

The Metalworkers' Tools from Tell Edh Dhiba'i

by CHRISTOPHER DAVEY

The magnificent metalwork of Sumer and Babylon is evidence of the well-developed and highly sophisticated craft of the ancient metalsmith (Maryon and Plenderleith, 1956: 624). The details of his techniques however remain largely a mystery to us because it is not possible to deduce with complete certainty the precise method used to manufacture an artefact by careful analysis of the artefact itself. An object's shape may give an indication of the processes involved in its fabrication and metallographic analysis can reveal the final phases of that production, (Hodges, 1966: 209-19), but even with the most thorough study the ancient craftsman will remain a shadowy figure until the actual tools of his profession are considered. Such tools were found during an excavation conducted by the Directorate of Antiquities of Iraq in 1965 at the site of Tell edh Dhiba'i in the suburbs of modern Baghdad (al-Gailani, 1965).

The artefacts discovered in the area of the coppersmiths' workshop at Tell edh Dhiba'i were all made from clay suggesting that before destruction objects of value were removed. (Metal objects in the form of rough castings for example were found in the workshop excavated at Kultepe (Özgüç, 1955: 79).) The approximate date of the destruction of the workshop can be inferred from other material which belonged to the Isin-Larsa and Old Babylonian Periods found at the site (al-Gailani, 1965: 33, 35). An exact date for the workshop is not important as the implements found undoubtedly testify to a long-standing metallurgical tradition. A date for the destruction of the workshop during the first quarter of the second millennium BC seems perfectly plausible.

In publishing the clay objects from the coppersmiths' workshop L. al-Gailani (1965: 37) included a report by W. Winton of the Science Museum who identified the objects from photographs supplied to him. Some of the identifications were quite straightforward, but a number presented difficulties which only an inspection of the artefacts themselves could solve. Such an examination was made by the author in 1977 and the results are significant enough to warrant further publication.

The author is grateful to the Director-General of Antiquities of Iraq for permission to study the artefacts found at Tell edh Dhiba'i and while in Iraq he particularly appreciated the assistance rendered by the Director, of the Museum Baghdad and his staff. The author also gratefully acknowledges the assistance of Dr N. J. Seeley of the Institute of Archaeology, London, and of Mr Ian Edwards of



Fig. 1 Metalworkers depicted in the reliefs in the tomb of Mereruka, Saqqara (after Duell).

Melbourne who commented on the ceramics; also the travel grant awarded by the British school of Archaeology in Iraq and the support and encouragement provided by members of the school.

1. Bellows (Fig. 2, Plate I, a)

The largest objects found in the debris of the workshop were two pots which were used as bellows. The two bellows were similar in size being about 0.45 m in diameter and 0.16 m high. Field numbers were missing from the vessels and have been allotted with reference to the photographs previously published by L. al-Gailani (1965: p1. 7). Inspection of the pots revealed them to be handmade from medium-fine clay which was then hardened by fire probably to a temperature around 500°C

Pot bellows, including these examples, have been discussed elsewhere in more detail by the author (1979; Arieh *et al.*, 1978: 175, Fig. 3. Plate 45). There appeared to be no reason why the pair of bellows could not have been operated reciprocally by the feet as depicted in the New Kingdom Tomb of Rekhmire, Thebes (Davies, 1943: Plate 17), and as suggested by the author (1979: 110, Fig. 5).

2. Crucibles (Figs. 2 and 3, Plate Ib, c)

A total of five crucibles and one fragment of a crucible were found at Tell edh Dhiba'i. Their condition varies from good in the case of the unused crucible 8 to very fragile for those at the end of their operational life.

The crucibles are very similar in size and shape and in fact crucibles 7 and 4 are almost identical as are crucible 8 and the fragment 5. The remaining two crucibles were slightly larger than the others. The uniformity would suggest that the crucibles were made by hand with the aid of a concave mould which formed the basic curved shape.

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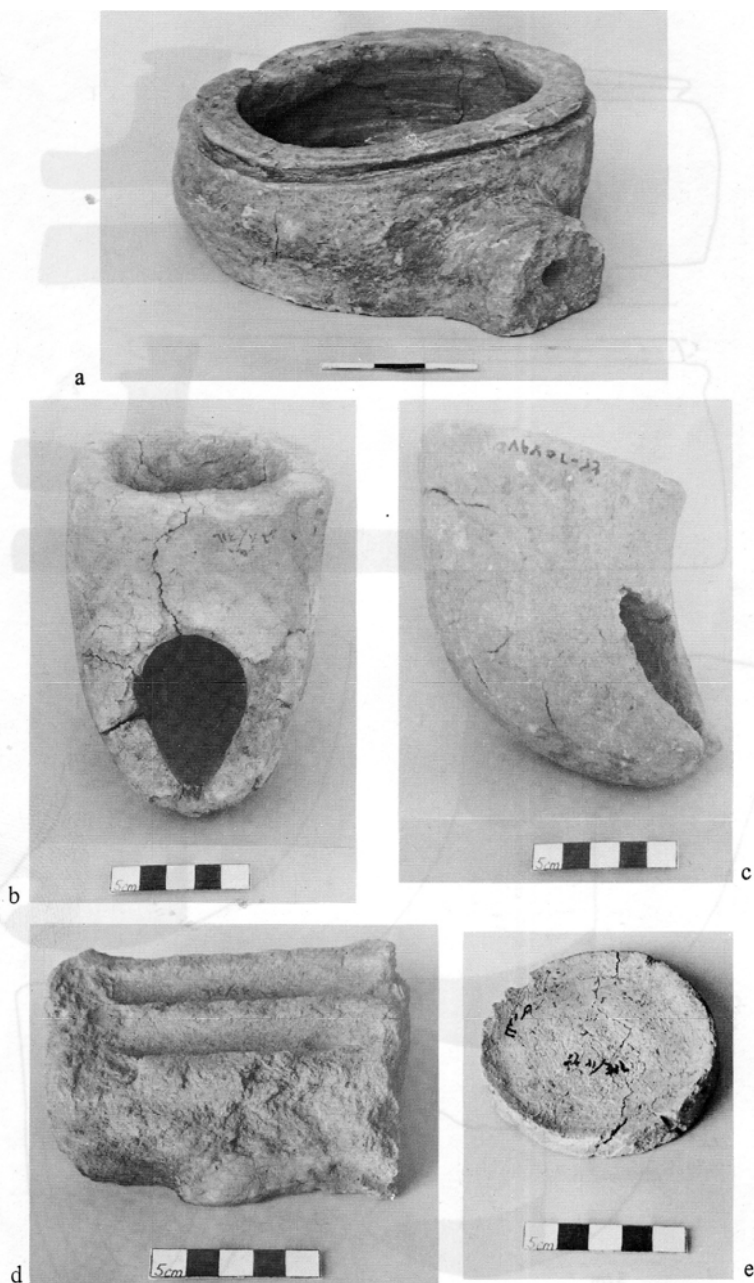


Plate I a, 614/1 pot bellows; b, IM65801 crucible; c, IM65797 crucible; d, IM65794 mould; e, 614/13 dish.

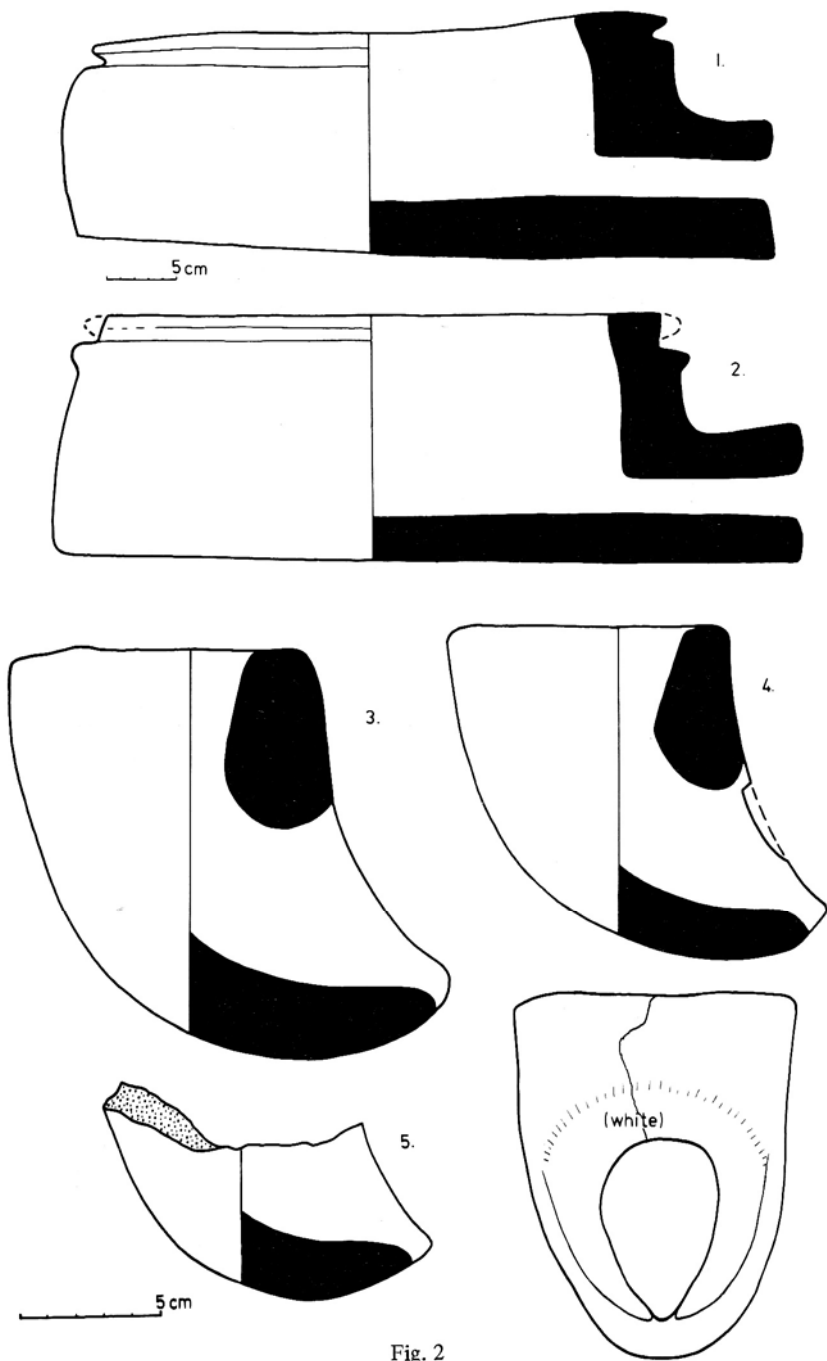


Fig. 2

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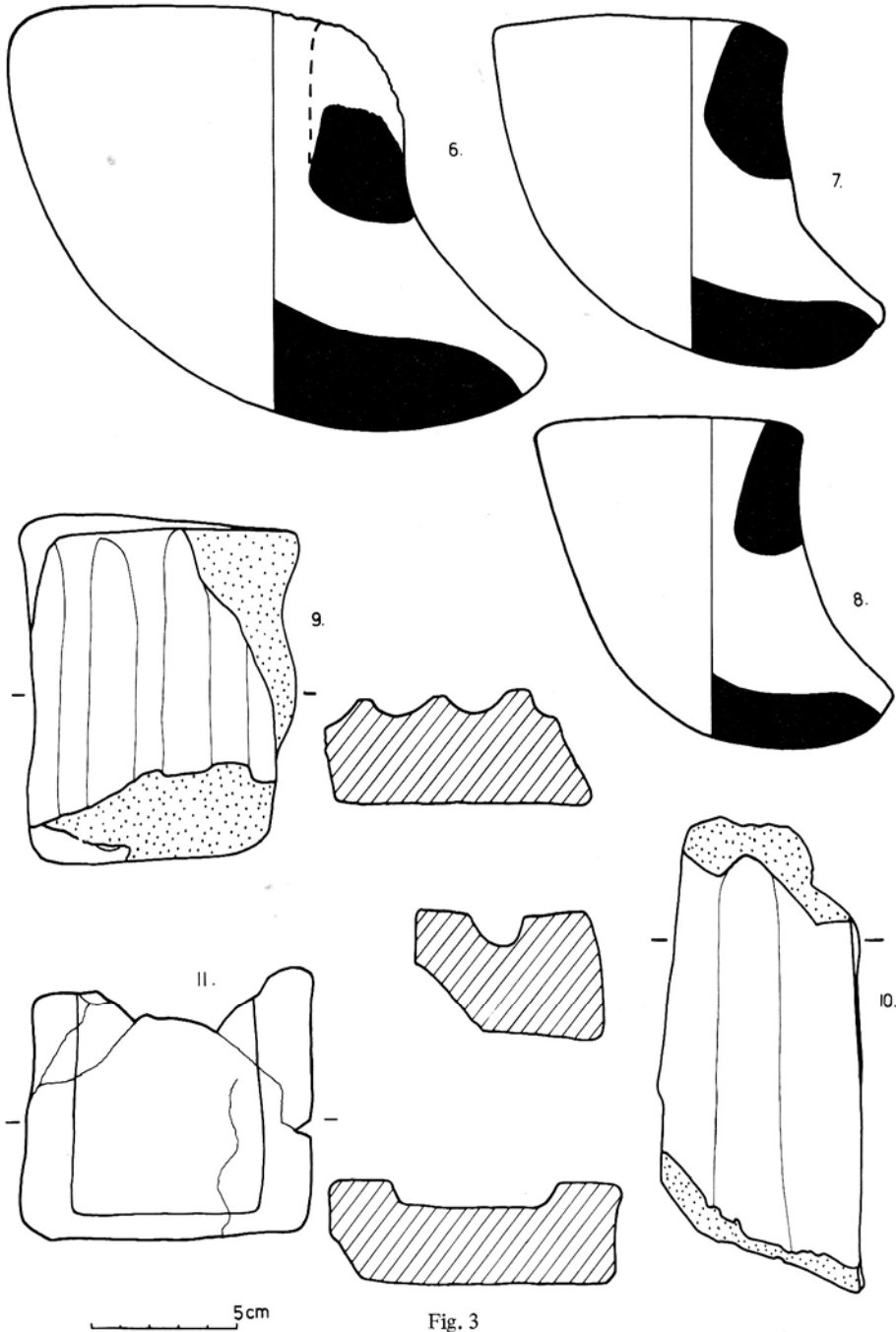


Fig. 3

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The fabric of the crucibles is fairly coarse containing silica and having holes left by straw which was consumed during firing. It is estimated that the vessels were fired to about 800°C and the exterior of the unused crucible seems to indicate that towards the end of firing they were subjected to oxidising conditions. The material from which the crucibles were made is therefore a very effective insulator and appropriate for a vessel intended to contain molten metal.

A fragment of corroded green material on the inside of crucible 4 was analysed by X-ray fluorescence, revealing that it contained copper, tin, arsenic and traces of iron and nickel. The crucibles were therefore used for the melting of bronze.

On most of its surface, crucible 4 (Plate I, b) has the normal pink tinge but around the area of the side opening it is white and friable. This variation indicates that the crucible was subjected to repeated applications of high temperatures in the immediate vicinity of the front opening which had burnt the clay out leaving a material with a high silica content and little bonding strength. If this observation is correct, then the front of the crucible was located in the hottest part of the furnace.

The operation of the crucibles presents a problem as it is clear that in their upright position they will not contain a liquid. Winton proposed that the crucibles were placed in a lying down position in the furnace until the metal melted and then were carried by a metal hook and manipulated with a pair of tongs when being poured (al-Gailani, 1965: Plate 6). Although this suggestion is not corroborated by the observations made with respect to the heat markings on the crucible, it is not entirely unlike that proposed by Tylecote (1976: 18, Fig. 11) for a Late Bronze Age crucible found at Keos.



The crucible from Keos is similar to one found at Byblos (Dunand, 1958: 847, Fig. 962 - Reg. No. 16653) and another found by Petrie in Sinai probably belonging to the same period (Petrie, 1906: 162, Fig. 161). However, these crucibles differ from the Tell edh Dhiba'i crucibles in that they are shaped like a bowl with a hole in the side so that in an upright position they would contain a reasonable amount of liquid. The Tell edh Dhiba'i crucibles would appear to be the only extant crucibles of their kind.

The technique of casting associated with the Tell edh Dhiba'i crucibles is probably best illustrated by reliefs in some Fifth Dynasty Egyptian tombs. The best preserved are those in the tomb of Mereruka, Saqqara (Fig. 1) (Duell, 1938: Plate 30) which depict both the melting and casting processes. Similar reliefs have been found in the Mastaba of Wep-em-nefert at Giza (Hassan, 1936: 192, 193, Fig. 219).

The reliefs reveal that melting is performed in two crucibles placed back to back and with six men using blowpipes aimed at the charcoal placed in front of each crucible. After the metal was melted the crucible was taken to the mould, held with the assistance of two stones or lumps of clay and then a blockage in the mouth of the crucible was removed to allow the metal to discharge into the mould. It is probable that at Tell edh Dhiba'i a technique similar to this was adopted with modifications to allow for the pot bellows and for different moulding equipment.

The crucibles in the Old Kingdom tomb reliefs are identical in shape to those of Tell edh Dhiba'i and must have been very common in Egypt because the shape gives rise

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to the symbol used by the Egyptians to signify copper. During the Old Kingdom this symbol resembles two crucibles  while in the New Kingdom it became the shape of a single crucible  (Gardiner, 1957: 490, 529. The suggestion that the shape is an 'ingot of copper' must now be amended to crucible. (See Davey, forthcoming in *JEA*).

3. Open moulds (Figs. 3 and 4, Plate Id)

A number of fragmentary open moulds were found within the workshop. They were all made from a coarse clay which had been briefly fired and are at first glance rather unexciting, particularly when compared with the stone moulds found in some other Ancient Near Eastern sites.

Moulds 9 and 14 contain matrices for long narrow objects which when cast would have had a 'D'-shaped cross-section. These shapes may then have been worked into knife or dagger blades. However, as there are a large number of these shapes on the moulds here and elsewhere, it is more likely that the objects were in fact bar or ring ingots used for trade (Tylecote, 1976: 16). Bars were a very practical way of handling metal because, unlike plano-convex ingots, they could be easily carried in the form of a ring and could be broken without difficulty by the metalsmith when the metal was to be cast. Mould 10 is similar to 9 and 14 but is for a larger object which again could be either an ingot or an implement such as a knife or sword.

Mould 11 is for a flat object which was probably worked into a vessel of some kind. A similar shape is to be seen on a clay mould found at Byblos with Registered No. 11124 (Dunand, 1954: 420, Fig. 444). This mould fragment is similar to those seen by the author which have come from the Old Kingdom town of Buhen in Nubia.

Object 18 has tentatively been called a mould, although its thin sides are uncharacteristic for moulds of bronze. It may possibly have been used for a material with a lower melting point such as gold, silver or lead.

4. Mould cover (Fig. 4, Plate IIa)

Object 12 and a fragment (not illustrated) were not identified by Winton who it appears could not gauge the relative sizes of objects from the photographs (al-Gailani, 1965: 38-614/9). The object is in fact a mould cover which fits exactly over the fragment of mould 14. This cover would have been placed over the mould and covered with charcoal in the furnace (see Fig. 6). Mould covers were used because they inhibited oxidation of the surface of the casting and by allowing the mould to be heated in the furnace, the solidification of the metal was retarded allowing it to flow more freely into the mould. Mould covers have been found and recognised in Europe and the Aegean, but never before in the Near East (Coghlan, 1968: 73). The design of the examples from Tell edh Dhiba'i is probably the result of a highly developed tradition which found it necessary to place a raised collar on the cover to make it easier to clear the charcoal away from the opening when a metal pour was to be made.

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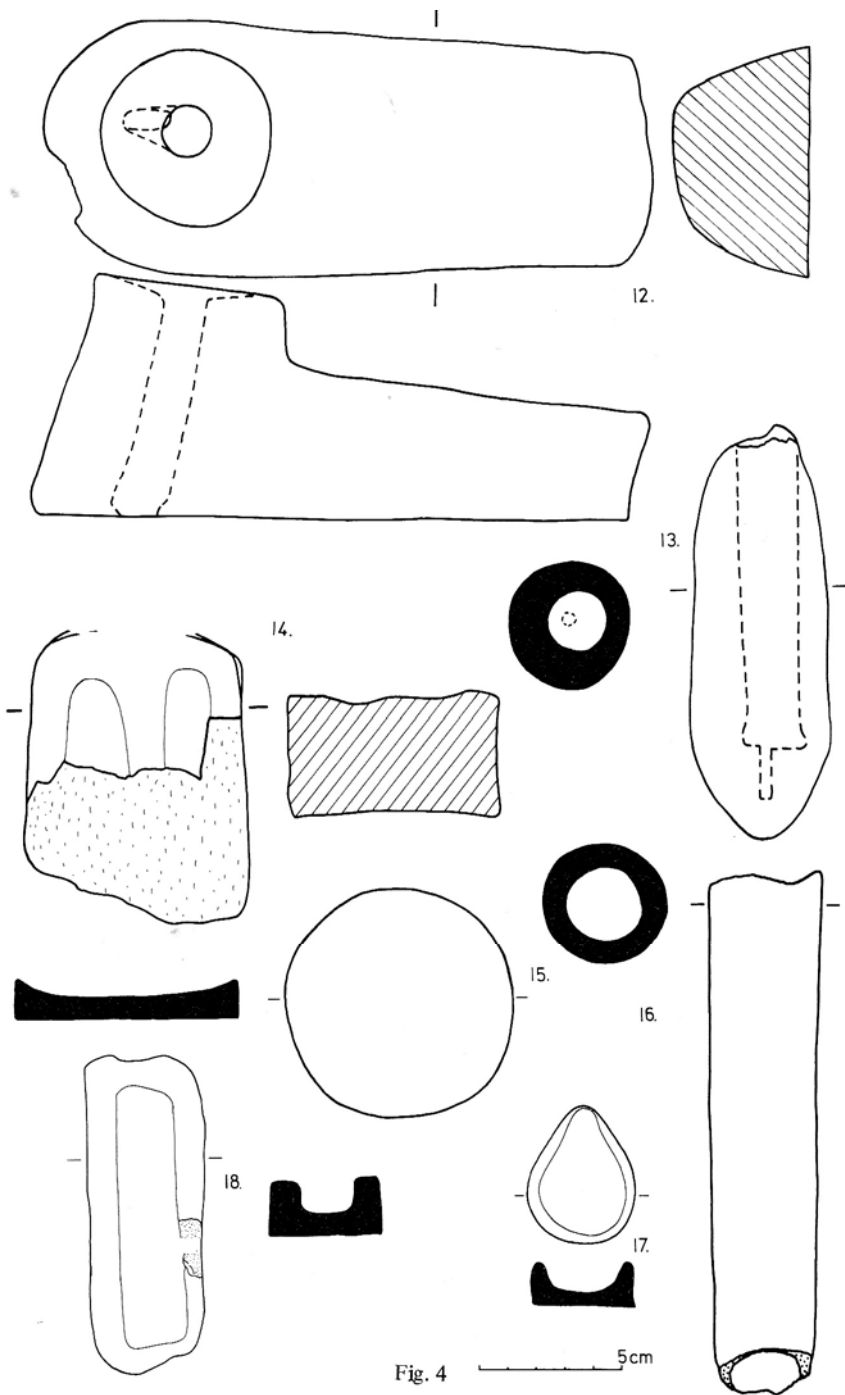


Fig. 4

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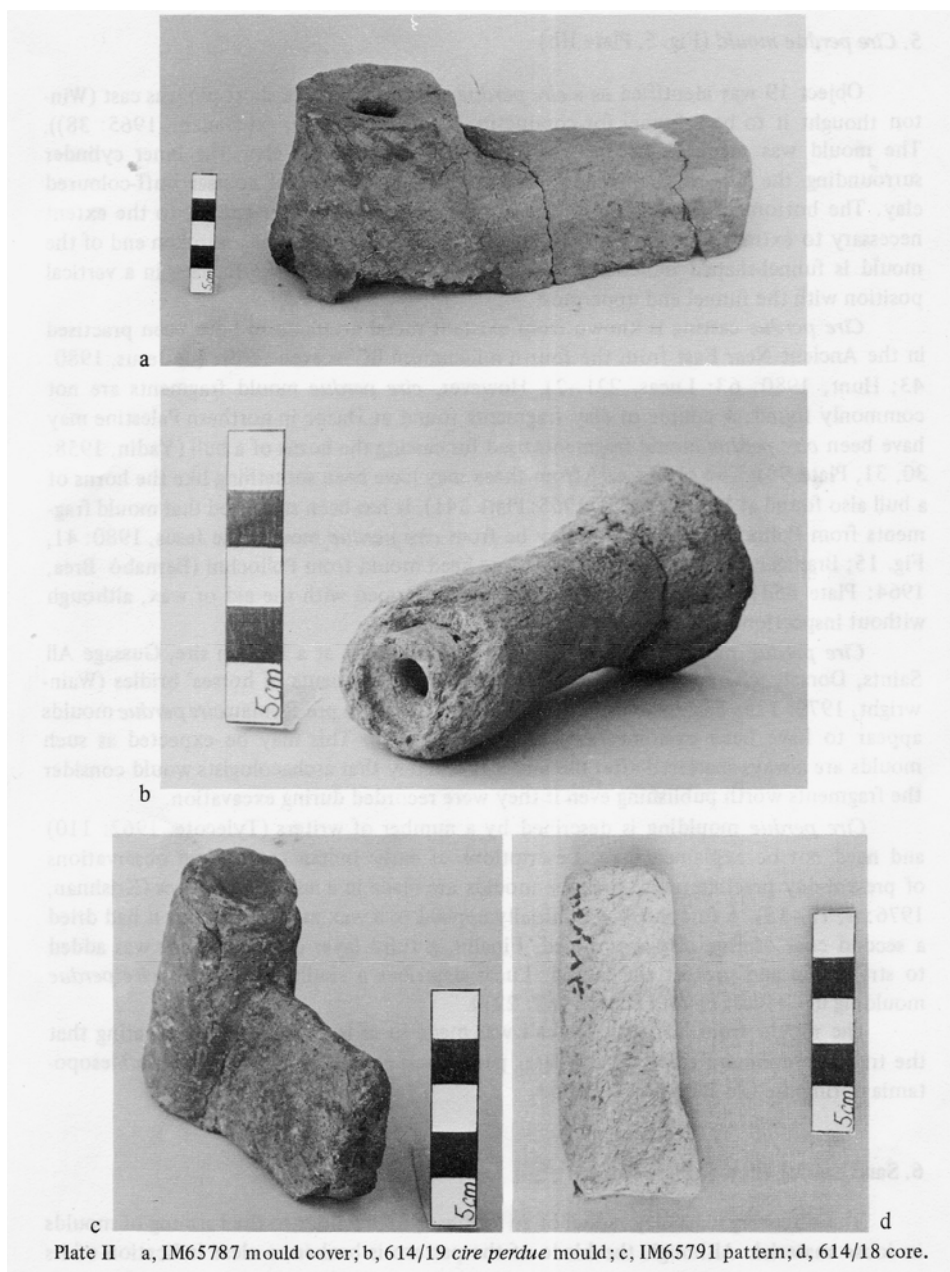


Plate II a, IM65787 mould cover; b, 614/19 *cire perdue* mould; c, IM65791 pattern; d, 614/18 core.

5. *Cire perdue* mould (Fig. 5, Plate IIb)

Object 19 was identified as a *cire perdue* mould in which a short pin was cast (Winton thought it to be a funnel for conducting air to the bellows (al-Gailani, 1965: 38)). The mould was made from two distinctly different types of clay; the inner cylinder surrounding the pin of fine yellow clay and an outer shell of coarser buff-coloured clay. The bottom of the mould has been broken although it appears not to the extent necessary to extract the pin. The mould was therefore unused. The unbroken end of the mould is funnel-shaped indicating that it was placed in or by the furnace in a vertical position with the funnel end uppermost.

Cire perdue casting is known from existent metal artefacts to have been practised in the Ancient Near East from the fourth millennium BC or even earlier (de Jesus, 1980: 43; Hunt, 1980: 63; Lucas, 221-2). However, *cire perdue* mould fragments are not commonly found. A couple of clay fragments found at Hazor in northern Palestine may have been *cire perdue* mould fragments used for casting the horns of a bull (Yadin, 1958: 30, 31, Plate 98). The object cast from these may have been something like the horns of a bull also found at Hazor (Yadin, 1965: Plate 341). It has been suggested that mould fragments from Poliochni and Thermi may be from *cire perdue* moulds (de Jesus, 1980: 41, Fig. 15; Branigan, 1974: 82, Fig. 4). The axe head mould from Poliochni (Bernabo Brea, 1964: Plate 85d) may quite probably have been formed with the aid of wax, although without inspection it is impossible to be definite.

Cire perdue moulds have been found in abundance at a Roman site, Gussage All Saints, Dorset, where they were used to fabricate components of horses' bridles (Wainwright, 1979: 125-53; Foster, 1980). However no definite pre-Roman *cire perdue* moulds appear to have been examined and identified as such. This may be expected as such moulds are always shattered after use and it is unlikely that archaeologists would consider the fragments worth publishing even if they were recorded during excavation.

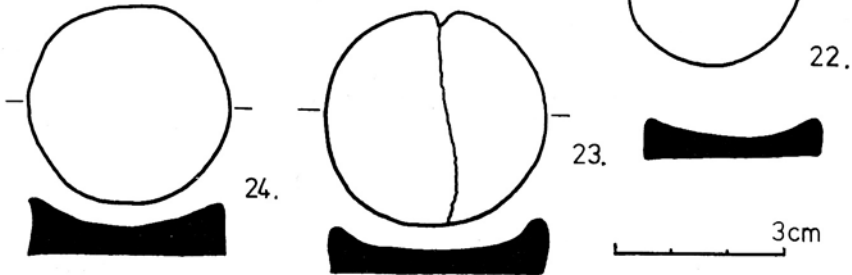
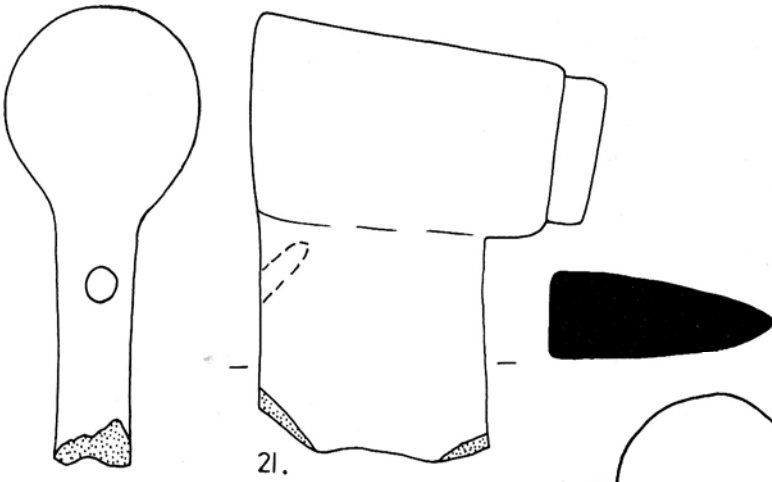
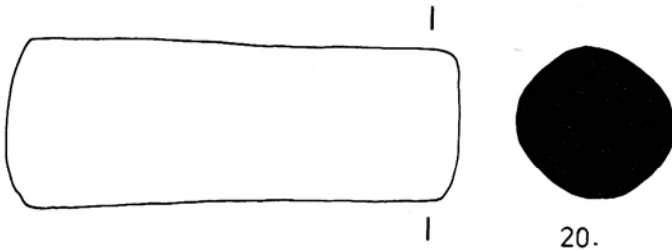
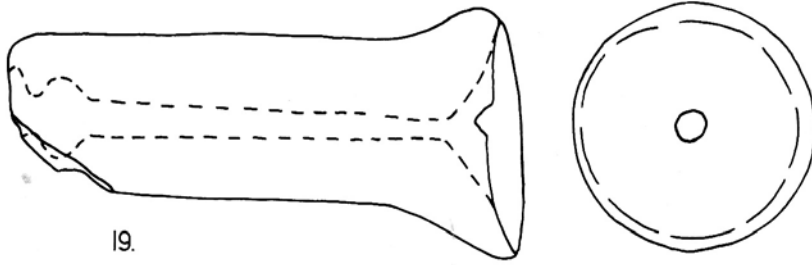
Cire perdue moulding is described by a number of writers (Tylecote, 1962: 110) and need not be explained here. Descriptions of early Indian casting and observations of present-day practice reveal that the moulds are made in a number of stages (Krishnan, 1976: 4, 13-15). A fine slurry was initially applied to a wax model and after it had dried a second coat of fine clay was added. Finally, a third layer of coarser clay was added to strengthen and protect the mould. Lucas describes a similar process of *cire perdue* moulding in classical Egypt (Lucas 1962: 221).

The mould from Tell edh Dhiba'i was made in at least two states indicating that the tradition common elsewhere at a later period was already well established in Mesopotamia during the Old Babylonian Period.

6. Sand casting (Fig. 5, Plate IIc; d)

The discovery of a clay model of an axehead, 21, testifies to the forming of moulds in loose material. Although the blade of the pattern is broken, a clear indication of its

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operation can be deduced. The model of the axe-head is shaped so that it can be impressed into a bed of material such as clay or sand and after it is withdrawn leave a stable impression of itself. The pattern could be held by inserting a handle into holes in the edge of the blade. One hole is visible and there was probably a second further down the blade inclined in the opposite direction.

The identification of the pattern was largely confirmed by the discovery of a core, 20, which would have been inserted into the hole left for it by the pattern so that it formed the shaft-hole in the axe-head.

The nature of the moulding material used in connection with the axe-head pattern found at Tell edh Dhiba'i cannot be determined from the pattern itself. It is generally believed that sand casting commonly used in foundries today was a technique developed in the 18th century AD (Tylecote, 1962: 110). Theophilus, however, described the use of clay as a casting medium in the 11th century AD (Hendry 1847: 313, Agricola, 1950: 405, 536).

The Biblical description of the manufacture of the bronze objects for the temple of Solomon states that it was executed by a metalworker from Tyre who cast them 'in the compactness of the soil' (1 Kings 7: 46). This is generally translated as 'in the clay ground' (Revised Version) although the Jerusalem Bible actually refers to 'sand casting'. The Bedouin today, quite independently of industrial Europe, have a tradition of using loose earth for casting (Weir, 1976: 67) and there is no reason why metalworkers during the Old Babylonian period could not also manufacture a waterless, sand-clay mixture into suitable material for casting.

7. Miscellaneous objects

One object, 13, which was possibly a mould was made by a slightly different method. Winton states, 'The inside is filled with burnt wood. A handle grip, or possibly, a one piece mould in the course of preparation. An object could have been first carved in wood then "invested" with clay and baked in the fire. In the process of firing the wood would burn completely away leaving a clay mould of the original shape of the wood carving' (al-Gailani, 1965: 79). While he goes on to say that this is very conjectural, an inspection of the object itself has not inspired any other explanation. If the small hole which continues from the end of the larger hole broke through to the end of the object, it would probably be the clay nozzle of a blowpipe (see Fig. 1).

A number of small flat round dishes, 15, 22, 23, 24, are in the collection. Some of them have a green and brown slag on their surfaces indicating that they were subjected to considerable heat. It is suggested that these objects were used in connection with the manufacture of jewellery for such processes as welding or soldering.

A pipe, 16, made from clay was found and seems to have been used for conveying air into the furnace. It was full of charcoal and this may have been a normal state of affairs. As the air passed through the burning charcoal in the pipe it would have been pre-

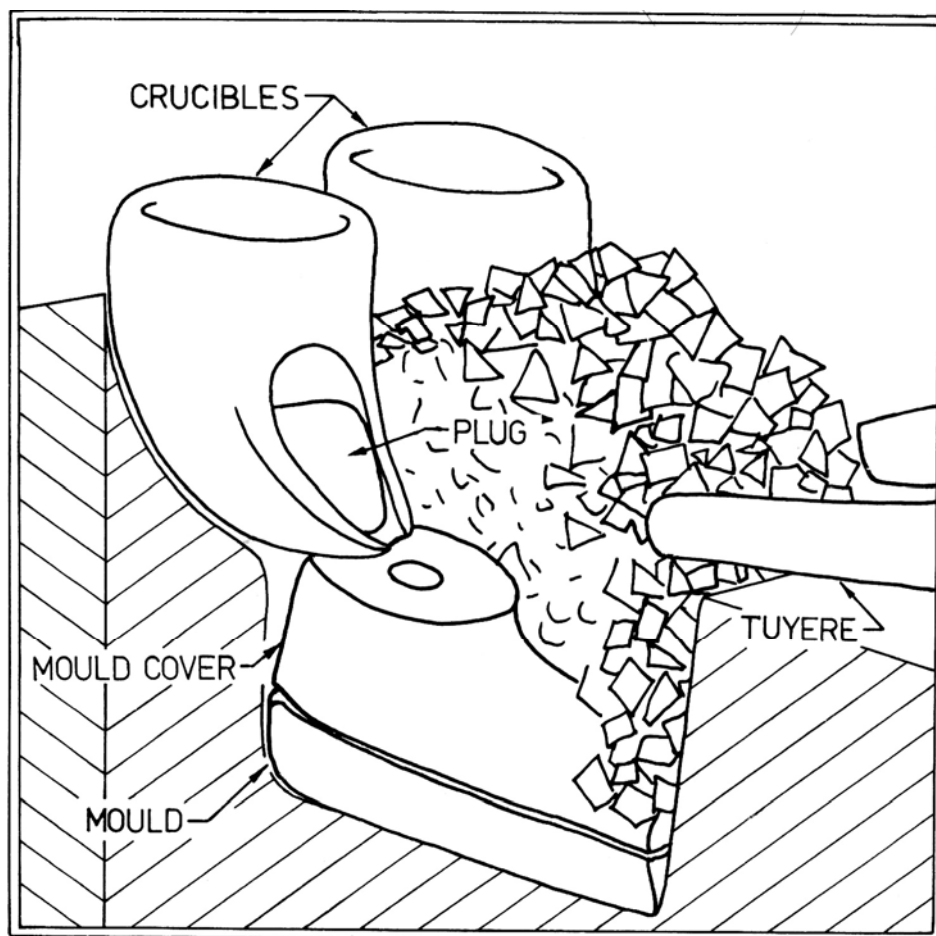


Fig. 6 A cutaway reconstruction of the proposed melting furnace using the crucibles, mould covers and moulds.

heated so that when it reached the furnace it would not reduce the temperature. The material not illustrated was undistinguished and does not warrant comment.

Discussion

The equipment found in the workshop at Tell edh Dhiba'i provides us with an insight into the techniques of an Old Babylonian metalworker. The operation of the equipment is not entirely straightforward and the reconstruction of a melting furnace postulated in Fig. 6 is not the only alternative.

The suggested furnace is sunk into the ground so as to provide maximum insula-

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tion. Adopting the practice illustrated in the Egyptian Old Kingdom tomb reliefs, a plug is placed at the entrance of the crucible and it is kept in place until the material is ready to pour. When that occurs, the charcoal is quickly pushed aside and the plug removed so that the metal can quickly flow into the pre-heated mould. Two crucibles are shown side by side in the illustration as there appears no reason why a number of pours could not have been made in quick succession.

The main design principle of this melting furnace is that of fuel efficiency. In Mesopotamia charcoal had to be brought considerable distances and so it was necessary to carefully control its consumption. The shape of the crucible and its operation in conjunction with large bellows meant that the metal could be melted and poured with a minimum amount of charcoal as all the heat was forced directly toward the metal itself. The pre-heated mould and its position ready for the pour meant that very little super-heat was required by the metal to obtain a successful casting.

A number of connections with Egyptian metallurgy have already been mentioned. The shape of the crucibles is the most definite connection with the Old Kingdom metallurgy. No parallels for the Tell edh Dhiba'i crucibles have appeared in the Ancient Near East to the present and if it were not for the reliefs in such places as the tomb of Mereruka at Saqqara, their mode of operation would be a mystery. The moulds have similarities in their construction with those found at the Old Kingdom town at Buhen and some shapes on the moulds parallel those found at Byblos, where there were long periods of Egyptian control and influence. The transfer of ideas was not in one direction only as the New Kingdom tomb of Rekhmire depicts bellows of the Tell edh Dhiba'i type used by Egyptians.

It may seem strange that metalworking equipment from neighbouring Anatolia and Iran do not find a place in the Tell edh Dhiba'i collection. These regions had trade links with Mesopotamia which involved transfer of metal, some of which may have been processed in the workshop at Tell edh Dhiba'i. Yet instead of moulds, crucibles and bellows of the type found in the workshop at Kultepe (Oaguy, 1955: 79) the metalworker at Tell edh Dhiba'i used equipment which clearly reflects an Egyptian technology. This relationship seems all the more strange because, with the possible exception of some moulds from Byblos ((Dunand, 1954: Fig. 444), No. 11124 is one example reminiscent of material found in the Old Kingdom town at Buhen), there are no sites between Egypt and Mesopotamia with metallurgical equipment similar to Tell edh Dhiba'i which would reveal how the technology was transferred.

The answer for this occurrence is probably to be found in the similar environmental constraints experienced by the metalworker in Egypt and most of Mesopotamia. Both found their fuel supply severely limited and expensive and so it is reasonable that they should use similar equipment which made the most efficient use of their resources. Metalworkers in Anatolia, Iran and the coast of the Levant had no such restrictions and could use large and easily operated furnaces which were comparatively inefficient. Technological practices can travel large geographical distances, it seems, and only be applied in places where the circumstances are conducive or relevant to those practices.

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Tell edh Dhiba'i is quite important in terms of the history of metalworking for it has yielded one of the earliest known *cire perdue* moulds, the earliest evidence for clays and casting, the only mould covers known in the Near East and foot-operated pot bellows known from a later period in Egypt. While in the course of time other earlier examples will no doubt be discovered, the Tell edh-Dhiba'i workshop will remain significant because of the distinctive nature of the Old Babylonian metalsmith who did not use stone moulds common to the Levant and northern Mesopotamia (Davey, 1977) or the open crucibles of the Levant, Anatolia and Iran (Tylecote, 1976: 20), but used moulds formed from loose earth and baked clay and closed crucibles known from Egypt.

In retrospect it seems appropriate to pay tribute to the excavators of Tell edh Dhiba'i who kept all the fragments of unattractive industrial refuse in spite of the fact that at the time the identification and purpose of some of the objects was not clear.

Abstract

A collection of metalworker's tools found at Tell Edh Dhiba'i in Iraq in 1965 is described and its significance for providing information about the techniques used by ancient metalworkers in Mesopotamia is discussed. These are shown to resemble those of Egypt rather than, as might have been expected, those of neighbouring Anatolia. It is suggested that the explanation may lie chiefly in the similar environmental constraints in the two areas.

Catalogue of objects

Drawing No.	Excavation No.	Iraq Museum	Identification	Size (mm)
1	614/1		Pot bellows	400 dia. 180 ht
2	614/2		Pot bellows	450 dia. 180 ht
3	614/4	IM65798	Crucible	110 dia. 150 ht
4	614/7	IM65801	Crucible	100 dia. 120 ht
5	614/8	-	Crucible fragment	
6	614/5	IM65799	Crucible	130 dia. 140 ht
7	614/3	IM65797	Crucible	100 dia. 110 ht
8	614/6	IM65800	Crucible	90 dia. 110 ht
9	614/27	IM65794	Mould	120 X 90 X 35
10	614/28	IM65795	Mould	160 X 70 X 45
11	614/12	IM65789	Mould	100 X 90 X 35
12	614/9	IM65787	Mould cover	210 X 90 X 85
13	614/15		Mould	140 X 45 dia.
14	614/14	IM65790	Mould	110 X 80 X 40
15	614/13		Dish	80 dia.
16	614/16	-	Pipe	180 X 40 dia.
17	614/11		Measuring dish	50 X 40 X 15
18	614/10	IM65788	Mould?	110 X 40 X 20
19	614/19		<i>Cire perdue</i> mould	90 X 40 dia.
20	614/18		Core	80 X 25 dia.
21	614/17	IM65791	Pattern	60 X 75
22	614/31(21)		Dish	30 dia.
23	614/20	-	Dish	40 dia.
<u>24</u>	<u>614/22</u>	=	<u>Dish</u>	<u>35 dia.</u>

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Other objects in the collection but not illustrated.

614/-	IM65758	Lamp	Provenance uncertain
614/23	IM54793	Pot spout	
614/32		Mould cover fragment	
-		Rim sherd	Provenance uncertain
614/29	IM65796	Pottery wheel hub	Incomplete
614/30	IM65802	Pot	
614/25		Roof material	
614/26		Roof material	
-		Mould	Small fragment

Also some pottery fragments including a rim sherd, body sherds from a well-fired pot and a strainer pot and a few indistinguishable pieces of clay.

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