Article

The Greek portable sundial from Memphis rediscovered

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Sergei J. Maslikov Novosibirsk Astronomical Society, Russia

Abstract

Experts studying antique astronomic instruments are well aware of a small class of so-called portable sundials from the Roman Empire. Over the past few decades, they have been considered in several important publications, including a recent book by Richard J. A. Talbert, in which he systematized the available information. Talbert and earlier J. V. Field described eight portable sundials of a "geographical" type, dating from about 2nd–4th centuries. Five are inscribed in Greek, the other three in Latin. The list of Greek dials also contains a dial from Memphis, information about which has been very scarce so far. Some authors even considered it lost. Fortunately, this instrument is stored in the collection of the State Hermitage Museum (St. Petersburg) and now we have an opportunity to study it more closely.

Keywords

Alexandrian calendar, Constantin von Tischendorf, gazetteer, Hermitage Museum, Memphis, portable sundial, Roman Empire

Introduction

A well preserved brass disc with a shackle for suspension and a gnomon mounted on its axis are stored in the East Department of the State Hermitage Museum, St. Petersburg. The disc's inventory number is W-1531 and the gnomon's number is DV-2177. (Below the author will explain why there are two numbers.) The disc is 133.6 mm in diameter and 1.8–1.9 mm thick; its height with the suspension is 150.0 mm. (The diameter is about the same as that of a similar disc in the Science Museum, London,¹ 135 mm; all other known portable sundials are smaller). Only two instruments available for research have retained such an important element as the gnomon: the Hermitage disc and the disc from the Oxford History of Science Museum.² All the inscriptions on the Hermitage disc are

Corresponding author: Sergei J. Maslikov, Novosibirsk Astronomical Society, A. Nevskogo street, 4-39, Novosibirsk 630075, Russia. Email: s.maslikov@gmail.com in Greek. Some other portable sundials have Greek inscriptions, too; others are inscribed in Latin, though the evidence links them also to the Hellenistic tradition.

The Hermitage disc arrived from Egypt. In the middle of the 19th century the disc, originally from the necropolis of the ancient city of Memphis, was discovered in Cairo by Constantin von Tischendorf (1815–1874), German biblical scholar and specialist in ancient languages. In 1859, during the scholar's third visit to Egypt, he managed (with the help of the Russian diplomatic mission) to gain access to rare manuscripts. Monks from the Orthodox Monastery of St. Catherine on Sinai Peninsula agreed to hand the manuscripts over to Russian emperor Alexander II who was considered to be the protector of the Greek Orthodox Church. Later Tischendorf delivered the manuscripts and artefacts (including the disc) to the Imperial Academy of Sciences in St. Petersburg. Codex Sinaiticus was published shortly afterwards. The scholar was also the first to make a detailed description of the disc (in 1860), although he was unable to explain its operating principles. Probably, this can account for the inaccuracy in the drawing of the scales. The size of the disc was not specified either.³

The instrument may have been initially stored in the St. Petersburg Kunstkamera Museum. Waves of turbulent Russian history brought some of the exhibits from the Kunstkamera to the other side of Neva River, to the Hermitage Museum. Twice Hermitage collections were evacuated away from the front lines, during World Wars I and II. In the end, the disc came to rest in the Department of Western Art, where it was kept as an "unidentified object" together with the collection of bronzes by French master Pierre-Philippe Thomire. In the meantime, the movable gnomon somehow made its way to the Egyptian Department. The disc and the movable gnomon were stored separately for a rather long time.

In 1969, Derek J. de Solla Price (1922–1983), a famous historian of science, made another attempt to trace the history of the disc from Memphis. He writes: "A recent search by Professor V. Chenakal of the Lomonosov Museum in Leningrad has confirmed that the gnomon of this dial is still preserved in the depository of the Foreign East section of the Hermitage Museum in Leningrad; presumably the circular dial plate may also still be there."⁴ This not quite accurate information confirms that the objects were stored separately for a length of time.

At some point, Doctor of Arthistorical Sciences Vera Zalesskaya of the East Department identified the names of some cities inscribed on the disc and moved it to the East Department. In June of 2015 the author of this article studied the Hermitage collection of astrolabes and came upon the disc, which was also listed as an astrolabe. After that the author initiated the search for the gnomon. Once found, the gnomon was transferred to the East Department. The two parts were reunited in 2017.

As already noted, the original drawing of the obverse of the disc performed by Tischendorf was clearly inaccurate and caused understandable doubts. However, as early as in 1971 German scholar Edmund Buchner (1923–2011) tried to reconstruct the appearance of the instrument.⁵ Now it is obvious that he was rather close to the truth (see Figure 1): on the obverse of the disc we see four calendar scales (in every sector), 2 hour scales (to the left and to the right of the center), and a 90-degree scale on the limb (see Figure 2). Below we will describe them in greater detail.



Figure 1. Obverse drawing (a) by Tischendorf, 1860; (b) by Buchner, 1971; and (c) the actual appearance.

Gazetteer

On the reverse side of the disc (Figure 3), there is a table of cities and provinces, or gazetteer. Thirty-six names are inscribed in Greek, each with the corresponding latitude. Table 1 closely coincides with the table presented by Tischendorf, except for one letter—Tischendorf had missed the letter ε in the name ANTIOX ε IA—and two digits. First, the latitude of Meroe (#2) is 16¹/₃, not 16¹/₂. The sign for ¹/₃ is used here only once. It is not found anywhere else on this disc. Second, the latitude of Thrace (#35) is 41, not 44 (Figure 4).

Before restoration, which began in 2018, three lines (#12–14) were unread because they were obscured by the tightly fixed suspension arm. But after the restoration we were able to identify the missing items (Figure 5). For comparison, the table shows the latitude values according to Ptolemy and the correct values.

The main conclusion about the dating of the Memphis disc based on the Gazetteer has already been made by other authors: the disc could not have been produced before AD 330, the year when Constantinople was founded. The latitude of Constantinople on our disk is the same as given by Ptolemy for ancient Byzantium, on the site of which it stands, that is, 43 degrees. Later, the latitude of the city was refined to 41 degrees.⁶ Therefore, it is considered that the disc from Memphis is one of the earliest, possibly made in the 4th century, as it was originally dated by Tischendorf (but without explanation).

Calendar scales

Four calendar scales in the form of fan-shaped sectors represent the months of the Alexandrian calendar, as shown in Figure 6. (See Table 2 for the relation of the Alexandrian calendar to the Julian calendar.)



Figure 2. Obverse of the disc. Photograph © The State Hermitage Museum. Source: Photo by Grigory Yastrebinsky.

The calendar scale is more detailed in two central sectors—each month is divided into three decades (except for two outside months that are bisected). Of these two scales, the upper one (contacting the degree scale on the limb) presents spring months (TY, MEXI, Φ AMEN, Φ APMO, Π AX, Π A), from the winter solstice to the summer solstice. The bottom one denotes autumn months, from summer solstice to winter solstice (EII, MECO, $\Theta \Theta \Theta$, $\Phi A \Theta \Phi I$, $A \Theta YP$, XO).

On the shadow scales 6 months are listed in the direct order ($\in\Pi$, M \in CO, $\Theta \omega \Theta$, $\Phi A \omega \Phi I$, A $\Theta Y P$, XO), and six in the reverse one. Those that are arranged from right to left are also read from right to left, and the letters are mirrored (the so-called Greek boustrophedon-style)—AII, XAII, YOM9A Φ , [N] $\Im M A \Phi$, IX $\Im M$, YT. Here and in Table 3, in letters in square brackets are those that are listed not on all four scales, but only where there was enough space for them.

The calendar scales simultaneously show the declination of the Sun at certain dates of the year. The central line of each of the four sectors corresponds to the equinoxes. The outside lines of the sectors correspond to the solstices.

In the 4th century A.D., the assumed time of production of our disc, the cardinal astronomical moments corresponded to the following Julian dates:⁸



Figure 3. The reverse. The dark stripe on the right was formed due to the fact that the suspension was fixed in this position for a long time (maybe many centuries). Photograph[®] The State Hermitage Museum.

Source: Photo by Alexander Lavrentyev.

Vernal equinox: March 20=Phamenoth 24 (not 1st Pharmouthi, as can be seen from the drawing);

Summer solstice: June 22=Payni 28 (not 1st Epiphi);

Autumn equinox: September 22=Thoth 25 (not 1st Phaophi);

Winter solstice: December 20=Choiak 24 (not 1st Tybi).

Thus, the astronomical moments correspond to the beginning of the months with an accuracy of 3 to 7 days.

The sun's declination at the vernal equinox and the autumn equinox is zero. Solar declinations at the summer and winter solstice, June 22 and December 20, are equal to obliquity of the ecliptic, 23°51, positive in summer and negative in winter. The maker could use the angles from Ptolemy's *Almagest*⁹ (see Table 3).

	Inscription		Locality and latitude		Ptole-my Correct latitude		Comments	
I	ΙΝΔΙΑ	Н	India	8°	_	?	?	
2	МЄРОН	ISL	Meroe	 6 ⅓	16°25′	16°56′	Ancient city in Sudan	
3	COHNH	KL<	Syene	231/2	23 50	24°05′	Modern Aswan	
4	BEPONIKH	KL<	Berenice	231/2	23 50	23°55′	Ancient city on the Red Sea	
5	ΜΕΜΦΙϹ	Λ	Memphis	30	29 50	29°51′	Ancient city in Egypt	
6	ΑΛΕξΑΝΔΡΙ	ΛA	Alexandria	31	31	31°12′	City on the Mediterranean	
7	ΠΕΝΤΑΠΟΛΙΟ	ΛA	Pentapolis	31	-	?	Greek colonies in N. Africa	
8	ВОСТРА	$\Lambda A <$	Bostra	311/2	31 30	?	Ancient city in S. Syria	
9	ΝΕΑΠΟΛΙϹ	ΛΑΓο	Neapolis	31⅔	33	32°13′	, Modern Nablus, Palestine	
10	KECAPIA	ΛВ	Caesarea	32	32 30	32°30′	Ancient city in Palestine	
11	ΚΑΡΧΗΔωΝ	ΛΒΓο	Carthage	32 ² / ₃	37 55	36°51′	Ancient city in Tunisia	
12	CAΛΔΑΙ	$\Lambda B <$	Saldae	321⁄2	32 30	?	? Modern Bijayah, Algeria ?	
13	TYPOC	ΛΓΓο	Tyre	33 ² / ₃	33 20	33°16′	Ancient city in Lebanon	
14	BHPYTOC	ΛΓΓο	Beirut	33 ² / ₃	33 40	33°53′	Capital of Lebanon	
15	ΓΟΡΤΥΝΑ	$\Lambda\Delta <$	Gortyn	34½	34 50	35°04′	On the island of Crete	
16	ANTIOXEIA	$\Lambda \varepsilon <$	Antioch	351/2	35 30	36°12′	Ancient Syria, modern Turkey	
17	POAOC	ΛS	Rhodes	36	36	36°26′	City and Island	
18	ΠΑΜΦΥΛΙΑ	ΛS	Pamphylia	36	-	37–38°	Region in the Asia Minor	
19	ΑΡΓΟΟ	$\Lambda S <$	Argos	36 ½	36 15	37°37′	Among oldest cities in world	
20	COPAKOYCA	ΛZ	Syracuse	37	-	37°05′	On the island of Sicily	
21	AƏHNAI	ΛZ	Athens	37	37 15	38°00′	Capital of Greece	
22	ΔΕΛΦΟΙ	ΛΖΓο	Delphi	37 ² / ₃	37 40	38°29′	Ancient city in Greece	
23	TAPCOC	ΛH	Tarsus	38	36 50	34°53′	Ancient city in the Asia Minor	
24	ΑΔΡΙΑΝΟΥΠΟΛΙΟ	ΛΘ	Adrianople	39	-	39°06′	Stratonicaea?	
25	ACIA	Μ	Asia	40	-	36–40°	Region in the Asia Minor	

Table I. Gazetteer.

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(Continued)

Table I. (Continued)

	Inscription		Locality and latitude		Ptole-my Correct latitude		Comments
26	ΗΡΑΚΛΕΊΑ	ΜΑΓο	Heraclea	4 ² / ₃	42 20	40°58′	Lyncestis, former Perinthus
27	ΡωΜΗ	ΜΑΓο	Rome	4 ² / ₃	41 40	41°54′	Capital of Italy
28	ΑΓΚΥΡΑ	MB	Ancyra	42	-	39°52′	Modern capital of Turkey
29	ΘΕϹϹΑΛΟΝΙΚΗ	МΓ	Thessalonica	43	40 20	40°38′	City in Macedonia, Greece
30	ΑΠΑΜΙΑ	ΛΘ	Apamea	39	38 55	38°04′	Apamea Kibotos in Phrygia
31	E∆ECA	МΓ	Edessa	43	40 20	40°48′	City in Macedonia, Greece
32	ΚωΝΟΤΑςΤΙΝΟΥΠΙ	МΓ	Constantinople	43	43 05	41°01′	Modern Istanbul
33	ΓΑΛΛΙΑΙ	MΔ	Galliai	44	-	43–51°	Region of Western Europe
34	APABENNA	$M\Delta$	Ravenna	44	44	44°25′	North Italy
35	ӨРАКН	MA	Thrace	41	-	41–44°	Roman province
36	ΑΚΥΛΗΙΑ	ME	Aquileia	45	45	45°46′	Ancient city in N. Italy



Figure 4. Portions of the gazetteer with localities whose latitudes have been corrected.

In order to verify this assumption, we measure the angles using the Corel Draw program. The presence of four calendar scales, in which declination is drawn on both sides of the equator allows us to obtain eight values of the angles. Thus, for the solstice, the values of angles 23.81; 24.13; 23.94; 23.93; 23.67; 23.61; 23.49; 23.79 have been obtained, which yields the mean value of inclination of the ecliptic $\varepsilon = 23.80^\circ = 23^\circ 48'$. This value is very close to Ptolemy's value ($23^\circ 51'$).



Figure 5. A portion of the gazetteer, which shows that Nos. 12–14 were once inaccessible.

Figure 6. Drawing of the scales after the photograph, with author's explanations. The position of the pointer on the latitude scale is shown for a latitude of 32°. Source: Author's drawing.

Thoth I	August 29*	Phamenoth I	February 25
Phaophi I	September 28	Pharmouthi I	March 27
Athyr I	October 28	Pachon I	April 26
Choiak I	November 27	Payni I	May 26
Tybi I	December 27	Epiphi I	June 25
Mechir I	January 26	Mesore I	July 25
		Epagomenae (5 days)	August 24–28

Table 2. Julian equivalent of the first day of each month of the Alexandrian year.

*Thoth 1 falls on August 30 if the August in question belongs to the Julian year preceding a leap year. Otherwise, Thoth 1 falls on August 29.⁷

For intermediate lines (a month and 2 months before and after the equinoxes), the average values 20.12° and 11.71° were obtained (compare with the values in Table 3). The good agreement between our measuring and values from the *Almagest* characterizes the accuracy of the maker's work. The root mean square error of the results is about 0.2°.

Angular scale

The angular scale or the scale of latitudes is plotted along the edge of the disk and is divided into equal 2-degree parts—from 0° to 90°. Under each 6th degree there is an inscription where numbers are also written in Greek letters: $\zeta = 6$, IB = 12, IH = 18, etc., up to qoppa=90 degrees. The beginning of the scale coincides with the equinoctial line (equator). On the scale of latitudes, all 6-degree fractions were measured. Their total span is 15. The first seven intervals are given with a surplus—about 6.1°, and the next eight—with a deficit—about 5.9°. The resulting error is $\pm 0.1^{\circ}$!

Flat hour scales

In the two non-central sectors there are flat hour scales for time measurement. Following other researchers, we call these scales subsidiary dials. Their circular lines are inscribed by Greek letters A, B, Γ , Δ , \in , that is, 1, 2, 3, 4, 5. At the top of one sector, a conical gnomon 13.5 mm high has been preserved (on the left in Figure 6). There is no gnomon at the top of second sector.

Such scales are found on two similar instruments: from Vathy Archaeological Museum (Samos, Greece) (diameter 68 mm) and from the Time Museum (Rockford, Illinois), up till 2004, (diameter 120 mm). Only discs without gnomons have survived for both instruments. As pointed out by E. Buchner in 1971 and J. V. Field in 1990, these subsidiary dials are in effect flat versions of the gnomon and scale used on the main dial.

To use these scales one first sets the support ring and its indicator for the correct latitude. One then suspends the dial from its support ring so that it hangs vertically (And so the conical gnomon is horizontal). Then one slowly turns the dial about the vertical axis until the shadow of the conical gnomon falls along the correct month line. The hour is indicated by the location of the shadow tip among the hour circles.

Inscription	Full month names	English month names	Astronomical moment (on the beginning of the month)	Sun declination (Ptolemy)
ЄП	Ε ΠΙΦΙ	Epiphi	Summer solstice	+23°51′
MEC[O]	MECOPH	Mesore		+20°30′
θωθ	θωθ	Thoth		+11°40′
ΦΑωΦ[Ι]	ΦΑωΦΙ	Phaophi	Autumn equinox	0
ΑΘΥΡ	ΑθΥΡ	Athyr		-11°40′
XO	XOIAK	Choiak		-20°30′
TY/YT	ТҮВІ	Туbi	Winter solstice	–23°51′
MEXI / IXЭM	MEXIP	Mechir		-20°30′
ΦΑΜΕ[Ν]/[Ν]ЭΜΑΦ	ΦΑΜΕΝωΘ	Phamenoth		-11°40′
ΦΑΡΜΟ[Υ]/[Υ]ΟΜ٩ΑΦ	ΦΑΡΜΟΥΘΙ	Pharmouthi	Vernal equinox	0
ΠΑΧΙ/ΙΧΑΠ	ΠΑΧωΝ	Pachon		+11°40′
ΠΑ/ΑΠ	ΠΑΥΝΙ	Payni		+20°30′

Table 3. Alexandrian calendar and declination of the Sun.

It follows that the angles at the tip of the gnomon G, drawn to the hour markers, must be multiples of 15 degrees, as shown in Figure 7.

For each hour, the length of shadow d can be expressed as follows:¹⁰

$$d = h \cdot \tan\left(n \cdot 15^{\circ}\right),\tag{1}$$

where h is the gnomon height, n is the number of the hour. The photo of disc was used in order to check the position of the hour arcs. The radii of the hour arcs (shadows) on both scales were measured and then the average values are recorded in Table 4.

As is seen, the measured values well correspond to the gnomon height 17.5 mm. The real height of the gnomon, that is, 13.5 mm, does not correspond to the measured values. It is possible that these scales were of a purely decorative nature, since there was a basic scale on the movable gnomon. It is also possible that the gnomon has lost some of its initial height, or that the maker of the astrolabe just made a mistake. In any case, the proportions confirm that, in making these hour scales, the maker used just this method of calculation (The discrepancy between the height of the gnomon and the length of the shadow is also observed in much later astrolabes¹¹).

Movable gnomon, or shadow caster

The movable gnomon of our portable sundial is 114 mm long, 23 mm high (see Figure 8), and 5 mm wide. It reminds us of a similar component of the instrument from the Museum of the History of Science in Oxford.¹² Other portable sundials either survived to our time without gnomons, or the instruments are considered lost along with the gnomons (there are preserved drawings of two of them—from Rome and from Crêt-Châtelard¹³). As

Figure 7. Angles and shadows for the flat hour scales.

Number of the hour	Angle between ray and horizontal gnomon	Measured arc radius, mm	Length of the shadow calculated by formula (1)			
			h = 13.5 mm	h = 17.5 mm		
A: I/II	75°	5.0	3.75	4.7		
B: 2/10	60°	10.5	8.1	10.1		
Г: 3/ 9	45°	18.0	14.0	17.5		
∆: 4/ 8	30°	30.5	24.2	30.3		
E: 5/ 7	15°	63.5	52.2	65.3		

Table 4. Flat hour scales..

compared to the rather simple form of the gnomon from Oxford, the shape of our gnomon has artistic contours and looks like a hull of a ship.

The bow of the ship (on the left) serves as a gnomon. The hour graduations are inscribed along the upper concave surface. The distances between these graduations correspond to the 15-degree "steps" of the Sun in the sky during each hour. The gnomon is placed in a groove made on the axis and rotates with the pin. The gnomon bears the traces of a thin foil gasket (pad) used for its more reliable fixation.

Telling time using the movable gnomon has been described in detail by Stebbins,¹⁴ Field,¹⁵ and Wright¹⁶. One sets the support ring and its indicator for the correct latitude and sets the gnomon for the correct time of the year. One then suspends the dial from its ring and shackle so that it hangs vertically. One then turns the dial until the shadow of the gnomon falls along the curved scale to read off the hour using the hour lines engraved on this curved scale.

Besides, as de Solla Price¹⁷ pointed out, once the latitude and the time of year have been set, the shadow can only fall squarely on the shadow-scale when the instrument has been turned to a particular orientation of the disc. When this has been done the plane of the disc is necessarily that of the meridian so that not only does the instrument show the time of day, but the edge of the instrument points to due north and south. The dial in fact gives a rapid and convenient method of astronomical orientation and must have been quite impressive before the magnetic compass was invented. Unfortunately, this method only works near the equinoxes (and only in the morning hours).

Figure 8. Movable gnomon or shadow caster. The lines are drawn from the gnomon vertex to the hourly scale on its concave surface. Photograph[®] The State Hermitage Museum. Souce: Photo by Grigory Yastrebinsky.

Figure 9. The height of the Sun at noon allows one to determine the latitude of the site: ϕ = 90° - h + δ .

From here, it is but one step to another possible way to use our device. At noon, when the time and date are known (and thus so too is the declination of the Sun), the device will show the latitude of the place. If the gnomon is set correctly (Figure 9), at noon it should be directed toward the Sun. The pointer of the device (in the place of suspension) is located at the point Z and shows the latitude of the place. Whether the ancients used this property, we don't know.

Metallurgical data

In 2018, the nondestructive X-ray fluorescence analyses were performed in the Department of Scientific and Technical Expertise of the Hermitage. Mobile spectrometer ArtTAX was used for this purpose.

#	Parts	Cu	Zn	As	Sn	Pb	Ag	Ni	Fe	Other
I	Disc	Main	18–20	>0	<0.8	<0.2	<0.3	>0	<0.4	
2	Conical gnomon	Main	10-11	<0.3	<0.3	<0.6	>0	>0	<0.3	
3	Movable gnomon	Main	10-12	<0.4	<0.4	3–4	>0	>0	<0.2	Sb
4	Pointer	Main	14-16	>0	<0.4	<0.2	>0	<0.5	<0.4	
5	Washer	Main	14-16	>0	_	<0.3	_	>0	<0.7	
6	Pin	Main	10-11	<0.3	~	<0.8	>0	>0	<0.4	Sb
7	Ring	Main	18–20	>0	>0	< 0.2	-	<0.5	< 0.5	

Table 5. Results of X-ray fluorescence analyses, percentage composition.

Components: Cu: Copper; Zn: Zinc; As: Arsenic; Sn: Tin; Pb: Lead; Ag: Silver; Ni: Nickel; Fe: Iron; Sb: Antimony.

All parts of the instrument are made of two-component brass (see Table 5). The basic element is copper, the dopant is zinc. The percentage of zinc ranges from 10% to 20%. Of the other elements, only a significant level of lead in the movable gnomon can be noted. This additive makes processing easier.

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Notes on contributor

Sergei J. Maslikov obtained his PhD in physics and mathematics in the Institute for the History of Science and Technology, Russian Academy of Sciences, in 2017. His dissertation, which was written in Russian, has the following title: *Astrolabe as astronomical instrument: from Antiquity to Early Modern period*. He described all the planispheric astrolabes that are stored in Russian museums. He is an author of books and articles on astrolabes and the history of Russian astronomy.

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