produced likewise as a result of a technical process, namely building with bricks set on edge.

On the other hand we have seen that a similar building technique was very common and still is used in the foothills between the mountains and the plains where certain kinds of stone are used.[43] Similarity in technique between these stone buildings and those made of plano-convex bricks can be observed in other details also, such as the special way of building at quoins and openings and the so-called rubble technique for the insides of walls. Moreover, the peculiar shape of the earliest inclosure wall at Khafaje is foreign to the plain but usual in hilly country.

All these points cannot be due to mere chance; they suggest that the early inhabitants of Mesopotamia brought their building traditions from the foothills, where stone buildings possessing all these features are still in existence. On the other hand there is no doubt that the plano-convex builders were closely connected if not identical with the bearers of the early dynastic Sumerian civilization. The origin of the latter has been one of the most discussed problems in the last few years. To quote Professor Langdon: "Early Mesopotamian racial and cultural origins are at present in a hopelessly obscure tangle,"[44] which many orientalists are trying to unravel as far as possible from the evidence in hand. Some are looking for the origin of the Sumerians in countries outside Mesopotamia,[45] while others are trying to establish a theory of the evolution of this civilization in Mesopotamia itself.[46]

[43] Dr. Jordan also, while excavating in Warka, had the impression that the plano-convex bricks and their use were not in harmony with the building traditions of the country. See Jordan, *Zweiter vorläufiger Bericht über . . . . Uruk . . . .* ("Abh. der Preuss. Akad. der Wiss.," 1930, Phil.-hist. Klasse, Nr. 4 [Berlin, 1931]) p. 18.

[44] *Op. cit.* p. 596.

[45] E. Speiser, *Mesopotamian Origins* (Philadelphia and London, 1930).

[46] H. Frankfort, *Archeology and the Sumerian Problem* ("Studies in Ancient Oriental Civilization," No. 4 [Chicago, 1932]).

The present inquiry into the method of building, undertaken from a purely technical point of view, brings into the discussion a new factor which certainly favors the first opinion, at least as far as the builders with plano-convex bricks are concerned. Moreover, it introduces a new detail which seems to have escaped notice until now, namely, that if this technique is foreign to the country, its origin should be looked for not in the high mountains but in the foothills rising from the plain. Considering that buildings of flat bricks have been found below those of plano-convex bricks, we can easily imagine that when the newcomers left their usual building material behind upon descending from the hills into the plain, they had to adopt the material used in the new country, but for a certain length of time continued to apply their own building traditions to this new material. It is most likely also that the original building traditions of the country survived and developed throughout the plano-convex period, and accordingly one may expect to find buildings of flat as well as of plano-convex bricks during the same period.

Of course, if the invaders were the stronger people and took over all the political power, they would naturally apply their own methods of building to the most important public buildings, such as palaces, temples, fortifications, etc. Thus it is only in the private houses of the poorer class, in settlements where conquerors and natives lived side by side, that the two building traditions can be expected to be found together. As yet this is a matter of hypothesis, for only a few settlements have been excavated and the future alone can confirm or refute our contention. But it seems that an indication for such a parallel development of the two cultures can be observed to a certain degree already in quite a different field, namely in the stylistic qualities of art objects such as relief plaques and especially in the much more numerous cylinder seals. A careful study of early Sumerian cylinder seals from this point of view, taking into account differences in materials, treatment, and especially style, would probably throw some light on this problem. Here, however, we can only indicate such a possibility, since a further digression would only distract from the particular subject under discussion.

II

THE TREATMENT OF CLAY TABLETS IN THE FIELD

Excavation

The first precaution necessary is to train all the workmen to recognize tablets. It is not difficult for a workman trained to trace crude brick walls and accustomed to distinguishing slight variations of color in the clay to recognize a tablet, for usually the tablets are of finer clay and differ in color from the surrounding earth. It is a good practice to

FIG. 33.—Tablets as found and partially excavated so that they can be removed *en bloc.*

insist that the tablet (as well as any other object) should be left *in situ* until one of the staff is informed, and only a specially trained man should remove it from the soil.

The difficulty of removal varies according to the character of the soil in which the tablet is found. When it is imbedded in soft débris, such as ashes, it can be extracted by hand, and little skill is required. However, this is not usually the case; tablets are sometimes found in the most unexpected spots, inside brickwork, for instance, or practically on the surface of the ground, exposed to the elements. Very few unbaked tablets are found unbroken, most of them being at least cracked, if not reduced to small pieces. In all cases it is better to dig round the tablet so as to take it out in a lump of earth (Fig. 33) and to leave the actual cleaning of the inscribed surface to be done in the workroom; if possible the epigrapher himself should do the cleaning and thus at the same time get a glimpse of the contents. However,

FIG. 34.—Tablets partially strengthened with paraffin

when the condition of the tablet is such that the handling of it entails risk, it is better to restrain this natural curiosity until after the baking.

If, as often happens, many tablets are found heaped together, they should not be taken out individually, for there is always the risk of damaging one tablet in the attempt to extract another. They should be removed together in lumps of earth small enough for practical handling (cf. Fig. 33).

Often, however, the tablet is too much damaged to be taken out of the soil by itself, and the surrounding soil, on the other hand, is not of a consistency which makes its removal in a lump together with the tablet possible. Such is the case, for instance, when it contains ashes, charcoal, etc. Then the tablet needs strengthening before it can be removed; the material that seems most suitable for this purpose is hard paraffin wax (Fig. 34). The wax should be melted and heated to a high temperature (about 200°–250° C.) before being applied to the

FIG. 35.—Apparatus for heating paraffin in the open air

object, for only in that condition will it penetrate into the cracks and under the surface far enough to provide a solid backing when cold. Figure 35 shows a simple, cheap, and practical device contrived in camp for heating the paraffin. It consists of a spirit stove put in a corner of an empty petrol tin and kept in position there by flaps cut from the bottom of the tin. The paraffin is melted in an ordinary enamel cup and applied by means of either a metal pipette or a brush. This apparatus, although primitive, proves quite satisfactory. It can be carried about very easily; the tin shelters the flame from the wind and at the same time keeps the dust off the wick and the paraffin. The fire must be regulated so as not to let the paraffin boil; for the fumes, besides being rather unpleasant, catch fire easily. A brush put into the liquid at boiling temperature (390°–430° C.) will burn almost at once. A simple way of cooling overheated paraffin rapidly is to drop in a few solid pieces, which will absorb a considerable amount of the heat. A lid should be kept in readiness to be put over the cup in case the paraffin catches fire.

The use of paraffin is recommended for more than one reason: it is obtainable everywhere, is comparatively simple to handle in the field, strengthens the clay sufficiently, and evaporates completely in the subsequent baking of the tablets. Since the baking of tablets treated with paraffin requires some special precautions, the wax should be applied only in the degree required by the state of the tablet. In particular, one should be careful to leave as much of the surface as possible untouched, so that moisture can evaporate freely before and during the baking.

Other materials, such as plaster of Paris, can be used in special cases, when the tablet is so near the surface that one side is completely gone and the remainder very thin, or when the tablet is so large and heavy that paraffin would not provide an adequate support. The disadvantage of plaster of Paris is that it must be applied wet, so that some water inevitably penetrates into the tablet and causes damage. Yet plaster of Paris is the obvious material to use when envelopes of tablets are found; for usually they bear on the inside the negative impression of the text of the tablet, and by applying plaster of Paris to this negative we get casts of the actual tablets. If the envelope is found in several pieces, it may be possible to reconstruct the whole tablet by putting together the casts obtained from them. Of course, it is advisable to bake the envelope before this procedure, so that the wet mass will not spoil it.

If tablet fragments are neither too numerous nor too small, they may be wrapped, as found, in tissue paper instead of being soaked with paraffin. There is no need to remove this paper and risk mixing the fragments before baking.

RECORDING AND CATALOGUING

A careful record should be taken in the field as to the locus and stratum of each tablet before it is removed to the magazine, where it is first catalogued by the epigrapher and then left to dry for a certain period before being baked.

FIRING

Before proceeding with the actual description of the firing, it may be well to survey briefly the most important changes undergone by clay during the process of baking.

THE EFFECTS OF FIRING ON CLAY[1]

All unbaked clays contain a certain quantity of water added originally to obtain plasticity. The rapidity with which the clay can be dried out depends on the size of the surface exposed to the air and the latter's relative humidity, which rapidly decreases as the temperature rises and quickens the drying correspondingly. As the water at the surface diminishes, the moisture from the core is drawn out by capillary action and the clay contracts. If the surface gives off more moisture than can be drawn simultaneously from the core, it will naturally contract more quickly than the interior, with the obvious result of cracking, so that it is essential for the drying process to be slow enough to allow even contraction.

A gradual warming to boiling point (100° C.), or in certain conditions to a somewhat higher temperature, will completely free the clay from all moisture. This ends the first stage of the baking. We may assume that at about 120° C. the clay is perfectly dry, but this does not mean that it contains no water. Even at this temperature, there is about 15 per cent of water in its chemical composition ($x\text{SiO}_2+y\text{Al}_2\text{O}_3+z\text{H}_2\text{O}$).[2] Raising the temperature still more eliminates this water and causes further contraction. This process, continued to a temperature of just over 400° C., results in a fundamental change in the physical properties of the clay. During the first stage of baking we could, by adding water to take the place of that which had evaporated,

[1] It is interesting to note that although the use of baked clay is one of the most ancient and universal crafts surviving into modern times, much of the practical knowledge involved is based on purely empiric traditions; many of the processes that take place in the clay have not found as yet a satisfactory scientific explanation. For example, the usual practice in the well known Wedgwood factories is to "season" certain varieties of clay for seven years before bringing them to the workshop; and it is said that certain Chinese potters prolong the process of seasoning for decades, while others claim that a few weeks or even days are enough.

[2] The x, y, and z are small integrals varying respectively for different kinds of clay.

have brought the clay back to its plastic state, but it is now impossible. Clay that has once lost the water which forms part of its chemical composition can never be made plastic again. The second stage of the baking, then, takes place between about 120° C. and the temperature of dull red heat, about 500° C.

During this and part of the next stage all the volatile matter disappears, and the organic matter gradually decomposes and burns out. The salt crystals lose their water of crystallization, and, in certain conditions, most of the calcium, magnesium, and iron carbonates are converted into oxides. The third stage of firing ends at about 900° C., the temperature of red heat. The more organic matter the clay contains, the longer is the time required at this temperature.

The last stage is from 900° C. upward, when the clay, free from water as well as from organic and other volatile materials, undergoes changes due to the fusing of some components, mostly alkaline. If the latter are present in small proportion, the result is greater solidity of the clay; but if the proportion of alkalines is large, the clay vitrifies and loses its original shape altogether. The clay of the tablets that we have found is of such composition that it stands a temperature of about 1,500°–1,600° C. without vitrification. At this temperature the firing should be finished.

These changes in the composition of the clay depend not only on the temperatures reached, but also on the length of time each temperature is maintained. For instance, if clay is heated too rapidly to a temperature of 120° C., not all the moisture will necessarily evaporate. Most probably the water in the core will be overheated, thereby causing small explosions and cracking of the clay. Similarly we can easily cause the clay to vitrify before all organic and volatile matter has disappeared.

The method by which the firing is brought to an end may produce either an oxidizing or a reducing atmosphere inside the kiln. This is of great importance in baking manufactured pottery, because it affects the color of the ware, but is not important in our case.

The cooling of the baked clay can be accomplished fairly rapidly from the highest point down to 1,000° or 900° C., but after that point cracks are likely to appear unless great care is taken to cool it as gradually as possible.

THE KILN

Since wood and coal are expensive and difficult to transport in Iraq, the fuel that suggests itself to us is naturally crude oil, which is both cheap and easy to transport. But its chief advantage lies in the very accurate regulation of temperature which can be obtained by firing liquid fuel. There are three ways of burning oil: (i) using a wick, (ii) vaporizing the oil by heating it before it reaches the air, and (iii) atomizing it. Only the last process, however, gives good results with crude oil of high viscosity. The British troops, after the occupation of Iraq, evolved for domestic purposes the very simple method of burning crude oil by dropping water on the heated oil. The burner I designed for the Iraq Expedition is a development of the same idea. Though it embodies no new inventions, I am describing it in detail, for, though simple and easily contrived by a local tinsmith, it fulfils all of the requirements for tablet-baking; moreover, crude oil will no doubt continue to be the most convenient and cheapest fuel in the Near and Middle East where clay tablets are found, owing to the installation of an oil pipe line from the oil wells of Iraq to the Syrian and Palestinian coasts.

In the diagram of our apparatus (Fig. 36)[3] *A* is the oil storage tank, the oil being poured in from above through the funnel (*K*), which is provided with a strainer of wire netting. A pipe conducts the oil into the oil-warming tank, which consists of a double reservoir; the oil enters the inner compartment (*B*), and the outer one (*DD*) is filled with hot water. This warming is necessary because the crude oil of Iraq is of high viscosity and becomes gelatinous in normally cool weather, thus making perfect regulation of the fire impossible.[4] The inner tank, usually hermetically sealed, can be opened by unscrewing the top cover (*R*). To empty tank *B*, valve *b* should be closed and the

[3] Unfortunately the original drawings from which the burner and the kiln were executed could not be recovered from the Arab contractor who built the headquarters of the Iraq Expedition at Tell Asmar, and therefore the drawings given here differ in some details from the apparatus actually in use.

[4] We installed a central hot-water system by putting an iron tank into a structure similar to the kiln (at left of kiln in Fig. 38). In Fig. 36 the pipes containing valves *e* and *d* are the hot-water pipes from this tank which supply the water for the warming as well as for the burning of the oil. This water can, of course, be supplied in any other way, but the water in the warming tank must be hot.

oil drained out by opening valve *c* and the valve connected with funnel *R;* only then can the top cover be unscrewed.

Inside tank *B* there is a device for installing a filter to be used if the crude oil contains an abnormal percentage of solid impurities, such as

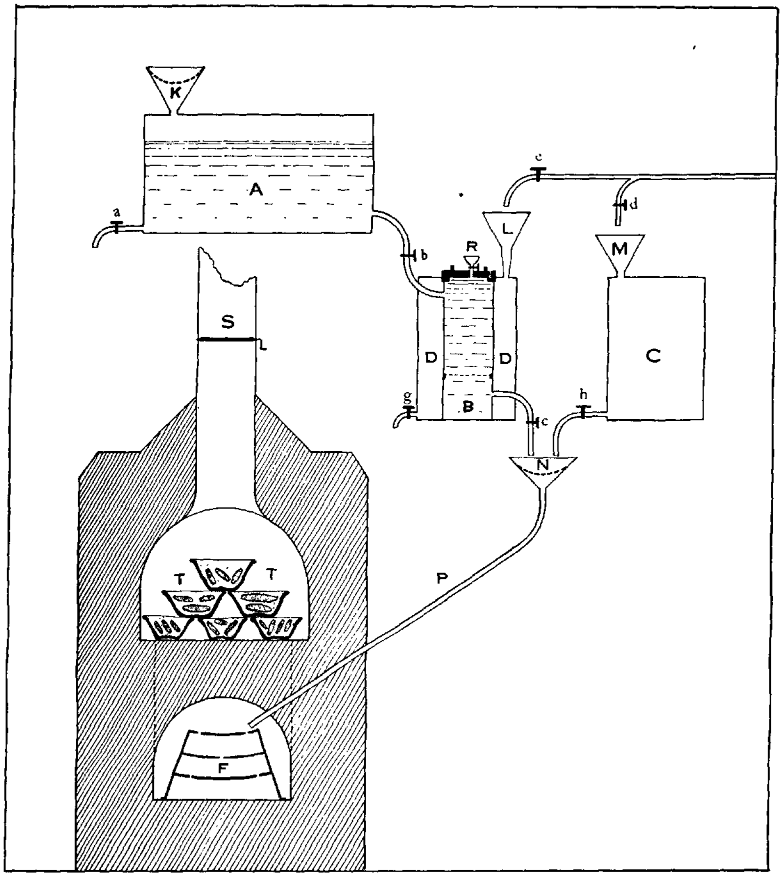

FIG. 36.—Diagram of the oil burner and the kiln

sand and gravel, which might affect valve *c* and thus interfere with the proper regulation of the oil. For the same reason a space is left between the bottom of *A* and the mouth of the pipe leading to *B,* as well as between the bottom of *B* and the mouth of the pipe leading to the oil regulator valve (*c*). These two traps usually prove sufficient, so that the filter has only rarely to be used. The water which accumulates at the bottom of *A* can be drained off by a special tap (*a*). From the oil regulator (*c*) the oil drops into a funnel (*N*), which is covered with wire netting to prevent the flame from projecting, and then through the pipe *P* to the grate *F* in the lower part of the kiln.

C is the water tank; the valve *h* is the water regulator. The water also passes through the funnel *N* and the pipe *P* to the grate *F*. This

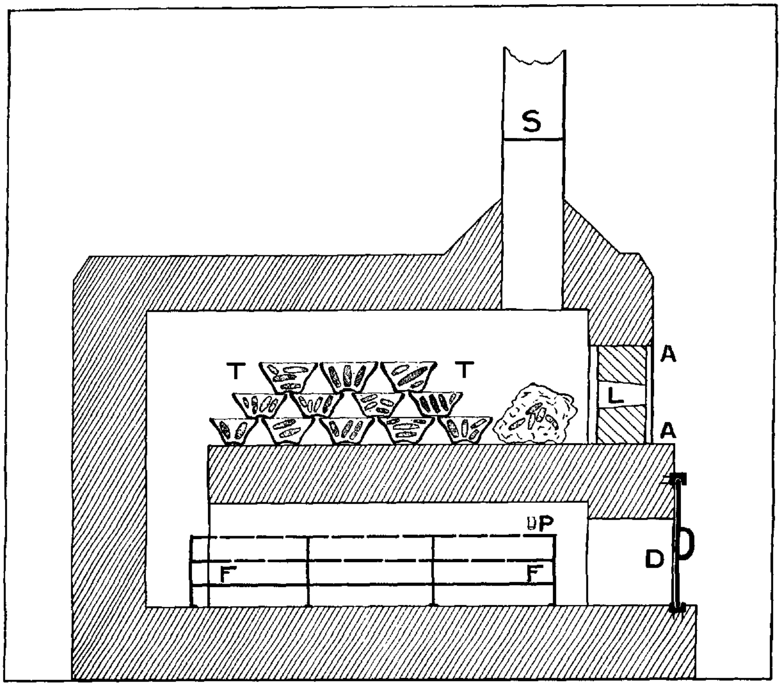

FIG. 37.—Cross-section of the kiln

grate consists of a few thick iron plates, one above another, pierced with holes so spaced that a hole in the top plate comes between two holes in the one below. The lowest plate is unpierced. Figure 37 shows a longitudinal section of these plates.

The kiln proper consists of two vaulted compartments; the lower (*F*) serves as a fire compartment, and the upper holds the tablets (*T*) which are to be baked. The door (*D*) to the lower compartment (see Fig. 37) is an iron plate which slides on grooves, so that the size of the aperture can be regulated. The kiln is built of local bricks of rather poor quality which are far from being fireproof, so that they are often damaged by the high temperatures reached in the kiln. Repairing these damaged parts with clay of good quality (which naturally is baked when the kiln is used again) is often quite satisfactory.

To start a fire the oil is introduced in a very small trickle, which drops on the grate and is ignited by a handful of straw or a piece of rag used as a wick. Crude oil being very difficult to ignite under these conditions, the flame is very small at first. Since the combustion is far from being complete at this point, much smoke is given off, and the temperature rises very slowly. This stage can be continued indefinitely. Although for domestic purposes this would be inconvenient, it is an advantage in the process of baking tablets, for it is thus possible to carry out the first stage of the drying as slowly as is needful.

In the meanwhile the grate, especially its upper plates, is gradually warmed and in the first few minutes reaches a temperature of over 100° C. It is possible to raise the temperature quickly from this moment by opening the water regulator and allowing water to drip in. When the first drop reaches the hot plate, a small explosion occurs which atomizes the oil and thus brings some of it into its most combustible form. The flame grows rapidly in this way, the amount of oil burnt increases, and the temperature of the grate rises. This in turn enables more water to evaporate and more oil to be atomized, so that the capacity of the burner increases; that is, a larger quantity of oil can be burned, and consequently the temperature can be raised. However, the process cannot be continued indefinitely, for the burner's capacity depends not only on the quantity of fuel but also on the amount of oxygen available, that is, on the strength of the draft. This in turn depends on various features of the kiln: the size and structure of the fireplace, the grate, the chimney, and so on. Only experiments can show what adjustment yields satisfactory results, for these points make our calculations extremely complicated. Since in any kiln the temperature can be reduced by diminishing the quantity of fuel and by changing the proportions of oil and water, it is advisable from the beginning to aim toward producing the maximum temperature by means of a strong draft. The three features of the kiln which are relatively easy to change and which affect the draft to a certain degree are the space through which the air is let in, that is, the door of the grate, the position of the grate in its compartment, and the chimney. If the draft does not prove satisfactory from the beginning, slight alterations in these matters may give better results.

The velocity of the air passing through the chimney, all other factors being constant, is proportional to the height of the chimney and the difference in temperature between the air inside the kiln and chimney and that outside. Thus by heightening the chimney we can obtain a greater draft. As for the other factor, the temperature, only the mass of air passing through the kiln counts, not the volume. Since the density of the air decreases as the temperature increases, it is obvious that the rising temperature increases the draft only to a certain limit. Simple physical laws show that this limit is reached (again all other factors being invariable) when the temperature inside the kiln and chimney (T° C.) is double that outside (t° C.) plus 273° C.[5]

THE BAKING

When the tablets which are stored in the magazine have dried as much as they will in the open air, they are packed in sand inside pottery bowls. These bowls, according to their size, contain from one to five or six tablets. The bowls are numbered, the contents of each carefully registered, and, when necessary, the size, contour, and a brief description of the contents recorded. Since the sand should be as clean as possible, it is well to sift, wash, and dry it before use. Even though difficult, it is advisable to procure sand of good quality, because the same sand can then be used indefinitely. The packing in sand serves many purposes. It keeps the fragments of the cracked tablets together and protects them from a too sudden change in temperature (since the time of the alchemists the properties of the so-called sand bath have been known in laboratories). It also keeps the tablets from being smoke-blackened; thus the natural color of the clay is retained. Finally, in the case of tablets treated with paraffin, it absorbs this material as it melts and at the same time holds the fragments in their original positions. Paraffin fumes being inflammable burn only when they reach the surface, and there is thus no danger of the direct flame damaging the tablet.

[5] 273° C. is the difference between 0° C. and absolute zero. The simple formula is: $T=2t+273$.

Paraffin wax melts, according to the variety used, from about 40° to 52° C. or from 52° to 60° C., and boils from 350° to 390° C. or from 390° to 430° C. Thus a temperature of about 60° C. must be maintained long enough to allow all the paraffin to melt and penetrate into the sand in which the tablets are placed; and a temperature of about 350° C. long enough to allow the paraffin to evaporate gradually without being overheated and to allow its fumes to reach the surface and burn out. Since the temperature of liquid paraffin coincides with that at which the water from the clay is dispersed, as little as possible of the surface of the tablet should be covered by the paraffin so as not to interfere with the evaporation of the moisture (see pp. 42-43).

The bowls containing the tablets are set in the kiln so as to leave a free and regular passage for the draft. This is made easier by the shape of the bowls used, large at the top and narrow at the bottom (Fig. 38). Then the upper chamber of the kiln is closed with bricks, leaving only one small aperture (*L* in Fig. 37) about 10×10 centimeters, or even smaller, which can be covered with thin glass if necessary. The opening should be placed so as to allow a good view of the whole interior of the chamber. The installation of a pyrometer involves difficulties which cannot be overcome in an ordinary camp, but this sighthole acts as a substitute by enabling one to obtain a rough idea of the temperature reached inside the kiln. It can be used also for observing tests with Seger cones, if they can be obtained. It is advisable to have, especially for test baking in a new kiln, a complete set of cones from O 22 up to 42 besides a few incomplete sets representing intervals of about 100° C.—for instance, O 22, O 18, O 14*a*, O 10*a*, O 5*a*, 1*a*, 6*a*, 10, 14, 18, etc.—allowing two or three cones for each baking.

After the fire has been started in the way described, it is kept small for about two or three hours while the temperature of the tablets is slowly raised to 100° C. Sometimes this first period can be shortened, but it should be considerably lengthened when baking fresh tablets that have been extracted from wet clay. In such a case as well as when the tablets have been treated with paraffin (see p. 41) the necessary gradual rise in temperature can be brought about by placing one or two lighted Primus stoves at the far end of the fire chamber for two or three hours before lighting the oil burner. During this first stage the combustion is not complete, and the inside of the kiln is gradually covered with a thick layer of soot—very fine carbon powder that will be completely burned off in the final stage of the baking.

When it is judged that all the moisture has evaporated from the tablets, the fire is increased by means of the oil and water regulators

FIG. 38.—Tablets packed in pots filled with sand are being placed in the kiln. The water-heater is shown at the left. Between the two heaters is seen part of the crude-oil burner.

(*c* and *h* in Fig. 36). The second stage of baking continues for about three hours. As a rule even then the combustion is not perfect, and a certain amount of smoke will still be produced. At about 450° to 500° C. (just before dull red heat) the temperature should be kept constant for one to one and a half hours.

To increase the temperature beyond this point we begin by augmenting the amount of water, and, since the grate is by this time red-hot, the explosions of the water become more violent and more oil can be consumed. Looking through the sighthole into the upper compartment, one can now see tongues of flame appearing at the far end. When the proportion of oil and water is adjusted so that the smoke disappears from the chimney, the fire can be made larger by increasing first the stream of water and then the stream of oil, until the smoke disappears again, and so on, until by very delicate adjustment we obtain a large, steady flame that should be kept as uniform as possible. The water at this stage acts not only as a physical factor in atomizing the oil while boiling, but a certain quantity of it dissociates into hydrogen and oxygen on coming in contact with the red-hot grate, and these two elements take an active part in the chemical process in the upper chamber where high temperatures are reached. The inner surface of the kiln and also the bowls containing the tablets become red-hot. It takes from two to two and a half hours of smokeless fire to obtain this result, and the temperature as it rises can be approximately judged by the intensity of the glow within. Thus we pass to the last stage of the firing.

The glow should be kept at a pale orange color for about an hour without reaching white heat; if the full capacity is not yet reached, the temperature can be increased and kept at its maximum (1,500°–1,600° C.). Then the supply of oil and water is cut off; and after a few seconds during which the fuel still left on the grate gradually burns out, the door is closed and sealed with clay. After a few minutes the damper (*S*) is closed, thus cutting off the circulation of air completely and making the cooling process more gradual. As a rule, when baking valuable tablets it is better not to reach the highest temperature, since even somewhat underbaked tablets will stand fairly well the normal handling necessary to museum pieces, that is, brushing or even soaking in water.

It is practical to set the tablets in the kiln in the evening and to start the fire early next morning, the baking usually taking all day and sometimes until late into the night. Usually they are sufficiently cool by the next afternoon to be taken out of the kiln and unpacked. This last procedure takes quite as long as the firing itself, for each bowl has to be dealt with individually. The bowl is placed on a wire net over a wooden box; then the tablets are taken out, identified, and placed in their original boxes according to their catalogue numbers. Finally, the sand is emptied out of the bowl onto the wire net, which acts as a sieve, so that there is no chance of losing even the most minute fragment. If such a fragment contains traces of an inscription, it can easily be fitted into its right place, since each bowl contains only a few tablets, and very often, in the case of badly cracked tablets, only one. In this way very small fragments have been saved and properly inserted.

TEST BAKING

When a *new* kiln is built it is important to discover one or two essential points, such as its maximum capacity and the highest temperature which it can attain. This gives a good opportunity to test the quality of the sand and the bowls which will be used later for the actual baking. It is not advisable to risk tablets of any importance in the first test baking; but otherwise it should be carried out as far as possible under actual conditions.

The maximum temperature should be maintained for about two hours. If it proves too high, the bowls may vitrify. Though not so frequently, the tablets themselves may be affected in the same way; and sometimes, if the sand is not pure enough, even this melts to a certain degree into crude glass lumps. If this occurs, the sand should be changed or washed, for pure sand can stand very high temperatures. Test baking should be repeated, with the last stage shortened each time, until the desired results are obtained. Exact records should be kept for each baking, detailing the length of the various stages of the baking, so that adjustments may be made in accordance with the results.

TREATMENT AFTER BAKING

Firing not only strengthens tablets so that even fragments which were very fragile before baking can be handled with comparative ease (with the result that the surface can be brushed and if necessary even treated in water), but also affects the salt which covers the tablets in various crystalline forms. The salt can rarely be removed from an unbaked tablet without damaging an inscribed surface. Even when it occurs on baked clay surfaces it cannot easily be removed, because the crystals usually adhere very firmly and are often even harder than the baked clay. During the firing these salts usually lose their crystalline water and most of the calcium, magnesium, and iron carbonates are transformed to oxides of the same metals, so that after the baking we find, instead of hard crystals, a more or less crumbly substance which can easily be brushed off, the more so since the surface of the tablet itself is now much stronger. This cleaning should be done as soon as possible after the baking, for some of these salts absorb moisture from the air and gradually crystallize again. Dr. Jacobsen found a medium-hard nail brush most suitable for this cleaning; no metal brushes should be used. If a hard tool has to be used, a fine needle fixed in a wooden handle is very useful, but should be handled with great care and only by a person who is familiar with the cuneiform script. When the fragments have thus been cleaned, they can be put together.

It is well to postpone the mending if there is a chance of finding any missing fragments and inserting them later. But if all the fragments are at hand, it is preferable to do the mending in the field if time can be spared, thus avoiding the great risk of losing some of the smallest fragments in the course of packing, shipping, and unpacking. In fact, the time spent on mending the tablets is well repaid during the packing, as it is much easier and quicker to pack one tablet of more or less regular shape than numerous fragments most of which are fragile and irregular.

The most satisfactory adhesive for this purpose is a solution of celluloid, for this is very strong and can be applied in a thin, almost invisible layer. It withstands moisture and changes of temperature fairly well. It is procurable ready for use under various names ("Ambroid," for instance), but can also be easily prepared in camp. The two best solvents for celluloid are acetone and amyl acetate, which must of course be brought out to the camp. The celluloid can easily be obtained from waste photographic films, by placing them in hot water and then scraping off the gelatin with a knife. Various solutions can be made by using one of the two solvents or a mixture of them in various proportions. Since acetone evaporates much more quickly than amyl acetate, the larger the proportion of the former the quicker will be the drying. A fairly thick solution of celluloid should be applied for mending purposes; but as the strength largely depends on the amount of celluloid which has penetrated into the pores of the pottery, the two surfaces should first be coated with a fairly thin solution containing a

FIG. 39.—Removing a tablet from the surrounding lump of earth after baking

higher percentage of amyl acetate. When the first coat is dry, one can proceed with the actual mending. The mend thus obtained is very strong and, if it is done carefully, the cracks are scarcely visible.

For temporary mending, if it must be done, paraffin wax can be used.

It should be applied as described on page 41. To separate the pieces again, the object is warmed just enough to loosen them, after which

FIG. 40.—The tablet in this lump, although cracked when bricks fell on it in antiquity, emerged without the fragments being separated.

the paraffin can be washed off completely with gasoline. There should be no attempt to remove the paraffin by melting in a high temperature in the open air. Such procedure almost always causes black spots to appear on the surface of the tablet. And if the paraffin catches fire the number of fragments will in all probability be increased.

When a single lump of earth containing many tablets is excavated, it can scarcely be packed in sand. It should be carefully dried before firing, then baked in the usual way. The tablets, usually of a finer quality of clay than the surrounding lump, will contract more during the baking and thus be separated from it. After baking, the lump is broken and the tablets carefully extracted. For this purpose a wooden mallet was suggested by Dr. Jacobsen. By dint of light tapping, the lump is broken in the most natural way, that is, along the cracks between it and the tablets. Thus the tablets can be removed without any damage even if they were originally very fragile or even cracked (Figs. 39 and 40).

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