

A MINIATURE IVORY SUNDIAL WITH EQUINOX INDICATOR FROM PTOLEMAIC TANIS, EGYPT

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In the following pages, we present an addition to the corpus of sundials preserved from Greek Antiquity. This is a miniature, conical sundial made of ivory, discovered in Egypt by W. M. Flinders Petrie during his excavations at Tanis (San el-Hagar) in 1884.¹ The dial had been burned and was found in pieces in the remains of a private house from late Ptolemaic times. In 1885 the sundial was donated by the Egypt Exploration Fund to the British Museum. Housed in the Department of Ancient Egypt and Sudan under the inventory number EA 68475, it lay in seventeen fragments until the spring of 2005, when it was reassembled and studied in detail for the first time. It presents three features that make it unique, or at least highly unusual, among the extant corpus of ancient Greek sundials: (1) to our knowledge, it is the only such dial made of ivory;² (2) it bears an inscription indicating that the lighting and shading of the undercut front face signalled the equinox; and (3) it was found among its owner's other effects in a private house, which allows us to view it in a particular cultural and archaeological setting.

Small portions of the dial (including the remains of the plinth or footing) retain a rich, reddish brown colour, but the bulk of the surface is in various shades of grey, as a result of exposure to heat. The dial fragments are also extremely fragile. In Figure 1 we see the face of the reassembled sundial. Seven day curves are incised, along with the usual lines for the seasonal hours. The 'floating' upper right corner cannot be joined to the main body of the dial, as too much of the ivory has been lost in between, but the approximate location that the fragment would have taken is illustrated in Figures 1 and 2. To judge by its shape (see Figure 2 especially), the floating fragment preserves a portion of the original, squared-off upper surface of the dial. In its design, this sundial is of the ordinary, south-facing conical type.

The maximum dimensions of the reassembled portion of the dial are:

width: 5.1 cm (not including the floating fragment)

height: 2.8 cm

depth: 3.1 cm.

Originally, the width of the engraved, conical surface was probably some 4.4 cm. However, as its right end is broken off, the current width is 3.5 cm (not including the floating fragment). The height of the engraved area, measured perpendicularly to the bottom surface of the object, is 1.9 cm. Only a few extant Greek dials of comparable type are so diminutive. We know of three miniature spherical dials in stone,³ but none is so finely made. None, for example, carries seven day curves. As far as we know, no other conical dial is of such a small size.

All the incised curves and lines were emphasized with a red material, of which



FIG. 1. Frontal view of the reassembled sundial, BM EA 68475, printed approximately 1.6 times actual size. The camera line of sight is horizontal. © The British Museum.



FIG. 2. Oblique view, slightly from above. © The British Museum.

substantial amounts remain. Analyses of the materials making up the dial were undertaken by the Department of Conservation, Documentation and Science of the British Museum. The red material shows the spectral signature of hematite, a naturally occurring iron oxide. Thus the red most likely came from an ochre pigment.⁴ That reddening of the incised lines was a common practice is shown by several Greek stone sundials,⁵ and by a number of Roman stone dials from Pompeii.⁶

One word is incised in Greek on the undercut front surface of the dial: ΙΣΗΜΕΡΙΑ, “equinox” (Figure 3). The reader may get a better sense of the fact that the inscription lies on a face that is undercut by comparing Figures 1 and 2. ΙΣΗΜΕ is certain. Of Π, the only traces are the vertical line and a short stroke running down from its top towards the bottom right. The expected further diagonal stroke linking the far end of the previous stroke to the middle of the vertical may have been drawn but was never carved. The remaining two letters are far from clear, perhaps as a result of damage to this part of the inscription. But there is little room for doubt that the inscription is, indeed, ΙΣΗΜΕΡΙΑ.

As is well known, on most extant conical dials the undercut front face was designed to be parallel to the equator. That is, the angle between the undercut front face and the horizon was supposed to be equal to the co-latitude of the place for which the dial was designed. This seems to be the case here as well. Measurement shows that the angle between the horizontal and the undercut front face is 57°, corresponding to a latitude of $90 - 57 = 33^\circ$, which agrees well with the latitude of Tanis (31°). The



FIG. 3. The Greek inscription on the undercut front face. © The British Museum.

significance of the inscription therefore seems to be as follows. Since, when the dial is properly oriented, the undercut front face lies in the plane of the celestial equator, the sun will never shine on this face during the spring or summer. The undercut face first becomes illuminated on the day of autumnal equinox. During fall and winter, by contrast, the sun shines on the undercut face all day long. The face ceases to be illuminated on the day of spring equinox. Thus it is clear that ΙΣΗΜΕΡΙΑ (“equinox”) labelled the undercut face itself and called attention to the fact that the illumination of this face served as an equinox indicator.

Although most conical dials have a similar construction (with the undercut front face in the plane of the equator), this is the only one known to us on which the undercut face is labelled “equinox”.⁷ Thus BM EA 68475 provides an important insight into the function of the undercut face as an equinox indicator, a feature that scholars have not sufficiently appreciated heretofore. In its general form, our miniature ivory sundial mimics larger stone sundials. For example, there is a plinth or footing that comes forward from the undercut front face, a common feature of larger stone dials of this type.⁸ On the stone prototypes, such a footing is important for maintaining balance (though many dials also have mounting holes for fixing them to a base). But on our miniature dial, the footing is small, almost vestigial, and served no real function, for, as we shall see, the dial was not set on the ground but rather nailed up to a post. The fact that EA 68475 was crafted as a miniature version of a conical stone dial suggests that the undercut front faces of the larger stone dials also were intended to serve as equinox indicators. The use of the covering and uncovering by shadows to indicate the time of equinox is also attested for a specialized astronomical instrument, the equatorial ring, discussed by Ptolemy in *Almagest* III, 1.⁹

A length of iron nail remains embedded in a piece of ivory that carries a small portion of the dial engraving. This is the ‘floating’ piece of Figure 1, which is shown from above in Figure 4. This nail was not the gnomon, which has been lost. The function of the nail was almost certainly to fix the sundial into a proper south-facing orientation, perhaps against a window frame or a post. A hole was probably drilled through the ivory before the nail was inserted, because attempting to hammer the nail through the dial would have risked shattering the ivory. Lead, traces of which remain, was poured into the hole, probably in the form of soft solder, and presumably so as to tighten the fit.¹⁰

Incised markings, possibly consisting of letters, were cut into the horizontal upper surface of the dial, but too little of the inscription remains for decipherment. The surviving portions of the signs are on the ‘floating’ fragment of ivory attached to the nail. See Figure 4.

In the case of south-facing, conical Greek sundials, the gnomon was almost always inserted into a socket located on an imaginary continuation of the noon line above the winter solstice curve. The theory of these dials requires the tip of the gnomon to be located on the axis of the cone.¹¹ On the dials with preserved gnomons or gnomon sockets, the socket is always located at the height above the winter solstice curve that would permit the gnomon to be horizontal.¹² Thus, the gnomon of BM EA 68475 was

located in the broken away place at the top centre of Figure 1, immediately above the meridian line, which is the sundial's line of symmetry.

Figure 5 is a tracing of the engraved conical surface. The quality of the conical surface is quite good, as shown by the fact that the tracing paper could be laid in smoothly. As can be seen, more is preserved on the left or morning side of the dial than on the right. The noon line, oriented roughly vertically in the sketch, would have been the sixth hour line counting either from the left or from the right on the intact dial.

It is possible to estimate reasonably well where all seven day curves crossed the noon line. These crossings are shown to scale in Figure 6. The meanings of the point labels and the positions of the points are given in Table 1. The positions are measured along the noon line, using the equinoctial noon point e as origin. The measurements are accurate to perhaps a third of a millimetre, but we retain tenths, in order to avoid round-off error in the subsequent calculations.

TABLE 1. Placement of day curves along the noon line.

w	winter solstice = beginning of Capricorn	+5.8 mm
2	beginning of Aquarius or Sagittarius	+4.6
3	beginning of Pisces or Scorpio	+3.0
e	equinox = beginning of Aries or Libra	0.0
5	beginning of Taurus or Virgo	-4.0
6	beginning of Gemini or Leo	-7.9
s	summer solstice = beginning of Cancer	-10.8

Rather than relying on a mathematical analysis based only on distances ew and se , we perform a simple graphical analysis that allows us to use all seven points and all six intervals. First, we make a fan-shaped transparent overlay, with one line representing the equinoctial ray, and other lines drawn at angles with respect to this ray of $\pm 23.9^\circ$, $\pm 20.5^\circ$, and $\pm 11.7^\circ$ (see Figure 7). These are the declinations of the Sun at the beginnings of the zodiac signs, assuming Ptolemy's value of $\varepsilon = 23.856^\circ$ for the obliquity of the ecliptic, which was not far from the value given by Eratosthenes and adopted by Hipparchus.¹³ The dial is so small that no perceptible difference would result from using any other reasonable value for the obliquity, including the round value of 24° .

By trial and error we shift the overlay with respect to the noon line until all seven rays can be made to pass as nearly as possible through the seven points marked on the noon line, as shown in Figure 8. The fit is reasonably good for nearly all points, showing that the noon shadows were constructed with good accuracy on this sundial. Only in the case of point 6 (beginning of Gemini) did the dialler place the mark a little less than a millimetre too high. The tip g of the gnomon must have been located as shown in the figure. The axis of the universe can then be drawn through g at right angles to the equinoctial ray. On ancient conical dials, the axis of the cone invariably coincides with the axis of the universe. But the half-angle ω of the cone is a free choice which the dialler may pick for convenience. The axis of the cone intersects



FIG. 4. Traces of incised markings on the horizontal surface of the small ‘floating’ fragment (in the upper part of the photograph). A broken portion of the embedded nail can be seen protruding at the very top, while the corroded head is visible at the bottom. © The British Museum.

the noon line (which is a generator of the cone) at the vertex v of the cone. The half-angle of the cone may be measured on Figure 8 and is found to be 34° . Gibbs¹⁴ gives a formula for computing ω from ew and se :

$$\tan \omega = \frac{se - ew}{se + ew} \cot \varepsilon,$$

where ε is the obliquity of the ecliptic. Using the values $se = 10.8$ and $ew = 5.8$ mm, we get $\omega = 34.2^\circ$, showing good agreement. But, of course, it makes no sense in this case to work more finely than the nearest whole degree.

By direct measurement on the sundial, the oblique angle between the noon line and the horizon is $\psi = 123^\circ$, as shown in Figure 6. Due to the unevenness of the conical surface, there is an uncertainty in ψ of a degree or somewhat more. Moreover, because the bottom of the sundial is uneven, it is not certain that when it is placed on a table it rests in the correct horizontal orientation. If the level uncertainty is included,

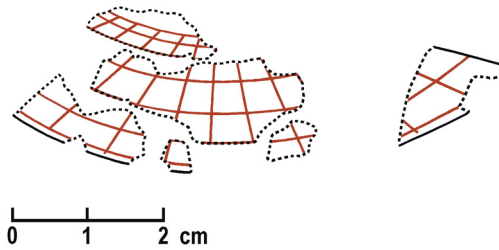


FIG. 5. The dial face, from a tracing of the conical surface, rolled out flat. Drawing by M. Marée.

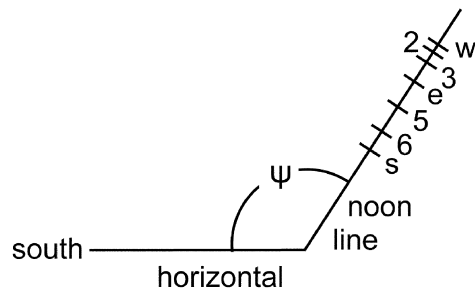


FIG. 6. The noon line and its crossings by the seven day curves (drawn to scale). The oblique angle between the noon line and the horizon is $\psi = 123^\circ$.

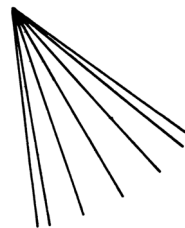


FIG. 7. Noon rays, for the dates of the Sun's entry into the zodiac signs. The central ray is for the equinox. The extreme rays, located $\pm 23.9^\circ$ from the equinoctial ray, are for summer and winter solstice.

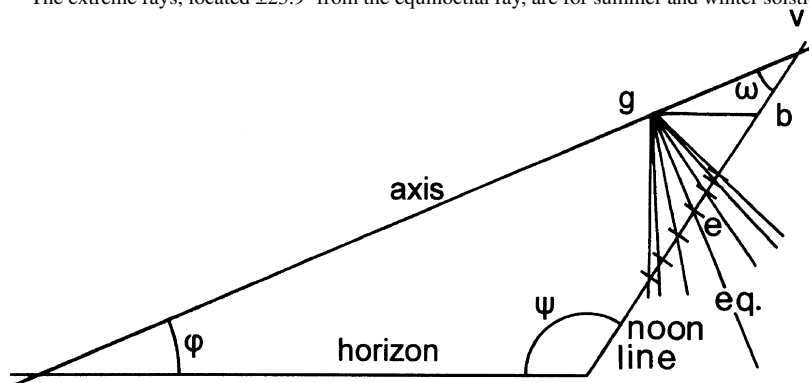


FIG. 8. Analysis of the sundial. By trial and error, the tip g of the gnomon is placed so that the seven rays pass as nearly as possible through the seven points on the noon line.

the measurement of ψ could easily be off by several degrees. If, as justified above, we assume that the gnomon was horizontal, its base must have been at b in Figure 8. By measurement on Figure 8, b is located 9.5 mm, measured along the sloping dial face, above the winter solstitial curve. And thus the distance eb of the gnomon hole above the equinoctial circle was about 15.3 mm. The exposed length bg of the gnomon was 14.3 mm.

Also by measurement on Figure 8, the radius of the equinoctial circle is

$$r_e = ge = 14.2 \text{ mm.}$$

Here it is possible to make several checks of the consistency of the sundial. In Figure 9, angle $gwe = 90 + \omega - \varepsilon$. Then, applying the law of sines to triangle gew ,¹⁵

$$r_e = ew \frac{\sin(90 + \omega - \varepsilon)}{\sin \varepsilon} = 14.1 \text{ mm,}$$

with use of 34° for ω and 10.8 mm for ew (as in Table 1). Similarly, angle $gse = 90 - \omega - \varepsilon$, and applying the law of sines to triangle ges gives

$$r_e = se \frac{\sin(90 - \omega - \varepsilon)}{\sin \varepsilon} = 14.2 \text{ mm.}$$

We can also estimate r_e by using L_e , the length (in millimetres) of an hour measured along the equinoctial circle. Five complete equinoctial hours are preserved (Figure 5). The average of all five lengths is $L_e = 3.82$ mm (see Table 2). A semicircle consisting of 12 such equinoctial hours would have the arc length $12 L_e = \pi r_e$, where r_e is the radius of the equinoctial circle. Thus

$$r_e = 12 L_e / \pi = 14.6 \text{ mm.}$$

All four ways of determining r_e lead to rather similar values, which confirms that the conical surface was well made and that points s , e , and w were accurately placed along the noon line. Note that the various estimates of r_e depend upon such linear measurements as se , ew , L_e and the single angular parameter ω (itself determined by

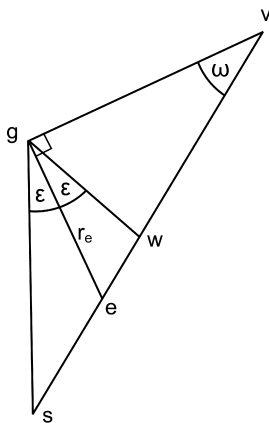


FIG. 9. Methods of determining the radius r_e of the equinoctial circle.

TABLE 2. Lengths of hours on the winter solstitial, equinoctial, and summer solstitial day curves.

	Average of all extant hours	4th hour
L_w	2.70 mm (average of 4 hours)	3.1 mm
L_e	3.82 (average of 5 hours)	4.4
L_s	7.95 (average of 2 hours)	8.2

fitting Figure 7 to the marks on the noon line). None of these involves any assumptions about the latitude.

As we have seen, the undercut front face shows that the dialler intended a latitude in the range 31–33° (for Tanis). A second, independent measure of the latitude may be taken from Figure 8, for the latitude φ should be equal to the angle between the axis and the horizon. Using $\psi = 123^\circ$ and $\omega = 34^\circ$, we obtain $\varphi = 180^\circ - \psi - \omega = 23^\circ$, which seems to indicate that the dial was not properly cut for the latitude of Tanis. Rather, the axis of the conical surface was cut in at an angle too close to the horizon by 8 or 10°. This discrepancy considerably exceeds the several-degree uncertainty in ψ .¹⁶

It is also possible to obtain an estimate of the latitude either by using L_w and L_e , or by using L_s and L_e . These are lengths (in millimetres) of the winter hour, the equinoctial hour, and the summer hour, as measured along their respective day circles. See Table 2, which presents average lengths of all the extant hours, as well as the lengths of L_w , L_e , and L_s for the fourth hour. The relevant formulas are given by Gibbs’s equations 2.5 and 2.6.¹⁷ But, in practice, analyses based on these two formulas are seldom useful or reliable. However, if we add Gibbs’s two equations and apply a trigonometric identity we obtain

$$\tan \varphi = \cot \varepsilon \sin \left\{ \frac{90(ew \cdot L_s + se \cdot L_w)}{(ew + se)L_e} \right\} \sin \left\{ \frac{90(ew \cdot L_s - se \cdot L_w)}{(ew + se)L_e} \right\}.$$

We offer this formula as potentially useful for analysis, as it incorporates all five measured quantities se , ew , L_s , L_e , and L_w , and thus provides a systematic way of including more than the minimum possible information. (On the other hand, it is really nothing more than the result of averaging Gibbs’s two equations.) On EA 68475, only for the fourth hour are all three hour lengths preserved. This should give more reliable relationships among the three hours than we would get using the averages of all the preserved values, because of the non-uniform preservation of the dial face from top to bottom. With the values of L_s , L_e , and L_w from the fourth hour, the values for se and ew in Table 1, and $\varepsilon = 23.9^\circ$, we obtain $\varphi = 34^\circ$. The fact that three different methods of determining the latitude give three somewhat different results shows that our miniature sundial was imperfectly executed. However, it remains an interesting and significant addition to the corpus for the light it throws on the purpose of the undercut front face of the common conical sundials.

As stated at the beginning of this article, our sundial is also notable for the archaeological context in which it was found. The dial is mentioned by Petrie in Part I of his

Tanis, where it features in the discussion of a house found just inside the west wall of the temple's main enclosure:

An important house, that belongs to the end of the Ptolemaic times, was cleared a short way north of the pylon; and much pottery was obtained from a neighbouring house of the same age, but that remains to be brought over. In this house, marked M on the Plan [which follows Petrie's plate 16], everything had been burnt. The whole of the finds brought over are in the British Museum, but two large figures of Bes in terra-cotta and pieces of an ivory sun-dial will come with the rest of the pottery.¹⁸

There can be no doubt that the "pieces of an ivory sun-dial" are our EA 68475, even though the 1885 entry in the British Museum register book does not refer to Petrie's comment. The identification is rendered certain by Petrie's statement that everything in the house was burned, as is clearly the case with our sundial.¹⁹

Petrie goes on to list a host of further objects that he recovered from the house. The finds associated with our dial lend it a rich context and are therefore discussed in some detail below. This must, however, be preceded by a comment on how the findspot and associated finds have been characterized, because pertaining documentation is rather confused. In his listing and earlier on, Petrie refers to the house and its contents as House, or Find, 15.²⁰ In conflict with this, the BM register book attributes the sundial, the Bes figures and an iron door-hinge to an otherwise undocumented "House 66".²¹ For the remaining objects, the register specifies no findspot within Tanis at all, except for an iron nail, which it does assign to "House 15".²² Christine Favard-Meeks has recently published an edited version of Petrie's object list.²³ Having herself consulted the register book in the British Museum, she assumes that the "House 66" tag is reliable and presents the objects so labelled as a separate group. Only for the other objects in Petrie's listing does she preserve his attribution to "Find 15". Favard-Meeks suggests that the "House 66" objects "proviennent d'une trouvaille près de la Maison M (lot 15)". This is in actual fact uncertain. Petrie himself states clearly that all the objects under consideration were found *in* the ruins of the burned house, not partly some distance away from it, let alone in a different house. It should be noted that the BM register speaks specifically of a "*House*" 66, a fact obscured by Favard-Meeks's rendition of this as "*Find*" 66 and as "une trouvaille"; hers are designations that could denote any kind of locus. If we accepted that our dial came from a separate "House 66", then the object's charred condition would mean that the fire was not confined to the interior of House 15 but also struck surrounding dwellings — despite the fact that Petrie speaks of only one burned house at this part of the site. The distinction between House/Find 15 and House 66 remains so elusive that the question arises whether it was a temporary one, eventually rejected as fictitious. Conceivably a "House/Find 66" existed in Petrie's original classification, after which he subsumed this locus with "House/Find 15", based on a greater understanding of the excavated remains. Petrie's ultimate, published account speaks of but one "important" house, due to the artifacts it yielded.²⁴ This makes it difficult

to believe that objects so important as the Bes figures and sundial originated from a different house, unworthy of this label. Indeed Petrie says nothing to support their separation from Find 15. It seems safest not to depart from the excavator's own final report, whereby the objects he lists came from a single dwelling only.

It is most unusual for an ancient Greek sundial to preserve associations with other possessions of a house's residents.²⁵ Most striking among these are the aforementioned pair of terracotta statues that represent the god Bes, a nude, ferocious-looking dwarf in a feathered crown and leopard skin.²⁶ The role of this popular deity was to guard over childbirth and sexuality, so his powers were widely invoked in domestic contexts. The god was also readily adopted by the Greeks, and later Romans, living in Egypt. Our standing figures on pedestals possess a height of almost half a metre. They must have been especially impressive in their original state, when they were covered in painted plaster, of which very little remains today.

A protective function was likewise ascribed to a *cippus* amulet that Petrie also found. It is a small plaque of blue faience, pierced twice for suspension, and represents the god Harpocrates (Horus-the-child) standing atop two crocodiles while clasping snakes and scorpions.²⁷ *Cippi*, in the form of stelae or smaller amuletic versions, served to ward off, or cure from, the harm that could be inflicted by dangerous animals. They were chiefly produced between the Saite and Roman Periods, but this is one of the very few examples with a clear archaeological provenance.

Among the objects from our house is also a small bronze statuette of Osiris, a mere 4 cm in length.²⁸ It is somewhat unexpected that this figure of the resurrection god should derive from a house, albeit located inside a temple enclosure. For some seven centuries, numerous metal figures of Egyptian gods had typically been deposited and hung up at shrines as votive objects.²⁹ The tiny figure under discussion has a vertically placed suspension loop at the back of the neck, but the present context suggests that it might have been given a different role; perhaps it was worn as an amulet. Petrie found also amulets of blue glass in the house, one being phallic and the other representing the *udjat*-eye of Horus.³⁰ An additional *udjat*-amulet was of green glass, with mosaic inlays of squares and stripes.³¹

Also further bits of glass were excavated from House 15. This includes two more fragments of mosaic glass, both with depictions of *was*-sceptres: one of these is from a finished plaque,³² the other from a 'cane' (which had yet to be sliced into plaques).³³ The production of mosaic glass met its peak in the last century B.C. Such plaques were used to adorn small furniture, but were likely also employed in jewellery. Our examples could have come from Alexandria, but they may well have been locally made.³⁴ The same may obtain for a fragment of "gold glass", which was a particularly rare find. It consists of two sheets of colourless glass, fused together with stylized gold foil depictions of vine leaves in between. Petrie assumed that the fragment comes from a bowl, but it has since been suggested that it belonged to the border of an ornamental plaque.³⁵ Of interest is also a broken bead of blue and yellow glass which represents the head of a beardless man, and this was once crowned with a suspension loop, from which it appears to have belonged to a necklace.³⁶ One should not confuse this

piece, as Petrie did, with a type of beads produced in Phoenicia back in the sixth and fifth centuries B.C. As stated by Cooney, our type is probably of Egyptian origin, and he notes that examples from Meroë have been dated by Reisner from the late first century B.C. to the first century A.D.³⁷ Petrie makes also reference to the discovery in the house of “three pieces of inlaid glass dumps”, but his terminology is puzzling and permits no identification of these in the BM collection.

Some rather more prosaic finds include the earlier-cited iron door-hinge³⁸ and an iron lock plate,³⁹ both with their rivets still attached, as well as nails of the same material.⁴⁰ All may well have belonged to the door through which the house was entered. In bronze there were, according to Petrie, a “small bucket-handle” and some manner of “ornament”,⁴¹ but these have defied identification among the British Museum holdings. A bronze human hand once formed part of a pair of tongs,⁴² and there were a number of Ptolemaic coins.⁴³ Also recovered were a bronze earring and part of a gold one, both of familiar Greek designs.⁴⁴ It is unclear what purpose was served by seven bone pegs⁴⁵ or by a small bone disk with central hole.⁴⁶ It may further be noted that Petrie mentions no pottery as part of Find 15, while the BM register does. The latter has again been followed by Favard-Meeks, but the jars in question, all sizeable and well preserved, may rather be the pottery that Petrie “obtained from a neighbouring house”.⁴⁷ The same may be true of a coarse pottery tube, perhaps once linked to a kiln.⁴⁸ Mention should finally be made of two clay seals which, according to Petrie, would have come “from burnt papyri”, though of the latter he makes otherwise no mention.⁴⁹ On stylistic grounds, a portrait head on one of these seals has been attributed to King Ptolemy XV (third quarter of the first century B.C.).⁵⁰

Among Petrie’s finds was also a scarab amulet in purely Egyptian style, its base engraved with a *hes*-vase and the figure of a baboon.⁵¹ These hieroglyphs were meant to invoke favour (*hesut*) from Thoth, a god to whom the baboon was sacred. In no way do they identify its former owner as a “priest of Thoth”, as misconstrued by Petrie. Indeed there was no cult of Thoth at Tanis; the temple of this town was dedicated to Amun. Also, functionary titles were not carved on scarabs when this specimen was made. Its design is more generic, with parallels from various parts of Egypt. In fact, this scarab is of greater antiquity than all the other items that Petrie attributes to the house; it appears to date back as far as the Third Intermediate Period. This means that this find was either intrusive, or that the occupant of our house had actually found and reused it for himself — a practice for which there seems to be evidence elsewhere.⁵²

Petrie’s dating of the house to the end of the Ptolemaic dynasty was based on the late style of the artifacts, counterbalanced by the fact that this and the neighbouring house have yielded Ptolemaic coins but no Roman ones. Leaving the scarab aside, all the listed objects can well be from the first century B.C. and not, in any case, of a much later date. The sundial can thus be dated accordingly. The associated objects reveal the owner as a literate person of some wealth and refinement, who moved comfortably in the bicultural world of partially Hellenized Lower Egypt. His house, its south side equipped with the dial, stood inside the walled precincts of one of

Egypt's greatest temples. Very few ancient Greek sundials can be situated in time and place with such precision. The question remains whether the owner was Greek or Egyptian. Most of the object types discussed above, including the religious ones, served both communities of Ptolemaic Egypt. That being said, the *cippus* and, perhaps, the hieroglyphic scarab do tend to favour the idea that House 15 was of an Egyptian. Living where he did, chances are that such a well-to-do Egyptian was attached as an administrator or priest to the nearby temple — even if we reject Petrie's reading of the signs on the scarab. Especially for someone employed as a priest, the sundial would have been a useful instrument. To the priests of Egypt, time-keeping had always been a major concern. A succession of sacred festivals was tied in with the annual cycle, and the daily ritual was performed at set times. Star observations, shadow clocks and clepsydras all came to play their part in temple life. Our dial would have been a convenient supplement to these, but was apparently used solely at the house where it was found. Nailed in position, it may have kept the owner abreast of time in between his duties at the temple, averting tardiness whenever he had to return to them. In Egypt, several types of time-keeping devices had been used since at least the early Eighteenth Dynasty, from around 1500 B.C. This was long before the invention of geometrical gnomonics and they effectively told different kinds of time.⁵³ Our Ptolemaic sundial, based as it is on Greek geometrical gnomonics, is further proof of the adaptability of the Egyptian élite at times of cultural cross-fertilization. Last but not least, the dial's exceptional material and delicate size made it an item of display, marking its owner as someone of means and sophistication. Such was the case, that is, until a fire claimed up his possessions — if not his life. What caused the blaze may never be known.

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REFERENCES

1. W. M. F. Petrie, *Tanis, I: 1883–4* (London, 1885), 20 and 34.
2. This is hippopotamus ivory, as kindly confirmed by Caroline Cartwright on close analysis. Even apart from the Greek corpus, the use of ivory for sundials is rarely attested. However, one apparent example is of ancient Egyptian manufacture and was discovered at Gezer (Palestine). A small, half-circular, vertical dial, it is divided into 12 equal pie-wedges and therefore not based on geometrical gnomonics. The cartouches on the back date it to the reign of Merenptah (c. 1224–1214 B.C.). See R. A. S. Macalister, *The excavation of Gezer 1902–1905 and 1907–1909*, i (London, 1912), 15, and ii (London, 1912), 331; Ludwig Borchardt, *Die altägyptische Zeitmessung* (Berlin, 1920), 48; and Marshall Clagett, *Ancient Egyptian science*, ii: *Calendars, clocks, and astronomy* (*Memoirs of the American Philosophical Society*, ccxiv; Philadelphia, 1995), 95–98. Unfortunately, the present location of this dial is not recorded in the literature. In the Landesmuseum Mainz (inv. R 2321) there is a small (68-mm diameter), disk-like, portable dial, inscribed with month names in Latin. This dial was found at Mainz (latitude 50°), but seems to have been made for a latitude of about 44°. Because it uses the month August, this dial is of the first century A.D. or later, but could be as late as the fifth century. The Mainz dial was described as ivory by Derek J. de Solla Price, “Portable sundials in Antiquity, including an account of a new example from Aphrodisias”, *Centaurus*, xiv (1969), 242–66, p. 246. Earlier, Joseph Drecker, *Die Theorie der Sonnenuhren* (Munich, 1925), 61, also had it down as being of ivory. In actual fact, this object is not of ivory but antler. See Hubertus Mikler, *Die römischen Funde aus Bein im Landesmuseum Mainz* (Montagnac, 1997), 24–25, 125, and plate 14.9. The Mainz dial is discussed most fully by Karlheinz Schaldach, *Römische Sonnenuhren: Eine Einführung in die antike Gnomonik* (Frankfurt am Main, 2001), 114–23. There is also a Roman cylinder dial of the first century A.D. made of bone, in the Museo Nazionale Atestino, in Este near Padua. See Mario Arnaldi and Karlheinz Schaldach, “A Roman cylinder dial: Witness to a forgotten tradition”, *Journal for the history of astronomy*, xxviii (1997), 107–17. In the Renaissance, of course, ivory became a popular material for small, portable sundials. See Penelope Gouk, *The ivory sundials of Nuremberg, 1500–1700* (Cambridge, 1988).
3. Of these, British Museum 1886,0401.1477 (also registered as 1909,0216.10) was found by Petrie at Naukratis in 1884–85: see W. M. F. Petrie, *Naukratis*, i (London, 1886), 16, with drawing on plate 18.6. This dial is no. 1040 in Sharon L. Gibbs, *Greek and Roman sundials* (New Haven, 1976). Gibbs gives its dimensions as 78 mm wide × 65 high × 34 to 50 deep (thicker at the top). According to Gibbs (p. 155), traces of engraved letters are visible below the spherical surface, a remark that was perhaps based on Petrie’s rough drawing. However, we have examined this dial carefully in raking light and find no trace of any inscription. Two other, rather inexactly made miniature spherical dials in stone can be mentioned. One, in the Archaeological Museum of Rhodes (inv. APX1113), is broken, but its original dimensions were roughly 90 mm wide × 55 high × 70 deep. The other, in Syracuse (Museo Archeologico Regionale Paolo Orsi, inv. 35080), is almost complete, with dimensions 40 mm wide × 34 high × 31 deep. We thank Karlheinz Schaldach for these measurements and for sharing his electronic photographs of these two dials. A photograph of the Syracuse dial appeared in Giovanni Bellina, *Su alcune misure di tempo degli Iblei: Circolo didattico “Paolo Vetri”* (Ragusa, 2002), 34.
4. The red pigment was analysed by Raman spectrography using a Dilor Infinity with a near-infrared (785 nm) laser. The spectra produced were compared with an in-house data base, and were found to correspond to the naturally occurring iron oxide, hematite (α -Fe₂O₃). This suggests that the red came from an ochre pigment. F. Shearman, J. C. Ambers, and D. R. Hook, British Museum Department of Conservation, Documentation and Science, Analytical Report 2005/60.
5. Greek dials preserving traces of red in the incised lines include Gibbs nos. 1002 and 3031 (in the day curves). The recent publication of Karlheinz Schaldach, *Die antiken Sonnenuhren Griechenlands: Festland und Peloponnes* (Frankfurt am Main, 2006), provides an important extension of Gibbs’s work. A number of newly published dials are included, all the sundials are illustrated by good-quality photographs and, for those for which it is possible, new analyses are undertaken, which

sometimes provide corrections or alternatives to Gibbs's. Moreover, colour JPEG images are included on the CD that accompanies the book. The colour photographs of Schaldach's Objekt Nr. 25 (= Gibbs no. 3023, a conical sundial from Piraeus) shows red colour in the meridian line and the three day curves and black colour in other hour lines.

6. Gibbs, *Greek and Roman sundials* (ref. 3), nos. 1023–27. On 1024 and 1026, all eleven hour lines and all three day curves were reddened. On 1022, only the third, sixth and ninth hour lines were reddened.
7. This is quite different from a label, “equinox”, on the equinoctial day circle. Quite a number of Greek spherical and conical dials have labels on the equinoctial and solstitial day circles. See, e.g., Gibbs, *Greek and Roman sundials* (ref. 3), nos. 1001, 1072, 3047, 3058, 3060, as well as the conical sundial in the Palmyra Museum (no. 25/92 G/1982 914) described by Kurt Locher, “Three further Greco-Roman conical sundials from Palmyra, Naples and Abû Mînâ”, *Journal for the history of astronomy*, xxvi (1995), 159–63.
8. For example, see Gibbs, *Greek and Roman sundials* (ref. 3), nos. 3022, 3027, 3043, 3044, 3048, 3075, 3076.
9. These instruments are mentioned twice by Ptolemy in *Almagest* III 1: G. J. Toomer, *Ptolemy's Almagest* (London, 1984), 133 and 134. For a discussion see James Evans, *The history and practice of ancient astronomy* (New York, 1998), 206–7.
10. A white patch on the nail shank and a small white metal fragment associated with the sundial fragments were examined using X-ray fluorescence spectroscopy and found to be of lead-rich composition. Shearman, Ambers and Hook, Analytical Report 2005/60 (ref. 4).
11. On the theory of ancient conical sundials, see Gibbs, *Greek and Roman sundials* (ref. 3), 30–39, and Schaldach, *Die antiken Sonnenuhren Griechenlands* (ref. 5), 163–4. An excellent treatment of sundial theory from a modern perspective is given by Denis Savoie, *La gnomonique* (Paris, 2007).
12. Gibbs, *Greek and Roman sundials* (ref. 3), 31.
13. Ptolemy, *Almagest* I 12; see Toomer, *Ptolemy's Almagest* (ref. 9), 63.
14. Gibbs, *Greek and Roman sundials* (ref. 3), 33.
15. As in Gibbs, *Greek and Roman sundials* (ref. 3), 32.
16. If the gnomon hole at b were preserved, the line through this hole and point g would have given an independent way to establish the horizontal, which would permit determining φ without using ψ . In this case, φ would be determined entirely by eb , ω , and r_c .
17. Gibbs, *Greek and Roman sundials* (ref. 3), Eq. 2.5 and 2.6, on p. 35. According to Gibbs, these formulae are due to Constantine Ionescu-Carligel, “Contributions à l'étude des cadrans solaires antiques”, *Dacia*, xiv (1970), 130–1. Note that there should be a π in the denominator of the right side of Gibbs's Eq. 2.1, on p. 33; however, the final equations (2.5 and 2.6) are correct. Using only Eq. 2.5 (involving L_w) we would get $\varphi = 16^\circ$; using only Eq. 2.6 (involving L_s), $\varphi = 46^\circ$. This provides an example of the well-known instability of analyses based on L_w or L_s alone. See Gibbs, *Greek and Roman sundials* (ref. 3), 75, as well as the scatter plots in Jacek Kościuk, “A conical sundial from Abû Mînâ”, *Bulletin de la Société d'Archéologie Copte*, xxxi (1992), 43–55.
18. Petrie, *Tanis* (ref. 1), 34.
19. This sundial has also been mentioned by Christine Favard-Meeks, “Mise à jour des ouvrages de Flinders Petrie sur les fouilles de Tanis”, in Philippe Brissaud and Christine Zivie-Coche (eds), *Tanis: Travaux récents sur le Tell Sâh el-Hagar* (Mission Française des Fouilles de Tanis 1987–1997; Paris, 1998), 113, where the Petrie reference is correctly linked to BM EA 68475.
20. Petrie, *Tanis* (ref. 1), 20 (“house No. 15”) and 34 (“Find 15”).
21. Petrie's book nowhere mentions a House (or Find) 66 — at least not with the number included. Unfortunately, the discoveries that concern us here do not feature at all in Petrie's field notebooks and “Journals”, so those throw no light on the question (originals at the Griffith Institute in Oxford, but for the notebooks, see the CD-ROM publication *The Petrie Museum archives*, issued by that museum in 1999). For more on the Bes figures and door-hinge, see the main text below,

- with details in refs 26 and 38.
22. BM EA 29083. Petrie, *Tanis* (ref. 1), 34, does mention “some nails” from this find. It should be noted that the register book also identifies six items of pottery as deriving from Find 15 (“San [el-Hagar, House] 15”), while oddly none occurs in Petrie’s listing. That he does not mention this material is all the more surprising in view of their considerable size and excellent preservation (for their inventory numbers, see refs 47–48 below). Favard-Meeks, “Mise à jour” (ref. 19), 114, might be right in assuming an omission on Petrie’s part, but one wonders if this is not the pottery that Petrie says “was obtained from a neighbouring house”.
 23. Favard-Meeks, “Mise à jour” (ref. 19), 113–14.
 24. See our quotation from Petrie’s book at the beginning of this discussion. In the same sense, Petrie, *Tanis* (ref. 1), 20, talks of “one good house”.
 25. See Petrie, *Tanis* (ref. 1), 34, and Favard-Meeks, “Mise à jour” (ref. 19), 113–14.
 26. One figure is now in the Museum of Fine Arts in Boston (86.779) and the other is in the British Museum (EA 22378). The latter was published in Susan Walker and Peter Higgs (eds), *Cleopatra of Egypt: From history to myth* (London, 2001), 99, no. 119, with a discussion by Sally-Ann Ashton; she does not mention Petrie’s book and incorrectly gives the provenance as “unknown”.
 27. BM EA 15916. Height: 2.7 cm, width: 1.4 cm, thickness: 0.8 cm. The scorpions have been reduced to rudimentary oval shapes and are not mentioned by Petrie.
 28. BM EA 22693.
 29. For the hanging up of divine metal figures at temples, at least in earlier times, see Olivier Perdu, “Des pendentifs en guise d’ex-voto”, *Revue d’égyptologie*, liv (2003), 155–66.
 30. BM EA 15887 and EA 15864 respectively. Both have been published; see J. D. Cooney, *Catalogue of Egyptian antiquities in the British Museum*, iv: *Glass* (London, 1976), p. 16, no. 160 (with ill.) and p. 161, no. 1854 (without ill.).
 31. This may be BM EA 15859, as suggested both by Cooney, *Glass* (ref. 30), 16, no. 159 (without ill.), and, with query, by Favard-Meeks, “Mise à jour” (ref. 19), 114, although no findspot in Tanis is given by the British Museum register book. Petrie, *Tanis* (ref. 1), 34, describes the piece he found as “an inlaid mosaic eye in glass, the cheek part being inlaid with stripes of squares of different mosaic patterns, all fitted into a green glass frame, with strips of white glass between the stripes — though much burnt and broken it is a fine piece”. In its present state, the decorated top surface of EA 15859 has completely broken away and apparently been lost.
 32. BM EA 15910; Petrie, *Tanis* (ref. 1), plate 12, no. 44; Cooney, *Glass* (ref. 30), 132, no. 1638 (with il.).
 33. BM EA 15936; see Cooney, *Glass* (ref. 30), 132, no. 1641 (without ill.).
 34. A glass workshop of contemporary date was discovered by Petrie at Gumaiyima, a few kilometres to the south of Tanis. See W. M. F. Petrie, *Nebesheh (Am) and Defenneh (Tahpanhes)* (London, 1888), 42–44, plate 18; Cooney, *Glass* (ref. 30), 112–23.
 35. BM EA 15835. See Cooney, *Glass* (ref. 30), 69, no. 761 (with ill.); J. H. Taylor, in H. Coultts (ed.), *Gold of the pharaohs: Catalogue of the exhibition of treasures from Tanis* (Edinburgh, 1988), p. 96, no. 88, with photo on p. 97 (centre).
 36. BM EA 22508; see Cooney, *Glass* (ref. 30), 29–30, no. 289 (without ill.).
 37. Cooney, *Glass* (ref. 30), 29–30, no. 289.
 38. BM EA 37137. Taylor, in Coultts (ed.), *Gold* (ref. 35), p. 95, no. 82, describes this item as “perhaps part of a tool or weapon, but its precise nature cannot be determined”. The British Museum register book calls it a “chopper”. There is no doubt, however, that this is a door element, along with the following two items. Curiously, EA 37137 is nowhere mentioned in Petrie’s book.
 39. BM EA 22713. The lock plate is wrongly cited with the number 22718 by Favard-Meeks, “Mise à jour” (ref. 19), 113. EA 22718 is in reality a square lead weight, acquired in the same year (1885) but with no documented provenance. The British Museum register book gives no provenance for EA 22713 either, but at some point it was labelled in the collection database as deriving from the house under discussion (called “House M”, as on Petrie’s site map). The lock plate is briefly

discussed by Taylor, in Coutts (ed.), *Gold* (ref. 35), 95–96, no. 82, last paragraph. Reading the catalogue entry, one should not confuse this object with one that is mentioned at the end of Taylor's preceding paragraph; there the item intended is EA 37137, which we describe as a door-hinge (*cf.* our previous note). Misleadingly, while EA 22713 and 37137 are both riveted fragments, only the latter is so identified at the top of this catalogue entry.

40. One of these being BM EA 29083 (*cf.* ref. 22 above).
41. Petrie, *Tanis* (ref. 1), 34.
42. BM EA 15898.
43. British Museum, Greek Coin Hoards no. 1724 at the Department of Coins and Medals.
44. BM EA 18348 and 22654; for the latter, see Petrie, *Tanis* (ref. 1), plate 12, no. 45.
45. BM EA 22495. Petrie, *Tanis* (ref. 1), 34, speaks of only one "pin-head" (with query). Also Favard-Meeks, "Mise à jour" (ref. 19), 113, fails to indicate that there are as many as seven pins, acquired together and given the same inventory number. She suggests that these pins, which are never more than 10 cm long or 1 cm wide, were used for weaving, though in what manner this would have been is hard to see.
46. BM EA 15819.
47. The jars in question are BM EA 22171, 22175, 22361, 22363 and 22384. Note that amphora EA 22171 was missed in the listing of Favard-Meeks, "Mise à jour" (ref. 19), 114, while on p. 131 she wrongly cites jar EA 22363 a second time as if it were part of Find 35, the well-known house of Ashokhi ('Bakakhuu').
48. BM EA 68473.
49. BM EA 15886 and 15932, both illustrated by Petrie, *Tanis* (ref. 1), plate 12, nos. 13–14. Petrie's comment about the papyri occurs only on his p. 62, in an index to this plate. For more recent literature on EA 15932, see also the following note.
50. P. E. Stanwick, *Egyptian royal sculptures of the Ptolemaic Period* (Ann Arbor, 2000), plate 209; and P. E. Stanwick, *Portraits of the Ptolemies: Greek kings as Egyptian pharaohs* (Austin, 2002), 61 and fig. 244.
51. BM EA 22480; see Petrie, *Tanis* (ref. 1), plate 12, no. 51.
52. On the possible reuse of ancient scarabs in Graeco-Roman Egypt, see the remarks by Erik Hornung and Elisabeth Staehelin, *Skarabäen und andere Siegelamulette aus Basler Sammlungen* (Mainz, 1976), 28.
53. For overviews of pharaonic time-keeping devices, see Borchardt, *Die altägyptische Zeitmessung* (ref. 2); R. W. Sloley, "Primitive methods of measuring time with special reference to Egypt", *Journal of Egyptian archaeology*, xvii (1931), 166–78; and Clagett, *Calendars, clocks, and astronomy* (ref. 2), 83–98. A tomb inscription first documents the use of water clocks for the reign of Amenhotep I (c. 1525–1504 B.C.). The oldest actual implement is an L-shaped shadow clock from the reign of Thutmose III (c. 1479–1425 B.C.), for which see now also Kristen Lippincott *et al.*, *The story of time* (London, 1999), 108, no. 101.