CHAPTER 10

THE NATURE AND USE OF ANCIENT EGYPTIAN POTTER'S WHEELS

by

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10.1 Introduction

What prompted this project was the discovery in 1987 of an upper pivot stone from a pair of stone wheel-bearings within the context of a pottery workshop at Amarna (building Q48.4: *AR* V: Chapter 4). I joined the Amarna team as a professional potter, with the aim of discovering, through a practical and experimental approach, how the ancient potters might have used it. What follows is partly a discussion of archaeological and ancient artistic evidence for the design of potter's wheels in ancient Egypt, and partly a description and evaluation of the first series of experiments which I carried out at the expedition house at Amarna, mainly in 1989 and 1990. Their aim was to produce a working replica of an Eighteenth Dynasty wheel. This chapter thus falls into three parts: an account of the evidence for potter's wheels, the making and testing of the first replica bearings and a range of wheelheads during the 1989 season, and the testing of wheelheads in 1990 using an improved pair of replica bearings. Further series of experiments to produce clays from local materials and to throw Eighteenth Dynasty-type vessels on the replica ancient wheel have since been carried out and will be reported at a later date.

During the Eighteenth Dynasty there is no evidence for the use of a kickwheel or, as it is sometimes termed, a double wheel, for the manufacture of pottery. It is therefore assumed that this pivot stone, as one half of a bearing, once formed part of a "simple wheel". This term denotes a low turntable, the upper part of which is a wheelhead mounted upon a pivot stone which turns within a perfectly matched socketed stone embedded in the ground. The rotation of this device is aided by lubrication, and momentum is imparted using the hand. Examples of paired stone bearings from Amarna (Ashmolean Museum 1929.417), Khartoum, Lachish, and Hazor have already been described by Hope (1981). The paired stones from Lachish and Hazor (Hope 1981: 129–30) were also found in association with potter's workshops, and a further pivot stone "lubricated with black resin" is included on a plan of a potter's workshop from the Middle Kingdom site at Nag Baba, Sudanese Nubia (Holthoer 1977: 16, Fig. 21). Childe (1954: 201) lists further paired stones from Palestine and Mesopotamia, and an additional Canaanite pair features in an article on experimentation by Amiran (1984).

10.2 Descriptions and appraisals of further Egyptian potter's wheel-bearings

In the course of my research on the background to the 1987 find, I sought out further examples of potter's wheel-bearings in museums, and took descriptions and made sketches of them.

British Museum 32621 (Figure 10.1)

Provenance: unknown, purchased from a dealer in 1900.
Material: white oolitic limestone.
Weight: upper 5.7 kg; lower 9.0 kg.

The height of the upper pivot stone is 15 cm, with an uneven, roughly hewn upper surface. The polished area measures c. 15.5 cm across, with concentric striae. The diameter of the tenon base is 8.5 cm, the height 5.5 cm. The end of this is worn, pitted, and discolored dark brown. The lower roughly carved socket stone is c. 15 cm high, and the interior polished socket-well and surround correspond exactly to the pivot stone. The base of the socket-well is worn, with traces

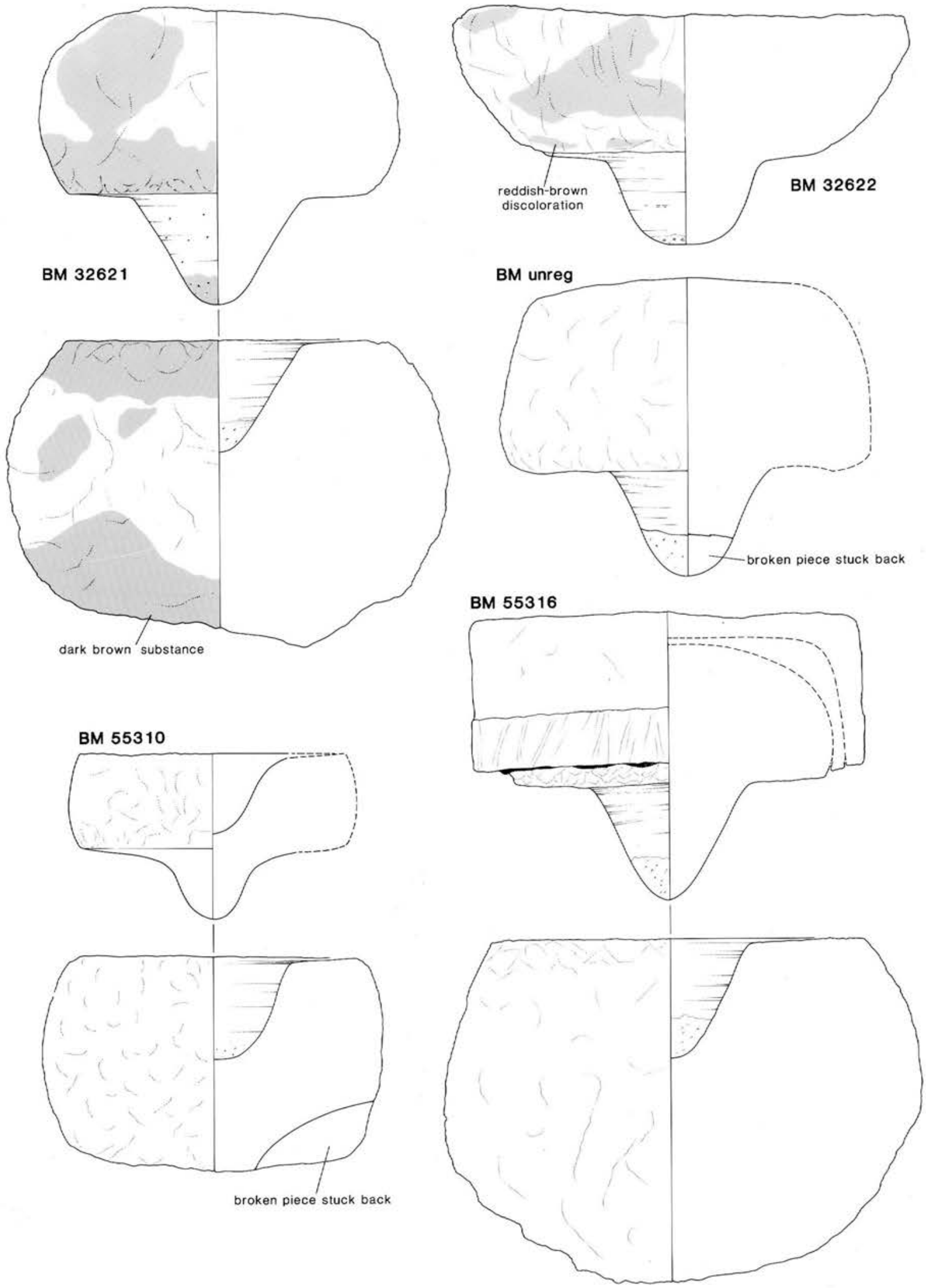

Figure 10.1. Potter's wheel-bearings in the British Museum. Scale 1:3.

of dark brown residue. When fitted together, they turn easily. The exterior of the stones is covered in a layer of a dark brown substance, particularly concentrated around the outside of the polished areas of both stones.

The specifications from this example were used to make a replica bearing that would be suitable as part of an experimental reconstruction of an ancient Egyptian wheel.

British Museum 32622 (Figure 10.1)

Provenance: unknown, purchased in Egypt 1900.
Material: upper pivot stone grey limestone; lower socket stone granite.
Weight: upper 6.2 kg; lower 6.8 kg.

Although each part is made of a different material, these stones were purchased as a pair, and the pivot and socket areas fit together perfectly. The upper surface of the pivot stone is circular and flat, measuring 24 cm across, with an evenly carved edge that curves inwards to a smaller-diameter lower or "interior" surface. Faint traces of a reddish-brown material adhere to its surface. The polished lower surface measures 14.5 cm across, with concentric striae. The tenon measures 8.5 cm in diameter at its base, with a height of 4.7 cm, the end being worn flat and discolored grey. When fitted together, the upper stone projects some 3–4 cm from the lower stone.

The lower stone is made from black granite, and measures 18 cm in diameter and 10 cm in height; the polished surface 16 cm, and the socket well 8 x 5.3 cm deep. The base of the well and outer edge of the polished area are worn. The stone is evenly and neatly carved round with a flat base. When the two stones are put together, their appearance is that of a small turntable.

British Museum 55316 (Figure 10.1)

Provenance: unknown, purchased in Egypt in 1913.
Material: limestone, with hardened bedded plane.
Weight: top 5.8 kg; base 13.1 kg.

This example is by far the most sophisticated which I have found, comprising three parts, two of which are joined. The upper pivot stone is made from hard, buff-coloured limestone measuring 15–16 cm across. The tenon measures 8.25 cm in diameter at its base, and is 6 cm high, the surround being 3–4 cm. The surface is polished and exhibits the concentric striae noticed on other examples. The end of the tenon is worn and pitted, and the outer edges of the stone are chipped. The whole is cemented with clay into a separate limestone cap, so that only the polished surface of the tenon and its surround is visible, and this projects 0.5 cm below the rim of the cap. The top shape is unknown, but presumably is either domed or flat. The "cap" stone is made from a single piece of limestone of two degrees of hardness. The top is circular and flat, measuring 20 cm across, its rim extending to a depth of 8 cm. This part of the stone is white and chalky, with a lower band, or bedded plane, which is hard and buff in colour, forming the rim, measuring 2 cm in depth and 1 cm thick. Vertical chiselling marks are clearly visible around the edge of the "cap". The top surface is smoother, possibly worn by age and use.

The lower stone measures 18 cm at its highest point, but is irregular and does not sit flat. The top portion is hard limestone (part of the bedded plane), and below this the stone is white and chalky. The polished area of the socket-well and its surround measures 16 cm across. The size of the socket-well corresponds exactly to the size of the tenon on the upper pivot stone. The bottom of this is worn, pitted, and discolored black and brown, and further discoloration exists, particularly in the immediate area outside the polished surface. We can assume that this discoloration is the result of using a lubricant to enable the stones to turn upon each other. This has adhered to the rough surface of the stones.

This apparently complete example of a simple wheel presents a puzzle, for here is a pair of potter's wheel bearings with what seems to be the part which is normally missing, which usually has "disappeared with time" (Amiran 1984: 108). The limestone cap appears to be the wheelhead, but its small size and thick rim mean that one must discount the possibility of its having been spun by hand. Although it turns, it could not be used as a momentum wheel for throwing small bowls. It could, of course, have had a further wheelhead attached in some way, but more likely is the use of this complete simple wheel in another, slower-forming process. This could be decorating finished pots, but more probably for coiling and smoothing larger vessels (perhaps *zirs*). Often the pot itself is turned and its own weight and mass assists momentum, often sufficiently so for the neck and rim to be "thrown". This process is described by Foster (1959a: 59) in connection with coil-made pots. Here the pot is turned with the potter's hands and bellied out holding a tool to the inside. It is then left for a day to firm up before an extra coil is pinched around the orifice. The potter spins the vessel anti-clockwise, imparting the motion by slapping it towards him with his left hand in bursts of three. An average speed of 60 rpm is attained although this is not continuous. The right hand meanwhile is wetted and supports and shapes the neck and rim by throwing. Both hands are used to complete the process.

Another possibility is suggested by Xanthoudides (1927: 125) in a description of the manufacture of Cretan *pithoi*: "made on small low turntables, an assistant aids turning whilst the pot is made in stages, throwing very slowly". By this interpretation this pair of pivoted and socketed stones would represent a complete "slow" wheel, i.e. one in which the wheel is a tool to assist the making of the pot and does not in itself provide the velocity for throwing to take place. The means of rotation, provided by lubricated pivoted and socketed stones is the same, but has been applied to construct a wheel for a different method of manufacture, determined by factors governing the size, shape, and type of the desired vessel. It could have existed alongside or separately from other types of wheel.

British Museum unregistered (Figure 10.1)

Provenance: unknown.
Material: grey basalt or granite (?).

This upper pivot stone is broken across one side. The tenon has also been broken but fitted back, and measures 5.5 cm in height and 8 cm in diameter at its base. A 3 cm polished surround has a slightly raised lip on its outer edge. The exterior has been relatively evenly carved to give a squarish profile and flat top. The entire piece is 15.5 cm high, with a diameter of c. 19 cm.

British Museum 55310 (Figure 10.1)

Provenance: unknown.
Material: pink and black granite.

This is an unusual example where one stone exhibits both pivot and socket. It is broken across one corner and badly chipped in another. However, enough remains to judge its original appearance when whole. Then it would have measured about 13 cm across, with a smoothly carved squarish edge 5 cm in depth. The lower surface includes a circular polished area with a projecting tenon 2.8 cm high and 5 cm in diameter. The polished surround is slightly convex. The lower stone in which this would have turned is missing. However, the upper surface also has a socket-well 5.5 cm in diameter and 4 cm deep. This and its surrounding area are concave and smooth but not polished.

The dual character of this stone could point to its having been part of a bearing that had an additional pivot or axis attached into the upper socket. In this it may have been part of a kick wheel in which an axle, having passed through a flywheel, fitted into the upper socket-well. This stone would have been fitted into a flywheel. The squarish edge may indicate the means of fixing, perhaps like a mortice joint.

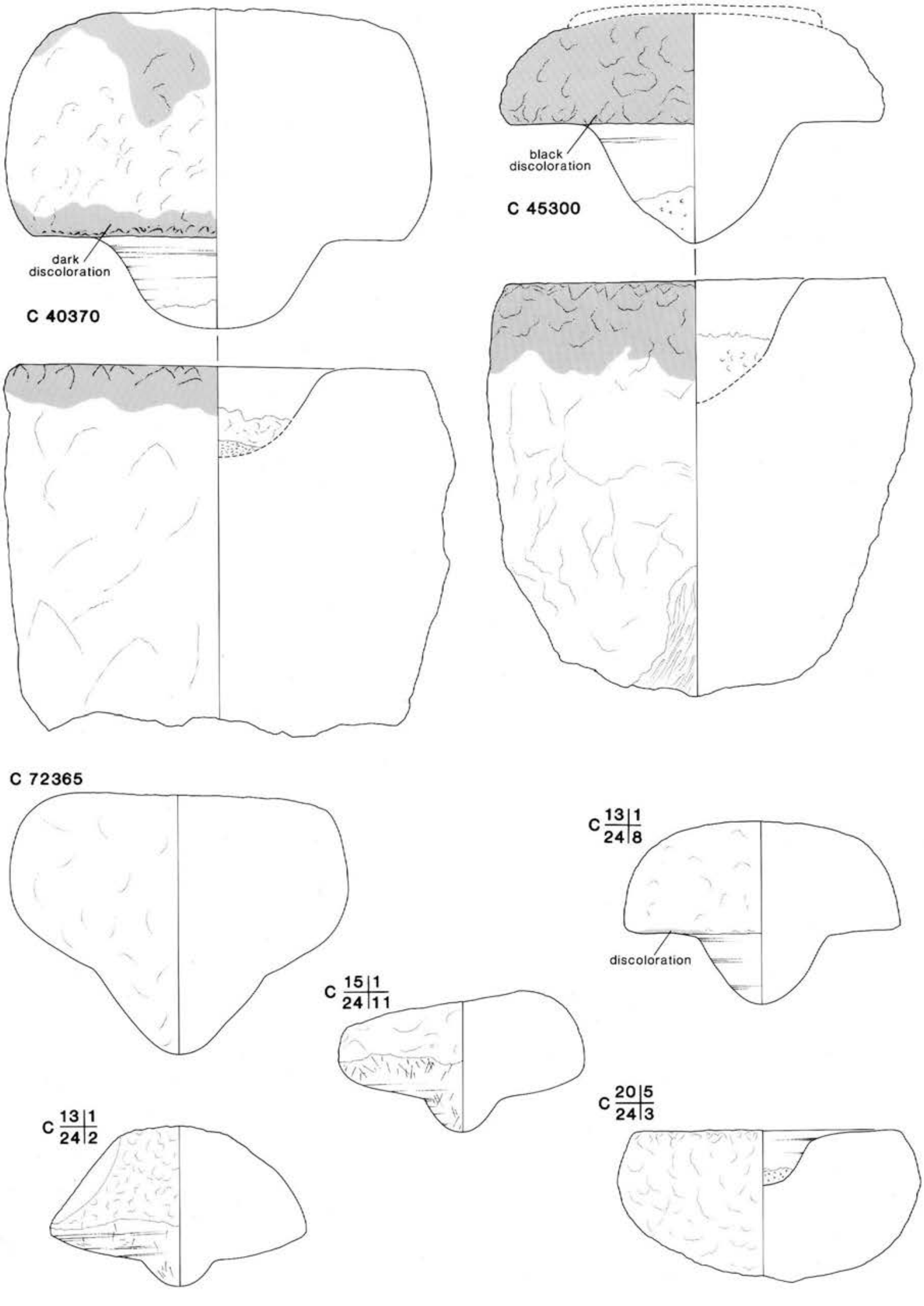

Figure 10.2. Potter's wheel-bearings in the Cairo Museum. Scale 1:3.

Cairo Museum

Room 34 of the Egyptian Museum, Cairo has a number of pivoted and socketed stones on display. The following descriptions include information from the *Catalogue général*, in which they are mostly described as hand-mills and thus appear in association with other milling equipment, and observations made through the display case. The specifications are thus approximate.

Cairo Museum 40370 (Figure 10.2)

Provenance: unknown
Material: "calcaire" (limestone)
Diameter: 22 cm

A pair that are separated in the display case. They appear to be made of different stones and have slightly different dimensions so that it is difficult to be certain that they belong together as a pair. The lower socket stone sits level. The exterior is crudely formed, with a sharply chiselled upper edge. The "interior" surface features a polished surround that is flat with slight striations. A socket-well extends to about twice the width of the surround, and the shoulder of this is highly polished. Below this, the socket wall is pitted and destroyed with discoloration. The upper pivot stone is more carefully and evenly carved. The lower edge leading to the "interior surface" is discolored dark, as is the upper surface of the stone. The polished area shows concentric striae, and the shoulder to the pivot appears most highly polished. The pivot end is ground down to be flat and smooth but unpolished.

Cairo Museum 45300 (Figure 10.2)

Provenance: unknown
Material: "silex" (?limestone)

The lower socket stone is crudely made and sits unevenly. The upper surface is flat with striations visible on the surround and on the shoulder of the socket which appears more highly polished. The base of the socket is worn away and pitted. The exterior upper edge is discolored black.

The pivot stone likewise has a crudely chiselled exterior, and this is heavily stained. A pad of clay appears to adhere to this upper surface. The lower "interior" surface features a corresponding wide pivot and flat surround with visible striations. The shoulder appears most polished. The pivot end is worn into an uneven point.

Cairo Museum 72365 (Figure 10.2)

Provenance: Giza (Selim Hassan)
Material: red granite
Diameter: 18 cm

This is described as a circular pivot for a door. It is the correct shape for an upper pivot stone for a potter's wheel, but no surface detail remains. It is perhaps an unfinished example.

Cairo Museum $\frac{13}{24}\big|\frac{1}{2}$ (Figure 10.2)

Provenance: unknown
Material: black granite
Diameter: 13.5 cm

This is an upper pivot stone finely carved with a domed upper shape that is flattened on one side. It might be a re-used piece of stone, or this shaped served to interlock it into another. The lower edge is angled inward and is smooth. The surround area of the lower "interior" surface is convex, with very slight striations and a good polish. Light scratching is also visible. The pivot tenon is small and hemispherical.

Cairo Museum $\frac{15}{24}\big|\frac{1}{11}$ (Figure 10.2)

Provenance: unknown
Material: black granite
Diameter: 13 cm

This is an upper pivot stone, wedge-shaped, one side being twice as thick as the other. It is finely carved with a smooth lower edge leading to a convex surround to a small hemispherical pivot tenon. Light striations and scratching are visible and a more highly polished "shoulder" area.

Cairo Museum $\frac{13}{24}\big|\frac{1}{8}$ (Figure 10.2)

Provenance: Tell Basta 1904
Material: limestone
Diameter: 9.5 cm
Height: 14.5 cm

An upper pivot stone. The exterior is a smoothly carved dome with a slightly inward chiselled lower edge. The lower interior surface exhibits a flattish surround and conical pivot. Slight striations are visible, but the stone is uniformly dusty.

Cairo Museum $\frac{20}{24}\big|\frac{5}{3}$ (Figure 10.2)

Provenance: unknown
Material: rose granite
Diameter: 16 cm
Height: 8 cm

A socket stone with a rounded lower surface that tilts the stone. It is evenly carved, and the interior surface exhibits a slightly concave surround that is polished. The shoulder area appears more highly polished, and below this the socket is well worn.

Amarna surface finds

TA79, no no. (Figure 10.3)

Material: black and white granite/diorite
Diameter: 17 cm
Height: 9 cm

An upper pivot stone with roughly pitted surface from having been left unfinished. However, the shape is distinctive, with a convex surround to a hemispherical pivot tenon.

TA92, Main City, reg. no. 21568 (Figure 10.3)

Material: black basalt
Height: 8.5 cm

This is a wedge-shaped fragment of a socket stone. It might be a re-used piece of stone, having a flattened smoothed plane that causes the upper surface to tilt. The surface of the interior features a concave surround and lip at the outer edge. The highly polished surround with

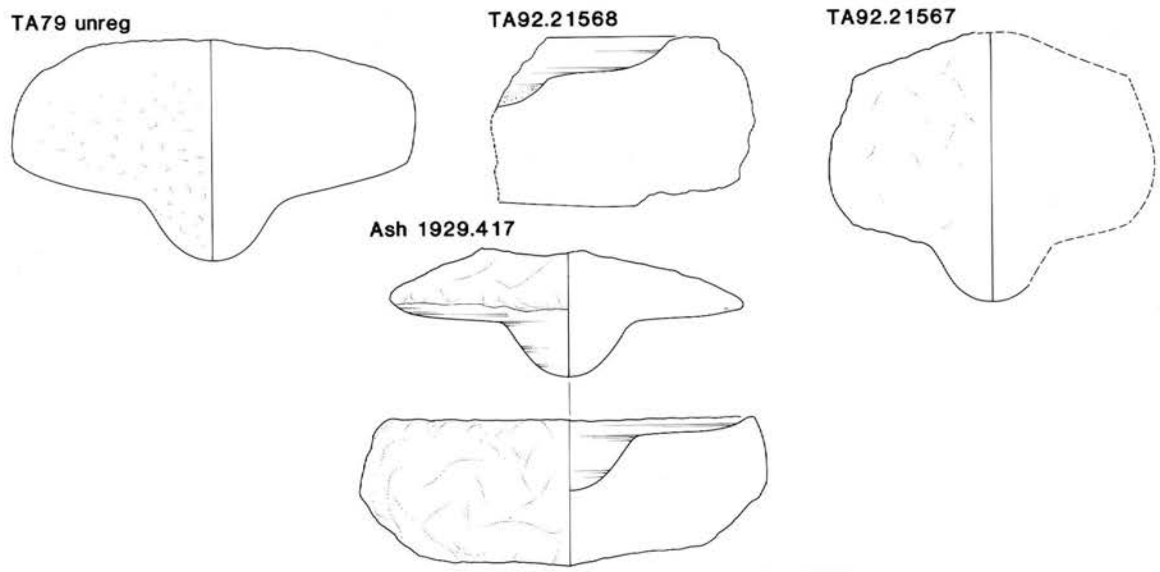

Figure 10.3. Potter's wheel-bearings from Amarna. Scale is 1:3.

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striations dips into a shallow socket that is worn and scored. The whole shape seems to suggest that this bearing would not run true.

TA92, reg. no. 21567 (Figure 10.3)

Material: black basalt
Height: 11 cm

This is a fragment of a pivot stone with roughly pitted surface from having been left unfinished. However, the shape is distinctive, with a domed upper surface and a lower surface with a convex surround to a hemispherical pivot tenon.

Ashmolean Museum 1929.417 (Figure 10.3)

Provenance: el-Amarna, North Suburb, house T36.11
Material: grey-black granite

This pivot and socket pair have been published by Hope 1981.

10.3 Discussion: general

The lack of provenance and date for many of these specimens of wheel bearings is a drawback, since their varying features cannot be arranged in chronological order or grouped geographically. Thus development can be measured in only the broadest terms. The presence of several types of potter's wheels in ancient Egypt is testified by representations in tombs from the Fifth Dynasty to the Roman Period (Holthoer 5–34). However, we are not yet in a position to judge whether the differences coexisted or reflected technological advance towards a faster wheel. Nor can we judge the degree of co-operation between potter and mason. The stones would have been made for the potter, and their specifications may owe more to the ability and energy of the local mason, assuming that the bearings would have been produced individually as required. Differences in material are inconclusive since stone was widely shipped within Egypt.

Nonetheless, I would like to put forward the following tentative conclusions.

10.4 Pivot-tenon and socket-well size and material

From a group of seventeen stones that I have observed, including the one from the 1987 excavation of Q48.4 (*AR* V: 82–95), fourteen can be set within two broad categories, although it scarcely needs to be pointed out how small and possibly unrepresentative this sample is.

Category (a)

BM 55310	Ashmolean 1929.417
Cairo $\frac{13}{24}\big\vert\frac{1}{2}$	TA87 Q48.4
Cairo $\frac{15}{24}\big\vert\frac{1}{11}$	TA79 surface
Cairo $\frac{13}{24}\big\vert\frac{1}{8}$	TA92 surface MC 21567
Cairo $\frac{20}{24}\big\vert\frac{5}{3}$	TA92 surface MC 21568

This group of ten is made from hard stones, such as granites or basalts, have generally smaller dimensions, with pivot-tenons or socket-wells measuring from 1.5–3 cm in height/depth and 3.5–5 cm in diameter. The pivot/socket shape is more hemispherical.

Category (b)

BM 55316	Cairo 45300
BM 32621	Cairo 40370

This group of four is made of various limestones, are larger in size and often more crudely carved. Pivot-tenon and socket-well size measures from 4–6 cm in height/depth and 8–11 cm in diameter. The pivot/socket shape is more conical.

It seems likely that these categories reflect a difference in use and/or the properties of rotation and velocity. Thus the bearings of category (b) might lend themselves better to a type of wheel where a large wheelhead is attached and spun by hand, a simple wheel. The long depth of pivot and socket would prevent the two from slipping apart or tipping over, particularly since jerky non-continuous hand movements are needed to build up momentum. A greater diameter for the upper surface would also provide more support for a large wheelhead disc. Amiran (1984: 108) has found that 60 cm is appropriate, and this is some three times the diameter of this category of stones.

The smaller stone bearings may have been part of a faster kind of wheel. The bearing has a smaller area of rotational friction, and the hardness of the stone is presumably better suited to greater pressure. The bearing would not then have formed a major structural part of the wheel. A heavier wheelhead or an assistant for the turning would have kept the bearing in place. It could also have been more suited to be part of a more complex machine such as a kick or double wheel, and the possibility that such existed cannot be entirely ruled out.

An alternative theory refers back to the masons who would have made the bearings. Those who specialized in limestone might have made the pivot longer because this would wear down, and the conical shape would ensure that it continued to function. The larger dimensions might also spread the effects of the wear on the bearing. Granite and basalt masons, on the other hand, might have achieved a functioning bearing with a small rounded pivot, the hardness of the material reducing wear, and with smaller dimensions the friction might also decrease.

10.5 The upper surface of the pivot bearing

The "exterior" shape of the upper pivot stones is significant and must reflect how the pivot was intended to be fixed, whether to a wheelhead of a simple wheel, or to the flywheel of a kick-wheel. An uneven or roughly hewn surface must have been fixed with a responsive and malleable material, namely, clay (as suggested by Hope 1981 and Amiran 1984), in which the rough texture of the stone would be advantageous for adherence. Some examples (Cairo $\frac{13}{24}\big\vert\frac{1}{2}$, Cairo $\frac{13}{24}\big\vert\frac{1}{8}$, Cairo 45300, Amarna TA87 from Q48.4) bear noticeably dome-shaped tops, and this feature may have served as an "anchor" within a receiving hollow on the underside of a disc and the embedding clay fixative.

The flat top of British Museum 32622 may be an indication that it has been more "thoughtfully" carved, and that a receiving depression on the underside of the disc could be accurately made for a tighter fit to be achieved. A flatter upper surface and thick even edge, such as displayed by British Museum 32621, British Museum unregistered, Cairo 72365, and Cairo 40370, may also aid the fitment of a metal band, as used by Amiran (1984). A final option is the use of the paired stones as a complete wheel without an additional attached disc, the small diameter of the upper stone being suited to a slower manufacturing process, coiling or decorating. British Museum 32622 could be seen as a possible example of this, and its use similar to that discussed in connection with British Museum 55316. A further possibility is that it could have been used in the process of painting on a slip (note traces of red pigment).

The lower socket stones, many of which were unevenly carved, we can assume were partly buried, with the upper surface projecting sufficiently to hinder dust from entering the bearing (and thereby impeding rotation), and, at the same time, providing adequate height for the wheelhead.

10.6 Evidence of lubricants

The limestone wheel bearings from the British Museum (nos. 55316, 32621) together with Cairo 40370 and 45300 show conclusively that a lubricant was used to aid the rotation of the stones. The light colour and less dense fabric of the limestone have enabled considerable traces to adhere and to survive visibly to this day, whereas this is not the case with the granite and basalt bearings. The dark brown colour could be the result of the discoloration of an oil (vegetable or animal) over time, its mixing with the surrounding Nile-mud clay, or the use of a naturally dark substance, such as resin. It would repay to analyse samples of the residues.

The slight convexity of the upper pivot stone matched to a slight concavity of the lower socket stone, which has been noticed on some examples, forms a well in which a lubricant could be contained, though it is probably a happy accident of manufacture.

10.7 Simple wheels featured in tombs

The representations of simple wheels in tombs (Holthoer 1977: 5–34) do not conclusively show pivot and socket stones used for bearings. There can be no doubt, however, that a pivot and socket of some sort is a necessary part of a turntable or wheel, and this much is actually suggested in tomb drawings. The most prominent feature illustrated is a large wheelhead, but the absence of such objects from archaeological finds connected with pivot and socket stones has left the wheel bearings lacking a conspicuous and essential part, and, therefore, unrecognizable until relatively recently. We cannot know from tomb pictures whether wood, or wood-and-stone, as well as paired stones, formed the simple wheel's bearings in the illustrations of potters at work

The following notes review a number of ancient representations of simple wheels, as described and illustrated by Holthoer (1977: 5–34).

Tomb of Ti, Saqqara, Fifth Dynasty. The earliest depiction of a potter's wheel occurs in the Fifth Dynasty tomb of Ti at Saqqara. A potter sits before a low turntable and turns the wheel with one hand whilst the other shapes the rim of a bowl. Alongside, other potters are shown shaping and finishing restricted vessels without the use of a wheel, resting their pots within small hollowed-out objects, and forming the vessel by hand. The illustration of a potter's wheel is thus shown alongside a process that gave rise to its invention, as an efficient "tool" to facilitate the easy rotation of the vessel.

Tomb of Khentika, Saqqara, Sixth Dynasty. Two potters are shown, both crouching before simple wheels. The wheelhead is delineated as separate but joined to an extended pivoted axis which is long and narrow, half the length of the potter's calf. Its end rests within a socket and this is drawn as a cross-section to show the hollow receiving the pivot end.

This design of a simple wheel, if we are to accept the illustration as fully reliable, is unsatisfactory. Its mechanics resemble those of a spinning-top inasmuch as, unless the pivot and socket extend much deeper and have not been illustrated, the pivot and a joined wheelhead would be awkward to keep upright and horizontal, falling over when the wheel slowed down. The drawing raises two possible explanations. The extended pivot may be an exaggeration drawn to emphasize its presence and function, yet in reality it might have been shorter, like the pivot stones. Alternatively, this simple wheel could have been situated in a pit, the long pivoted axis supported by a plank placed across the top of the pit with a hole for the axis to pass through. This type of pivot would have been made from wood (for a similar type from India, see Saraswati and Behura 1966: 2–22).

Tomb of Bakt III, Beni Hasan, Eleventh Dynasty. Here a more graphic breakdown is provided of the pottery workshop and its attendant processes. Seven wheels are shown, each with two parts, differentiated by colour. The upper sections are painted red, and this includes both wheelhead and adjoining "pivot" or "axis", which rests on a grey-painted "socket". The heights of the wheels reach halfway up the potters' calves, and the width of the wheelhead appears at least as long as their forearms.

As well as the manufacture of restricted forms, bowls are being formed off a lump of clay. In three instances the potter is using both hands to fashion the bowl. From my experience, two hands are necessary to throw a bowl, both to support the soft clay and to achieve even walls and rim. Vessels are placed in some instances next to the potter. These could have contained water necessary for throwing, to wet the clay. This strongly indicates that throwing is taking place, and that this type of simple wheel was in use for this purpose, attaining both the necessary speed and momentum. At this point we are no longer dealing with a tool to assist manufacture but with a true machine.

Potters are also shown with one hand supporting the vessel whilst the other turns the wheel. Here the suggestion is that the speed of the wheel was discontinuous and needed to be constantly renewed. It is worth noting that the overall appearance of the simple wheels shown here is close to that of my own reconstruction, as described later.

Tomb of Khnumhetep III, Beni Hasan, Twelfth Dynasty. A potter kneels before a simple wheel using one hand to turn whilst the other touches the rim of a restricted vessel. It is not clear whether throwing or a slower process is involved.

Tomb of Amenemhat, Beni Hasan, Twelfth Dynasty. A very similar pottery workshop scene occurs. Four wheels are shown. Again the top section, including both wheelhead and adjoining pivot/axis, are painted red. The length of the pivot is extended, perhaps an artistic exaggeration, as suggested above. The tips of the pivots rest within black-painted sockets. In two instances these sockets appear to be completely above the ground, perhaps another element of artistic license to show their presence.

Bowls are being thrown off a lump of clay, one potter using both hands, another supporting the bowl with one hand whilst turning with the other. A further potter uses a string to cut a bowl from the lump of clay, whilst his other hand either turns or stays the wheel. Lastly a potter forms a restricted vessel directly on the wheelhead, which is turned by hand.

Tomb of Qenamun, Qurna, Eighteenth Dynasty. A scene of a pottery workshop includes a simple wheel, "a tray painted white and a pivot painted red" (Holthoer 1977: 19). A potter places a large lump of clay on the wheelhead, which he supports with a foot, whilst an assistant steadies or turns the wheel. Whilst the activity, material of the wheel, and the bearing arrangement are unclear and confusing, it can be seen that a simple wheel is in use, perhaps requiring an assistant to turn it.

10.8 Models of potters with simple wheels from tombs

Models of potters with simple wheels have been found in tombs, and present similar information to the tomb wall scenes (see Holthoer 1977: 10–16 for the examples). A limestone model from the Sixth Dynasty includes a low red-painted simple wheel with a broad attached pivot. The potter fashions a bowl, turning the wheel with one hand. Two wooden models from the tomb of Karenen at Saqqara (First Intermediate Period) feature low grey-painted wheels, again with broad pivots. One potter forms a cylinder whilst the other throws a bowl from a lump of clay. The wheels are turned by hand. A wooden model from the tomb of Gemniemhat from the Middle Kingdom at Saqqara includes a simple wheel, grey with red edges, upon which a bowl is formed from a lump of clay with one hand, the other turning. In the tomb of Usermut and Anpemhat at Saqqara a potter sits in front of a red-painted simple wheel, his hands stretched over an object, no longer preserved but presumably a pot.

10.9 The material of the wheelheads

As we have seen, wheelheads are usually represented painted red whenever colour is recorded. Holthoer (1977: 32) argues that this implies the use of fired clay, and when grey is used this is a result of staining of the wheelheads by clay during use. Unfired clay is always represented grey. However, the use of colour could also be interpreted as a system for differentiating between clay used for forming vessels and the wheel itself. Fired clay discs identified as wheelheads are reported from the Near East and the Aegean (Childe 1954; Xanthoudides 1927). However, so far nothing of this kind has been discovered in Egypt associated with pottery workshops. The models of potters with simple wheels in three cases show grey-painted wheels, and this raises the possibility that the wheelheads themselves were constructed from unfired clay. Nor can the use of wood or stone be excluded.

10.10 The modern Indian simple wheel as a comparison and working model

Simple wheels from India in use today bear a resemblance to the simple wheels from ancient Egypt, as we reconstruct them from the available evidence. There are many variations of the simple wheel, and these are minutely described and their distribution mapped by Saraswati and Behura (1966). Four groups can be discerned: pivoted spoked wheels, pivoted block wheels, socketed block wheels, and socketed spoked wheels. The structural differences amongst the four types have not been observed to bring any marked changes in speed and efficiency.

Spoked wheels are the most common. The wheelhead comprises spokes in a variety of arrangements, radiating from a central wooden hub. A weighted clay circumference forms the rim. This design serves to throw the weight of the wheel outwards when turned, causing momentum to build up and to sustain itself for some minutes. This distinctive type is not illustrated in the Egyptian evidence, and we can discount its presence in ancient Egypt. Another difference is the frequent use of a stick to turn the wheel, something for which again there is no Egyptian evidence.

A type of wheel more closely related to the ancient Egyptian simple wheel is described as the "blocked wheel", and is found in southern India. The wheelhead is made from a solid disk, either stone, wood, or clay, both fired and unfired. The pivoted "block" wheel itself measures 50–60 cm in diameter, and is 2–5 cm thick. In one variety a pivot of wood or iron projects 48–50 cm, tapering towards its base which rotates in a socket embedded in a pit 38–40 cm deep. A plank covers the pit and the pivot passes through a hole lubricated with castor oil. By this means the wheel is prevented from falling over when it slows down. This extended pivot has the disadvantage of running out of its socket, which is only 1.5 cm deep. Potters in this area are recognised by the scars on their legs!

Another type of "blocked" wheel is even more closely comparable to our ancient Egyptian model and includes a stone pivot and socket (Saraswati and Behura 1966: 9, Fig. 19). The pivot measures 7.6 cm with a circumference of 11.4 cm. The socket is 7.6 cm deep, with a circumference of 38.1 cm. This lower stone is partly buried in the ground. The pivot stone is fixed to the underside of a disk measuring 58–68 cm. At the periphery it is 4.5 cm thick, increasing to 8–10 cm at the centre, where the pivot is embedded. Wheelheads made from unfired clay include straw and hair tempering for strength. A similar stone bearing is described in Coomaraswamy (1908: 220, Fig. 134). The stone pivot has a tenon and small surround, fitting into a matching socket stone of larger size. The upper surface of the pivot stone is dome-shaped, fitting into a mount on the underside of the wheelhead.

The socketed block wheels are found in northern and western India. The wheelhead is a solid disc made from stone or unfired clay. A description of the manufacture of an unfired clay disc provides useful practical information utilized in my own wheelhead-making experiments.

Diameters vary between 76–100 cm, with a thickness of between 7.6 and 10 cm (note the 1:10 ratio). The clay is tempered with grass, hair, fur, molasses, dung, and cotton. This mixture is left to bind for two weeks. It is then formed into a disk, consolidated by beating, and left to harden. In areas where the clay is short, i.e. loose and sandy, a wooden cross is built in, its four arms interwoven with creepers, bamboo splints, and coconut fibre string. A stone socket is fitted to its underside. The pivot which projects into this is made from wood embedded in the ground and projecting 5–10 cm. This is sometimes fitted into a slab of stone, clay, or wood to facilitate its easy transport.

The weight of a blocked wheelhead varies between 56 and 93 kg according to size, and is heavier than the spoked wheel (37–47 kg). A heavier wheelhead maintains a longer momentum unless its weight is concentrated in the centre, and this can lead to the use of an assistant to turn the wheel. Otherwise the wheel is spun by the hand of the thrower or a stick engaged in a notch is used to twirl the wheel. Speeds of 100 rpm can be attained and momentum lasting for up to 10 minutes. Lubricants for the pivot and socket of all types and arrangements include castor oil, ground-nut oil, or coconut oil.

Every type of ware is made on these wheels, from bowls thrown off a hump of clay to large cylinders. The posture of the potter varies from standing, bending over the wheel, squatting, and sitting.

10.11 Reconstruction of an ancient Egyptian simple wheel

From information gathered and from my own experience as a potter, I set about the reconstruction of a simple wheel as they are featured in Egyptian tomb drawings and models. A plaster copy of a stone pivot and socket was made for the bearings of this, and taken out to Amarna for the 1989 season.

10.12 Making the first version of the replica pivot and socket bearings

These were made in stages, working from measurements taken from specimen 32621 in the British Museum. A positive shape of the lower surface of the pivot stone (the projecting tenon and its surround) was turned from a lump of leather-hard clay upon a kick wheel. A plaster cast was taken from this, to produce a negative mould. This was inverted, soft soaped, and a wall built around to contain the batch of plaster for the pivot "stone". Crystacal plaster, a hard mix used for industrial models, was mixed with a solution of PVA and water in a 1:10 ratio. This was poured into the mould. The resulting positive pivot "stone" was inverted, and soft soaped. The socket "stone" was likewise cast from it. Excess plaster was chiselled away from both of them in an attempt to replicate the rough-hewn domed exteriors of the originals. The fineness of the plaster gave the pivoted and socket surface a polished appearance.

The shortcomings of this copy became evident when I put the bearings into practice on site at Amarna. Inevitable slight inaccuracies on the clay positive were duplicated in the plaster moulds, and were enough to hinder their easy rotation. This necessitated hours of sanding until the two interior surfaces of the pivot and socket were absolutely compatible, and turned with ease.

The porosity of the plaster proved to be another drawback. Crystacal was the densest plaster available, but, even though it was mixed with a degree of plastic, it remained porous. The lubricant oil soaked into the plaster after a few minutes, leaving a greasy rather than an oiled deposit inside the "stone" bearings. More soaping, coatings of PVA, and even of varnish, did not alleviate this problem. This limited the success of this first replica wheel because it became necessary to keep dismantling it in order to oil the bearings.

However, this initial experiment did serve to stress the importance of the pivot and socket stones being ground together to achieve an exact fit, the use of a non-porous material for this type of bearing, and of a free-running oil lubricant. Furthermore, the overall experience of making and using an experimental wheel, even if it was defective in some aspects, was sufficiently useful to encourage me to persevere with this direction of research. It was also an essential element in my experiments to create a satisfactory wheelhead.

10.13 Testing lubricants

To begin with, in 1989, four substances were tried in an attempt to encourage the easy rotation of the plaster pivot and socket "stones". The first was water. This proved ineffectual because it was quickly absorbed into the plaster of the socket. A fine clay slip was also tried, but with the same effect. Both results are, of course, not really valid because the original pivot and socket were made from a non-porous stone. Palm oil (of cooking quality) was found to be an improvement but tended to solidify once the bearings had stopped rotating. Castor oil, widely available in ancient Egypt, turned out to be ideal. It provided a fine, free-running lubricant that enabled the plaster pivot and socket stones to rotate with ease. Unfortunately, again, this, too, soaked into the plaster after a time. In the subsequent season, 1990, when I was able to work with a newly made replica stone pivot and socket, I experimented with castor oil, linseed oil, and (for running-in the new wheel) modern machine oil. The results are measured and commented upon in the latter part of this chapter.

The slight convexity of the upper pivot "stone", matching a slight concavity on the lower stone and noticed on some of the ancient bearings, had been sanded away on my copy. This allowed the seepage of the lubricant oil from between the stones, something especially pronounced when the wheelhead was attached to the pivot, increasing the pressure and forcing the lubricant out of the bearing. This affected the outside appearance of both "stones". The seeping oil mixed with the clay surrounding both the buried socket and embedded pivot, leaving dark brown traces concentrated particularly just outside the polished areas of the "stones". This effect can be observed on the ancient examples BM 32621 and 55316, and was later repeated with the replica stone bearing (Figure 10.7).

10.14 Making the wheelheads

As previously discussed, wheelheads were probably made in ancient times from wood, stone, or clay, either fired or unfired. It seemed sensible to try each of these (apart from stone) to ascertain their effectiveness and characteristics when part of a simple wheel, and this was done during the 1989 season. Each wheelhead was designed with an emplacement or mount enabling the removal of the pivot stone for the tests. The original type would probably have had the pivot stone permanently built in. For each test, the pivot was attached with heavily tempered clay.

10.15 Wooden disc wheelhead

A wooden disk was made, from three planks 1.75 cm thick, cut down to a circle measuring 46 cm in diameter, and battened together with two cross-pieces of wood, nailed from both sides. Two additional pieces of plank, shaped into curves, extended between the battens to form a roughly circular emplacement 2.5 cm deep for the pivot stone. The interior of this was chiselled to form a slight depression and left rough to grip the holding clay between the wooden wheelhead and the upper surface of the plaster pivot "stone".

The result of attempting to use this wheelhead was to find that it was too light (2.5 kg) and so lacked sufficient spin to attain the necessary momentum, although it did serve as a satisfactory turntable. The clay used to hold the pivot stone in place had only weak adhesion; a swift spin of the wheelhead by hand often dislodged it, leaving the clay and pivot behind.

10.16 Fired clay wheelheads

Four clay disc wheelheads were made and fired in a replica of an ancient Egyptian kiln (the kiln described in Chapter 8). A mixture of Nile clay and desert marl was used. Nile clay has a high shrinkage factor and is prone to cracking; it was to prevent this that the sandier marl was added. Temper in the form of *tibn* (chaff) and donkey-dung were added. The clay was wedged into large lumps and spread over the surfaces of convenient nearby flat stones (Figure 10.4), a layer of sand and ash having first been sprinkled over them to prevent sticking. A thick circular layer of clay was built up and compressed, first by hand, and, when the clay had hardened, it was carefully beaten with a hammer-stone. A slight depression was made in the centres.

Figure 10.4. Making the wheelheads. For a drawing of that on the left, see Figure 10.12(c), and for that on the right, see Figure 10.12(e).

The edges were next gently but firmly squeezed and smoothed to make a comfortable hand-hold. Plastic was used to cover the circumference, to allow the disc to shrink evenly as it dried, since clay shrinkage over a large area can cause cracking at the outer edges. In this way the discs were allowed to dry for a week.

Two small discs were made. Using the relative sizes of wheelheads depicted in tombs as a guide, I made their diameter to be roughly equal to the length of my forearm. The first was 32 cm across and 2.5 cm thick, the depression 17 cm by 1 cm deep. The second disc measured 36 cm across with a thickness of 3.5 around the central depression, tapering to 2 cm at the periphery. The depression measured 18 cm by 1 cm deep. Their weights once fired were 3.5 and 4.5 kg respectively. Two further discs were larger. One, of medium size (Figure 10.12b), had a diameter of 46 cm and a depth of 1 cm, its thickness ranging from 4.5 cm near the centre, tapering to 3 cm at the outer edge. This weighed 9.25 kg when fired. The other and largest of the series measured 60 cm across, was 4.5 cm thick tapering to 4 cm at the periphery, and, when fired, weighed 21.25 kg. This last disc was not fully fired and consequently broke in half.

10.17 Attachment of the pivot stone to the fired clay wheelheads

The attachment of the pivot "stone" to the underside of these wheelheads was successful. The slight depression made on the upper surface of the disc was used as a hollow to help hold the plaster pivot stone. This hollow was wetted to encourage the fixing-clay to adhere to the porous surface of the fired wheelhead. Soft clay, heavily tempered with coarse chaff to prevent shrinkage, was applied in wadges and coils to form a bed for the exterior shape of the pivot stone. The pivot was adjusted in this until its polished surface sat level. Clay coils were placed around the edge of the pivot until it was firmly held. This was allowed to harden before the wheelhead, with attached pivot, was turned over and inserted into the embedded socket which had been previously lubricated with oil.

The two smaller fired clay wheelheads made good turntables, but their diameter was insufficient for building up momentum, and the energy expended in constantly turning them rendered throwing impractical. It was also found, with this size of disc, that a weightier centre and thinner edge made no appreciable difference. The medium-sized wheel was a noticeable improvement. It was possible to throw a small bowl from a hump of clay, but only with an assistant turning the wheel. The largest (60 cm) fired clay disc proved to be the most successful. It was a comfortable size to sit at and turn by hand; it was possible to spin the wheel by fully extending the arm and pulling towards the body. This movement felt natural and not strenuous compared with what was required to turn the smaller discs. The wheelhead maintained its own momentum for several revolutions. Unfortunately, this disc broke in half. It had been only partly fired, yet was under more stress because of the large diameter proportionate to the thickness, and the relatively small area of support it derived from the upper surface of the pivot stone lying below.

10.18 Making an unfired clay wheelhead

No large fired clay wheelheads have been identified from excavations in Egypt. This could point to wheelheads having been made from a material that disintegrated or was rendered unrecognisable over time. The common use of unfired clay for Indian simple wheels made this an option worth investigating.

Two 71 cm-long pieces of *gereed* (the central rib of a palm leaf) were tied to form a cross (as described in Saraswati and Behura 1966). This was strengthened by battening in the form of a square over the middle. Bundles of reeds taken from an old floor-mat were tied together in a circle to form the circumference of the wheelhead, which measured 71–74 cm in diameter. This was laid over and tied to the *gereed* cross. It then became apparent that this, too, needed support. Sixteen short spokes were laid out radiating from the centre to the reed circumference. *Gereed* fibres and string were woven in and out of these spokes until the structure resembled a large crude table-mat.

A mixture of clay tempered with *tibn*, donkey dung, and chopped *gereed* fibre was allowed to bind for a couple of days. This was first applied to the centre of the wheelhead, and also around the circumference reeds, to reinforce the structure. Further clay mix was added, working slowly from the centre outwards and squashing the clay around the spokes and *gereed* "matting". This was continued over two days, allowing the clay to harden and shrink before more was applied. The wheelhead was turned over a number of times to enable both surfaces to be worked on. The reed circumference was built up to be thicker and heavier in order to aid the momentum of the wheelhead. This weighted rim was 6–8 cm deep and 4–6 cm across. The rest of the wheelhead was 3–4 cm thick. Finally a hollow was made which measured slightly more than the diameter of the plaster pivot, 19–21 cm, and 1.5 cm deep. This formed an enclosure for the pivot and fixing clay. The pivot stone was attached in the manner already described (Figure 10.12a).

The momentum of this wheelhead was good for it rotated several times after being spun by hand. I felt that the weighted rim assisted this. However, as soon as pressure was brought to bear on its centre, by "centreing" a lump of clay, it slowed to a halt, something which I considered that improved pivot and socket bearings would prevent. The diameter, at 71–4 cm, was found to be slightly too large for it knocked against my shins when I leant over to "centre" the clay. The large size also caused the wheelhead to tip and dislodge itself from the pivot stone.

10.19 The replica stone bearing

For the following (1990) season a mason (Tim Smith of Kingsland Stone) was commissioned to make a second copy of a wheel bearing, this time in stone. Again it was based on the example British Museum 32621. The copy was made from a block of Carera marble, the cheapest of the suitable stones available. Granite was considered, but since this is more difficult to carve it would have added considerably to the cost of production. The block of marble was cut into two, and roughly hewn into hemispheres. The lower socket bearing-stone was made first, and this was larger. From the upper surface of the stone a central drill hole was sunk to the desired depth of the socket well. A cross was marked over this to the edges of the stone, and using a reverse template (taken from a drawing of a cross-section of BM 32621), this cross was cut down to the exact template profile. The socket well and surrounding area was then chiselled out, accompanied by repeated turning of the stone and checking against the template and with compasses.

The upper pivot bearing-stone was made next. Another reverse template was used, and a true section of the projecting tenon and its surround was worked directly across the stone. This was repeated from the other side of the stone, leaving a roughly square central tenon which was then rounded off and the surround area evened out.

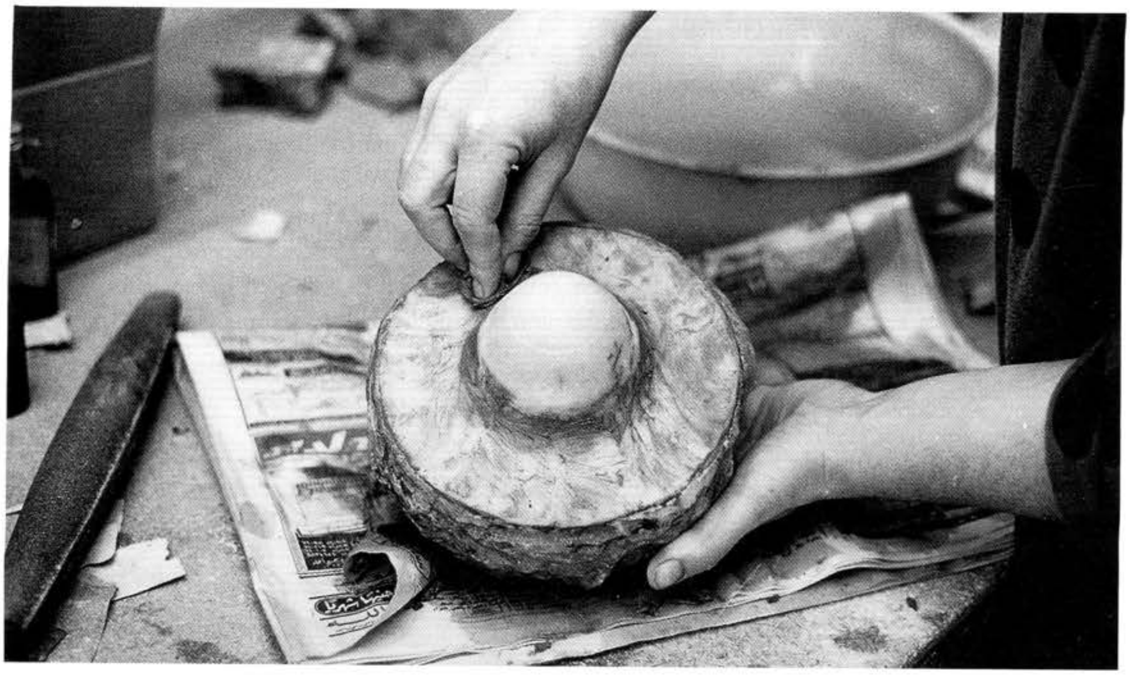

Figure 10.5. Polishing the pivot stone.

10.20 Working the two stones together

Although the pair of stones fitted well, it was obvious that they would need considerable grinding and polishing together before they would resemble the original and function as a smoothly-running bearing. To achieve this, silicon carbide abrasive grit was mixed with water and applied as a paste between the pivot and socket surfaces (Figure 10.5). The stones were ground together by repeated backwards and forwards motions, and pressure was applied to the upper pivot stone. A coarse 46-grade grit was used first, with a strong cutting edge to wear away unevennesses and to match up the surfaces. Finer grades, from 200–1000, were used to smooth and polish. As the stones were worked together, it was necessary to keep separating and washing them, as the abrasive powder and marble dust tended to form a bonding material. The abrasive could be retrieved and re-used by pouring away the marble dust in suspension with water. Gradually, after many hours, the pivot and socket stones matched one another, and shone and closely resembled the original ancient bearing.

At this point a problem manifested itself. The industrially produced and finely graded and sorted silicon carbide ground the surfaces together to form a near-perfect fit. It is unlikely that ancient and easily available sources of abrasive would have done so. The resulting stone bearing fitted and spun beautifully for a few minutes before suddenly locking tight, separating only by the use of a chisel and mallet. This was a result of the spinning motion and the interaction of the two cone-shapes of the pivot tenon and socket well which expelled all the air and thereby created a vacuum. This action is comparable to that of a cylinder brake, quite the opposite of the continuous and unimpeded motion desired.

10.21 Reworking the stones

Various remedies were tried to alleviate the braking action, including the use of lubricants between the stones (castor oil, linseed oil, palm oil, and even modern lubricating oil), as well as clay slip and water. These were found to affect the rate of rotation of the bearing to varying degrees, reflecting their differing viscosities, but not the persistent locking that occurred after a few minutes. It therefore became necessary to reappraise the workings of the bearing and to reconsider the wear marks noted on the originals. As described, in most cases these exhibited a worn pivot end and a correspondingly worn socket well. It had been presumed that this was caused by extensive use and the inevitable dust and grit working their way down into the interior of the bearing. However, it could also have been the case that the pivot end was the "point of spin", and that it was the focus of pressure on this, rather than time and use, that was the cause of the wear patterns. Also the illustration of potter's wheels in the tomb of Amenemhat suggested that this may have been the case, i.e. that the pivot extended above the socket.

Other remedies were consequently tried. A piece of cambric, 1 cm square, was inserted between the pivot end and socket well. This prevented the locking, by raising the pivot and allowing air into the bearing, but also introduced an area of friction that reduced the efficiency of the rotation, as did cotton fibres and a small pad of clay. Next grains of sand were introduced into the socket to act as bearings but this caused immediate and severe scoring and wear-marks to the pivot end. These solutions were considered unsatisfactory.

Figure 10.6. The finished reproduction stone pivot and socket. The scale is 10 cm.

A further reconsideration of the original stone bearings was required. In every one of the ancient examples, the two stones were shaped to fit together and, therefore, to move together. The concentric striations common to both testify to this, as does the high polish described on the "shoulder" areas. The introduction of an addition to the bearing seemed without sense, as did raising or extending the pivot tenon. This would cause the wheel (pivot with large attached wheelhead disc) to wobble, and would also negate the purpose of the broad flat surrounds on both of the stones. These areas seem intended to extend the area of rotation, and, at the same time, to stabilize and support the spinning motion. I felt it preferable to see the bearing as operating as a whole, the upper pivot stone fitting the lower socket stone, simultaneously spinning and floating within a free-running lubricant so that no surfaces actually touched which would inevitably restrict the spin. This would become possible by reworking the polished areas of each stone separately to prevent them from fitting quite so tightly. This proved to be successful. The bearing then spun superbly, at a top speed of 130 rpm, and neither braked nor sucked together.

10.22 An experimental design

With the new wheel-bearing (Figure 10.6) and the lessons learnt in the previous season, I moved quickly to a working reconstruction of an ancient Egyptian potter's simple wheel, in order to test wheelheads made in the previous season as well as new ones. I was looking to create a potter's wheel that was comfortable, easy to use, and attained speeds sufficient for throwing (in my own pottery workshop these range from 48 rpm to 180 rpm using an electric and a treadle wheel). I devised a series of questions that I considered provided a suitable experimental framework:

1. Which is the more effective, a wheelhead made from unfired or from fired clay?
2. What is the optimum diameter which combines a good working surface and ease of turning?
3. How heavy should a wheelhead be to provide and maintain a good rotation?
4. Is the distribution of weight across the wheelhead a significant factor in good performance?
5. How much does the addition of a load of working clay affect the rotation of the simple wheel?
6. Which oil provides the most effective lubricant between the paired stone bearings?
7. How well do the various wheelheads perform when actually put to use for the making of pots, thus staying firmly adhered to the pivot stone, remaining comfortable to turn after a period of time, and having a reasonable length of life?

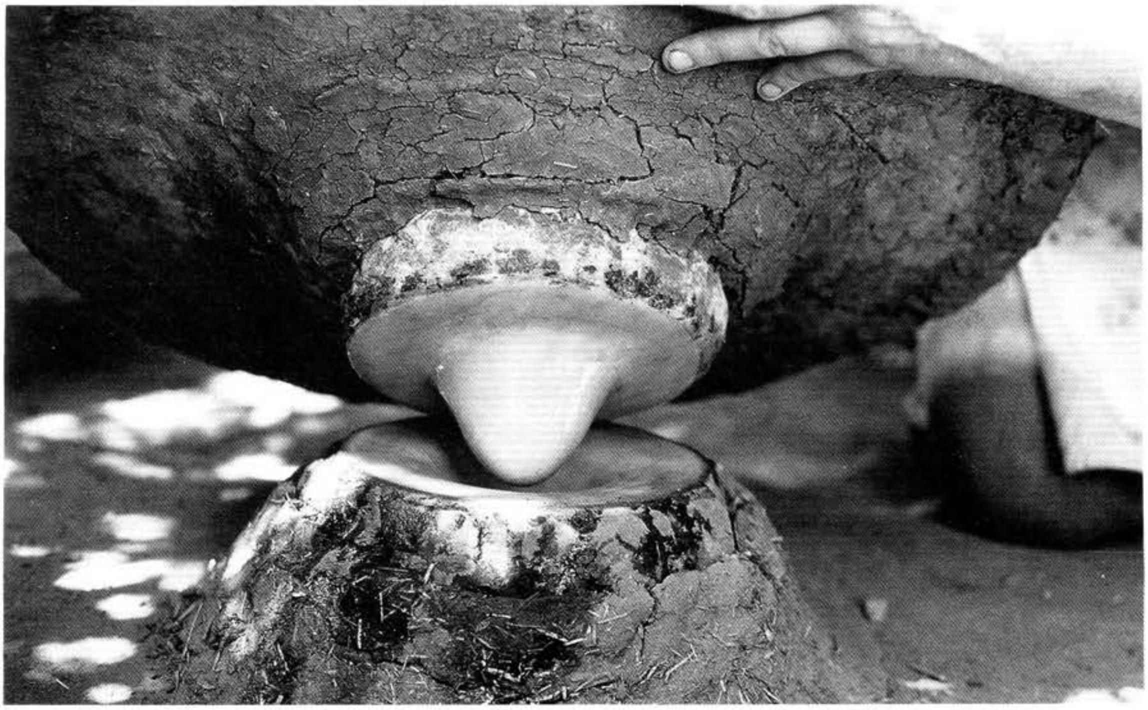

Figure 10.7. The reconstruction "simple wheel" showing the pivot and socket arrangement.

10.23 Testing wheelheads

The new lower socket stone was firmly fixed into a hollow in the ground in the same manner as before. For each test, heavily tempered clay was used to set the upper pivot stone into a slight hollow in the underside of the wheelhead (Figure 10.7). It was found to be preferable to invert the wheelhead and attached pivot on to the socket stone immediately and adjust the upper surface to a level plane whilst the adhesive clay was still soft. This was then left to harden for a day. A stool built from three courses of mud brick or a log of wood were found to provide a comfortable height from which to operate the wheel, the wheelhead being set at around 15–20 cm from ground level (Figures 10.8–10).

The new stone bearing was first tried out with existing wheelheads from the previous season's experiments before embarking on tests with new models. However, the new stone bearing was not yet "run in", and could be made to work satisfactorily only with a modern light lubricating oil. In later tests oils were used which would have been available in ancient times. The speeds were measured by pulling the wheelhead towards myself, using my left hand to produce an anti-clockwise rotation, one pull with each revolution. When left after sufficient momentum the wheel

Figure 10.8. Turning the "simple" wheel.

Figure 10.9. Centreing the clay.

Figure 10.10. Throwing and shaping a bowl on a hump of clay.

Figure 10.11. Turning or finishing the base of a bowl.

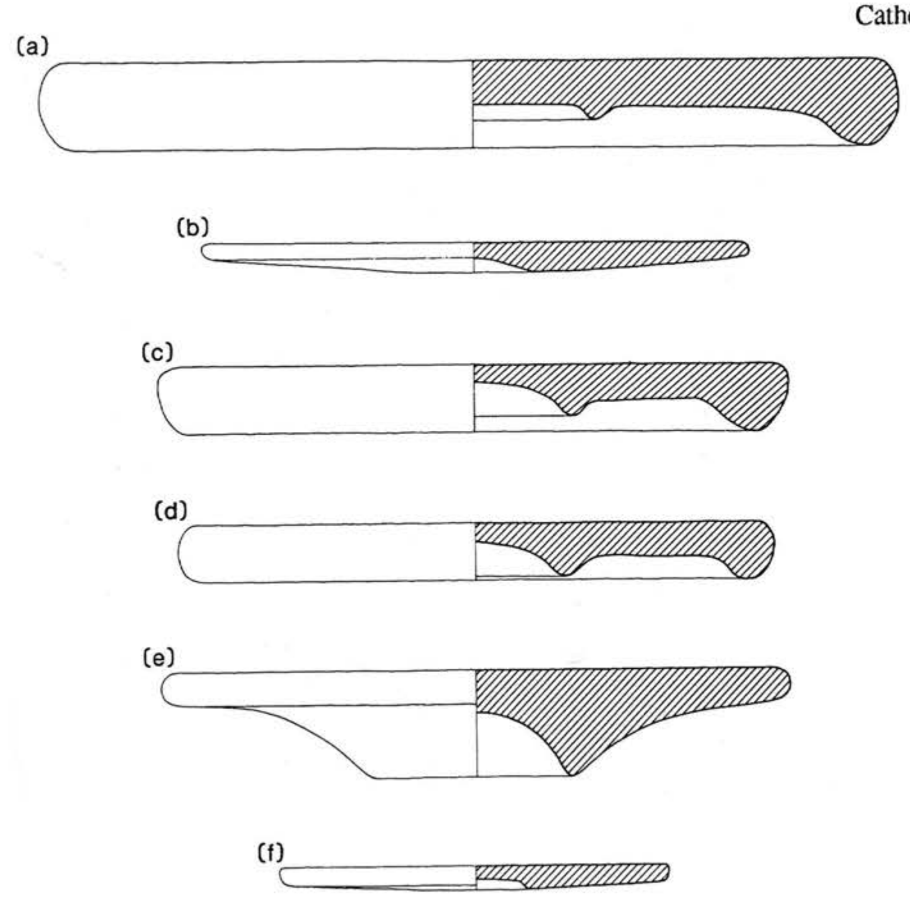

Figure 10.12. Sections through wheelheads, at 1:6 scale. For (c), see Figure 10.4, left; for (e), see Figure 10.4, right.

continued to rotate three or four times before slowing to a halt.

The first test wheelhead (Figure 10.12a)

Wheelhead type: made during the 1989 season from unfired clay over a *gereed* former.
Specifications: see section 10.18.
Lubricant: modern all-purpose lubricating oil ("3-in-one").
Speeds:

revolutions	seconds	rpm
60	84	43
60	50	72
50	49	61
60	80	45

average rpm 55

Results. The design of this wheelhead was based on modern Indian potters' simple wheels. These have a large diameter and weighted rim to build up momentum; the potter turns it energetically for a momentum that lasts for up to seven minutes (Saraswati and Behura 1966: 19). However, these wheels have a different bearing arrangement, often an extended pivot, and I formed the view that the Egyptian stone bearing did not work in the same way. I had no sense of a build-up of momentum, even when increasing the number of pulls per rotation. The wheel continued to slow and halt after being left. The large diameter also made it feel ungainly to turn by hand. The adherence of the pivot stone to the underside of the wheelhead was so effective that a chisel and mallet were needed to separate them.

The second test wheelhead (Figure 10.12b)

Wheelhead type: made during the 1989 season, fired clay.
Specifications: see section 10.16; weight 9.25 kg.
Lubricant: modern all-purpose lubricating oil.
Speeds:

revolutions	seconds	rpm
52	46	68
60	48	75
60	47	77
60	49	73
	average rpm	73

Notes. It was noticed that the speed of the wheel was not improved by pulling with each revolution. One pull every third revolution was enough to build up and maintain the speed.
Results. This wheelhead, in conjunction with the new stone bearing, attained speeds which were easily adequate for throwing. The diameter was, however, somewhat small and the receiving hollow for the pivot stone on the underside of the wheelhead needed to be improved since the pivot was apt to come away.

The third test wheelhead (Figure 10.12c)

Wheelhead type: made during the 1990 season; a mixture of Nile silt and desert clay (4:1) combined with ash, *tibn*, and *gereed* fibres. This was left unfired and was given no internal structural support. The wheelhead was made over several days, as layers of clay were built up, and allowed to dry for more than a week, keeping the outer edge covered.
Specifications: weight 14.9 kg; the wheelhead was fixed with 1 kg of clay (Figure 10.4, left); wheelhead diameter: 53 cm; outer rim depth: 6 cm; overall thickness: 3–5 cm; pivot emplacement diameter: 17 cm.
Lubricant: linseed oil.
Speeds:

revolutions	seconds	rpm
60	30	120
60	50	72
60	33	109
60	40	90
60	55	65
	average rpm	91

Notes. The heavier weight of the wheelhead combined with the better running of the bearing enabled a lubricant to work effectively that had been considered too viscous previously. The wheelhead began to slow after five revolutions but remained turning for a further six to nine before stopping.

The same wheelhead with additional load of working clay. An additional quantity of "working" clay was shaped into a cone and placed at the centre of the wheelhead to check how this affected the rotation of the wheel.

Speeds with weight of clay at 6 kg:

revolutions	seconds	rpm
60	35	103
60	30	120
60	45	80
60	48	75
	average rpm	94.5

This represents a 3% increase in speed.

Speeds with weight of clay at 12 kg:

revolutions	seconds	rpm
60	30	120
60	27	133
60	40	90
60	45	80
	average rpm	106

This represents a 12% increase in speed.

The same wheelhead with different lubricants.

Speeds with castor oil as lubricant:

revolutions	seconds	rpm
60	50	72
60	40	90
60	60	60
60	57	63
	average rpm	71

This lubricant was much more viscous than the linseed oil. It was necessary to pull the wheel every three revolutions (compared to every five or six with linseed oil) to build up momentum. After being left the wheel remained turning for only five to seven revolutions before slowing to a halt.

Speeds with palm oil as lubricant:

revolutions	seconds	rpm
60	43	84
60	39	92
60	45	80
60	49	73
	average rpm	82

Although an adequate lubricant, it was not as successful as linseed oil.

Results. This wheelhead felt the most successful. Its adherence to the pivot stone was excellent and could be envisaged as lasting for a long time. The heavy weight seemed advantageous, the lubricant worked well, and the wheel was easy and comfortable to turn, not requiring excessive energy. The diameter corresponded with the length of my arm, making turning a natural and easy movement. An added load of working clay seemed to improve the speed of the wheel, something which requires further investigation.

This wheelhead was used again in a series of experiments intended to replicate the throwing of small open bowls. An examination of the wheelhead at the end of the season revealed that a crust of additional clay had built up on the outer edge where I had been turning the wheel with hands covered with clay slurry. The centre of the wheelhead showed signs of wear from the water that is used as part of the throwing process, raising a question as to the durability of an unfired wheelhead. However, I have learnt from a recent conversation with an Indian potter who has made a simple wheel with unfired clay wheelhead that a coating of cow-dung serves to waterproof unfired clay. This practice is used extensively in India where unfired clay wheels last for several years before disintegrating.

The fourth test wheelhead (Figure 10.12d)

Wheelhead type: made during the 1990 season with Nile clay and a small amount of desert marl. Ash and *tibn* were added as temper, and the wheelhead was fired in the main experimental kiln at Amarna (see Chapter 8) to around 800°C.
Specifications: weight 11 kg, plus 1 kg of fixing clay; wheelhead diameter: 50 cm; outer rim depth: 5.5 cm; overall thickness: 3–5 cm; pivot emplacement diameter: 17 cm.
Lubricant: linseed oil.
Speeds:

revolutions	seconds	rpm
60	35	103
60	34	106
60	50	72
60	55	65

average rpm 86.5

An additional load of 6 kg of working clay produced the following speeds:
Speeds:

revolutions	seconds	rpm
60	43	84
60	40	90
60	45	80
60	39	92

average rpm 86.5

Results. The fixing of the pivot to the underside of the wheelhead (in this case fired) was not perfect. The fixing clay tended to shrink away unless the upper surface of the wheelhead was kept damp. However, this did not prevent the wheelhead from remaining serviceable as part of a simple wheel. The appearance of the wheel resembled a model of a potter's wheel from the tomb of Gemniemhat (Holthoer 1977: 11) which shows a red-coloured (fired clay) wheel with some grey colour. This wheelhead also had grey stains especially concentrated at the edges where my clay-covered hands had gripped the wheel to turn it. This clay quickly dried and flaked away from the wheelhead, leaving it intact and unworn, and with a red edge.

The fifth test wheelhead (Figure 10.12e)

Wheelhead type: made in the 1990 season, again from unfired Nile clay with the addition of a small amount of desert marl, and tempered with *tibn* and ash (Figure 10.4, right). The outer edge was left unweighted and was kept fairly thin. By contrast, the centre pivot-emplacement was built up in order to concentrate the weight of the wheelhead at this point.
Specifications: weight 15.5 kg, plus 1 kg of fixing clay; wheelhead diameter: 53 cm; outer rim depth: 3 cm; overall thickness: 3–9 cm; pivot emplacement diameter: 17 cm.
Lubricant: linseed oil.
Speeds:

revolutions	seconds	rpm
60	37	97
60	45	80
60	50	72
60	45	80
	average rpm	82

Results. This wheelhead performed satisfactorily. The pivot stone was held firmly. The outer edge was not as comfortable to turn as the thicker edge of the other models, and, although it attained speeds easily adequate for throwing, it was not as fast as the version with weighted rim. It did not provide conclusive evidence as to whether the distribution of weight across the wheelhead was significant.

The sixth test wheelhead (Figure 10.12f)

Wheelhead type: made during the 1989 season with Nile clay and fired in the main experimental kiln.
Specifications: see section 10.16; weight 3.5 kg, plus 1 kg of fixing clay.
Lubricant: linseed oil.
Speeds:

revolutions	seconds	rpm
60	60	60
60	48	75
60	40	90
60	58	62
	average rpm	72

Results. Although this wheelhead rotated well it did not spin, and the small diameter made it feel cramped both for turning and for providing a good working surface. A simple wheel of this size would not be suitable for throwing but adequate for slower forming processes, and for decorating.

10.24 Concluding remarks on the wheelhead tests

Large disc-shaped wheelheads made from unfired and fired clay provided a very satisfactory solution to the question of what was the nature of the missing part of an ancient Egyptian potter's wheel, the part that needed to be added to the stone wheel-bearings found at Amarna and elsewhere in Egypt. The fabric — clay — is easily available and already familiar to the potter as a construction material. However, it is possible to envisage that wooden or even stone discs would be equally effective, and these experiments do not discount the possibility that these materials might also have been used to form wheelheads.

The overall appearance of the reconstruction of the simple potter's wheel using the experimental wheelheads corresponded well with illustrations and models of simple wheels found in tombs, and the use of this wheel to throw small bowls was further corroboration. On the other hand, although the wheel worked, and bowls could be made and finished on it (to be described in a future report), it was not efficient, and I could not make larger vessels on it. By "efficient" I mean that the amount of energy expended did not justify the result. The persistent problem was that the wheel slowed down too quickly. Several possible solutions can be considered.

The first is that an assistant was used to keep the wheel turning, as is suggested by the pictorial evidence in the tomb of Qenamun. Earlier and later tomb paintings, however, do not include assistants, whilst the wheelhead experiments demonstrate that the stone and pivot socket bearings worked extremely well, running both fast and smoothly. It might seem unlikely that a developed bearing, and presumably a valuable piece of equipment, would not be fully utilized, although this has been argued by Foster (1959b).

A second solution might be that adjustments are needed to the way the wheel has been constructed or set up. The mechanical laws governing potter's wheels have been summarized thus (Van der Leeuw 1976: 124):

"a) There is an inverse relationship between the momentum of the wheel and its optional velocity of rotation. The heavier the wheel the slower it goes.

b) There is a direct relationship between the linear velocity of a point on the wheel (the speed with which the wall of the pot passes the fingers of the potter during construction) and its distance from the centre.

c) Momentum and velocity of rotation determine between them how strongly the turning wheel will resist any kind of friction and how long this resistance lasts".

According to these, my reconstruction potter's wheel can be described as being high-velocity, low momentum. This severely restricts the range of wares that can be produced upon it. The excavation of building Q48.4 (*AR* IV: 82–95) showed that, as well as small bowls, tall offering-stands and biconical vessels had been made, presumably on a wheel using the stone pivot found.

Increased momentum is the obvious solution, and this may already have been indicated in the wheelhead experiments which featured additional loads of working clay. Instead of an increase in speed, a slowing down using a heavier wheelhead might improve the functioning of the wheel. Comparable simple wheels from India have been described as having wheelheads between 56 and 93 kg. In addition, it would be advantageous to use a lubricant with a higher viscosity (such as castor oil) which does not improve speeds but reduces the immediate effects of friction that occur when applying pressure to throw the clay.

The third possibility is that the reconstruction bearing is at fault. The model chosen, BM 32621, is of relatively large size which made it (to an untrained eye) a likely candidate for success. It might, however, belong to a different class of wheel and therefore be inappropriate in a reconstruction of an Amarna potter's wheel.

Behind the practical work there lies the understanding of an idea: "The essence of the invention of the potter's wheel, and its cultural consequences is not an elaboration of material form, but the idea, the recognition of the possibilities of exploiting centrifugal action" (Foster 1959b: 99).

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