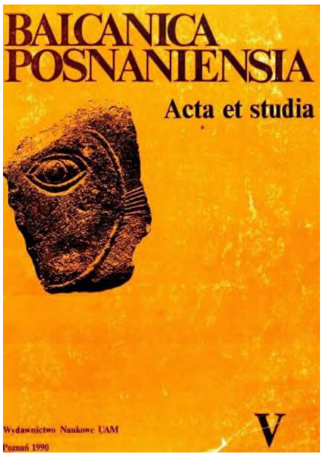

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BALCANICA POSNANIENSIA V
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ANCIENT SUNDIALS FROM MOESIA AND THRACIA (THE SUNDIAL FOUND AT MONTANA)

PETER VALEV

ABSTRACT. Valev Peter, *Ancient sundials from Moesia and Thracia* (*The sundial found at Montana*) Balcanica Posnaniensia. Acta et studia, V, Poznań 1990, Adam Mickiewicz University Press. pp. 163 - 181, 7 figs. ISBN 83-232-0007-6. ISSN 0239-4278. Text in English.

Considerations of the author in this article are about the sundial found during excavations conducted in 1972 - 1978 in the Roman villa near the ancient Montana in Moesia Inferior (today Mihajlovgrad in the northern Bulgaria).

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Excavations and archaeological research at various sites of Graeco-Roman antiquity across Europe, Asia and Africa have yielded a few hundred finds of sundials, which were introduced to substitute for the early Egyptian and Chineese water-clocks and fire-clocks.[1]

Sundials are primitive devices (not sophisticated mechanical clock-works) for noting the passage of time and were used to measure local apparent solar time.[2]

According to Vitruvius, the invention of the various types of shadow receiving surfaces should be attributed to the sundiallers of ancient Greece.[3] The early Hellenistic diallers not only possessed impressive astronomic and geodetic knowledge[4] and an exuberantly inventive engineering vision,[5] but a great craftsmanship in the

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[1] L. Zajdler, *Dzieje zegara*, Warszawa 1956 (1977), p. 58 - 98, 99 - 120; F. A. B. Ward, *Time Measurement*, London 1970, p. 9 - 14; F. S. Zavelskij, *Vremja i ego izmerenija* [*Time Measurement*], Moskva 1972, p. 28; V. N. Pipunyrov, *Istorija časov s drevnih vremen do naših dnej* [*A History of Clocks from Ancient till Modern Times*], Moskva 1982, p. 104, fig. 57, 58.

[2] V. K. Hristov, *Geodezičeska astronomija* [*Geodetic Astronomy*], Sofija 1964, p. 99.

[3] Vitruvius IX, 8, 1.

[4] J. L. E. Dreyer, *History of the Plαnetary Systems from Thales to Kepler*, Cambridge 1906; O. Neugebauer, *Über eine Methode zur Distanzbestimmung Alexandria — Rom bei Heron*, København 1938; M. Glagett, *Greek science in antiquity*, New York 1955.

[5] J. G. Landels, *Engineering in the ancient world*, London 1978.

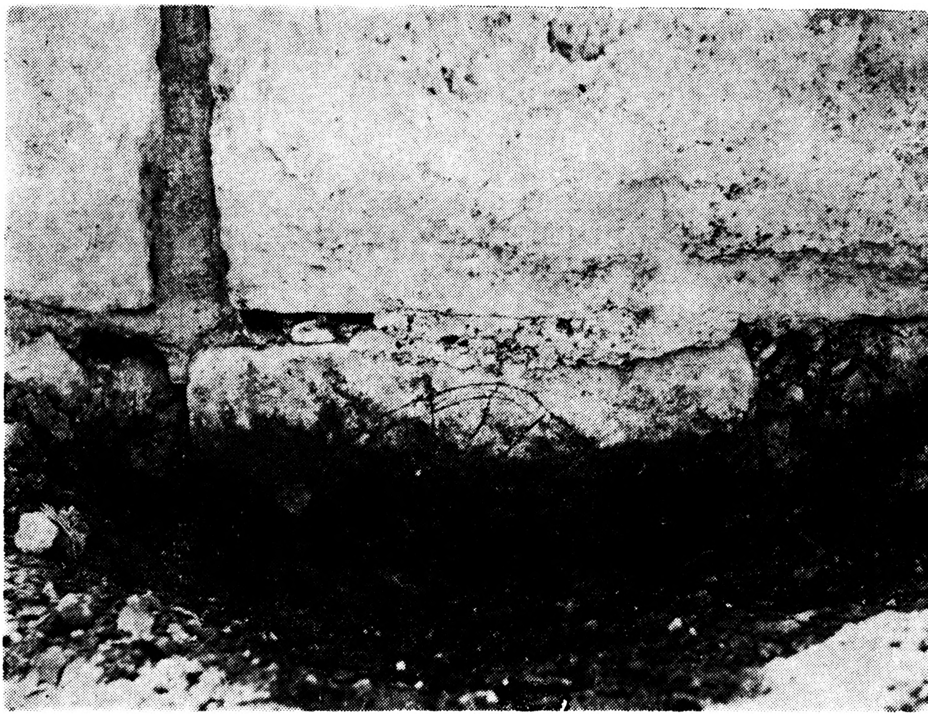

Fig. 1. The fortress at Shumen. Church No 5. A stone with an inscription of vertical sundial which had been used a second time in the base of the church (most probably from the fortress wall). Photograph by E. Georgiev

art of elaborate and accurate stone carving, as well. It should be borne in mind, however, that Babylon and Egypt are the birthplaces of gnomonics.[6]

So far nine ancient sundials have been found in Bulgaria – one in the region of Diocletianopolis,[7] one at Durostorum,[8] one at Montana,[9] one at Serdica (Unpublished), one at Shumen (Unpublished; Fig. 1), two at Marcianopolis[10] and two at the village of Kamen Bryag (in the district of Tolbuhin).[11]

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[6] A. Tarnawski, *Najważniejsze pomoce przy nauce geografii matematycznej*, I, *Gnomon i jego użycie*, Lwów – Warszawa 1930; E. Guyot, *Histoire de la détermination de l'hedre*, Neuchâtel 1969, p. 20 - 36; H. G. Harris, *Collecting and Identifying old Clocks*. New York 1977, p. 9 - 17.

[7] Dončev, *Hisarskite bani* [*The Hissar mineral spas*], GPNBM, 1935 - 1936, p. 185, fig. 97.

[8] J. Mlađenova, *Solnečnye časy s relefom Orfeja iz Dórostorumu* [*A sundial with images of Orpheus from Durostorum*], Sovetskaja Arheologija, 196S, 4, p. 274 - 278; P. Valev, *Sl'nčavijat časovnik ot Durostorum* [*The tsundial frhm Durostorum*], Arheologija (forthcoming).

[9] G. Aleksandrov, *Dva sl''nčevi časovnika ot Montana* [*Two sundials from Montan*] IMSB, 2, 1978, p. 33 - 38.

[10] A. Angelov, I. Ivanov, *Sl''nčev časovnik ot Marcianopol* [*A sundial from Marcianopolis*], Interdisciplinarni izsledovanija, 10, 1983.

Fig. 2. A stone bay (Caisson?) found in the region of Sofia. The network of lines and curves and the hole of a missing gnomon are clearly visible. Photograph by E. Georgiev

[11] The second sundial from Marcianopolis (present-day town of Devnya) and the two sundials found at the late ancient fortress in the Yayla region, near the village of Kamen Bryag have not been published yet. The specimens found at the fortress are heavily fragmented and were primitively made. The day length was divided into 5 parts. The change of guard followed the movement of the gnomon's shadow. The specimens from Diocletianopolis (present-day town of Hissar) and from the Shumen fortress have ten hour lines, which verifies the hypothesis for the existence of fortress sundials in antiquity, used for the regulation of the change of day-guard.

Another stone object (a caisson?) found in the region of Sofia (Unpublished) might have been used as a sundial (Fig. 2). Since it is not easily amenable to mathematic computations a more pragmatic approach should be undertaken. The object ought to be taken into a sunny spot and exposed to daylight. It should be placed facing South and a gnomon of varying length should be inserted in different positions until the most probable gnomon position is hypothesized.

The geometrically inscribed tile found in the necropolis of the Ancient Villa No 2 at Montana had not been used as a sundial.[12] The inscription from Pautalia served only as evidence that a sundial, which had disappeared during an invasion used to exist but has not been discovered yet.[13] The two inscriptions with sundial images on tomb stones found at Odessos bear evidence for the locality of the scene or for the attitude of either the deceased or of the tomb maker towards the technical scientific activities of the period.[14]

If we are to follow Jibb's classification,[15] the most popular sundials in ancient times used to be the ones having *conical* shadow receiving surfaces. This type of sundials has not been discovered in Bulgaria so far. *Spherical* sundials rank second in number. The sundial found in the region of Serdica belongs to that type. It has non-standard hour-lines which could be attributed either to an error made by the dialler or to a gnomon of unconventional shape. Ranking third are the *planyr* sundials. Examples belonging to this type are the sundials discovered in the region of Diocletianopolis, at the fortress in the village of Kamen Bryag and at the fortress near Shumen. Ranking last, according to Jibb's classification are *cylindrical* sundials. They are in fact some of the rarest and unique specimens of antiquity. The two sundials found in the region of Marcianopolis and the one at Montana evidently belong to this type. The most difficult for classification has turned out to be the sundial found among the ruins of ancient Durostorum. According to Jibbs[16], although rather unconvincing, its shadow receiving surface is a flattened quarter sphere.

It appears that the first task a researcher faces is to determine the type and parameters of the receiving surface — i.e. the dial face on which the shadow, cast by the gnomon point falls. While the dial faces of planar sundials have horizontal or verti-

[12] Aleksandrov, o.c., p. 38 - 39. Tiles and marble slabs with similar inscriptions were used for floor covering or wall decoration; cf. S. L. Gibbs, *Greek and Roman Sundials*, New Haven and London 1976, p. 84, 128, plate 1.

[13] L. Ruseva-Slokoska, *Nadpis za sl"nčev časovnik ot Pautalija* [*Inscription on a sundial from Pautalia*], MPK 2 - 3, 1974, p. 60 - 65, fig. 1. The stone slab with the inscription kept in the town of Kyustendil has surprising dimensions (510 × 1445 × 1130 mm). A number of grooves are preserved on the horizontal plane. They were used for fixing the sundial. Their position suggests that this particular specimen had a considerable size and must have had several receiving surfaces; cf. Gibbs, o.c., p. 346.

[14] G. Tončeva, *Dva nadgrobni pametnika ot Odesos* [*Two tombstones from Odessos*], Sbornik Izsledovanija v čest na Karel Škorpil, Sofija 1961, p. 236.

[15] Gibbs, o.c., p. 12, 73, 78, 85.

[16] Ibid., p. 168, 170, plate 9.

cal planes, the other sundial types have concave dial faces — with either spherical, conical, cylindrical or any other non-planar type of surface.

If we take a material straight segment (an unsharpened pencil, the edge of a short ruler, a piece of steel wire, etc.) we can easily find out that wherever we place it upon a spherical shadow receiving surface, the distance from the middle point of the segment to the spherical surface remains constant. At a segment length of 2a and a distance *h* from its middle point to the sphere, we get for the radius of the sphere:

$$r = \frac{a^2 + h^2}{2h} . \qquad (1)$$

Moving the segment as a generator round a conical or cylindrical surface we observe that it is closely tangent to the surface. Moving along a conical surface the generator is directed towards a single point (the vertex of the cone) outside the sundial,[17] whereas rotating along the cylindrical surface the generator remains parallel to itself. In this way it has been established that the sundials from Marcianopolis and Montana had erroneously been attributed to the spherical type. Although having small deformations, characteristic of the Rhodes — Kos school of dialmaking they are in fact cylindrical, thus ranking deservedly in the list of rare specimens.

The second procedure a researcher should undertake is to determine the length of the gnomon and the geographical latitude for which the sundial under investigation had been intended. There are two ways to accomplish this task: a graphoanalytical[18] and a theoretical one.[19]

A fanlike network of hour-lines used to be engraved on the faces of the sundials.[20] Generally the hour-lines either started from the base of the gnomon or were directed towards it. When the shadow of the gnomon point coincided with any of the hourlines, the passage of a whole hour was indicated. And since the shadow receiving surface was exposed to daylight from sunrise to sunset irrespective of the day length, it follows that the ancient summer hours used to be longer than the winter hours.

[17] With the exception of the unique conical sundial found in Izmir, Turkey. The vertex of its conical surface lies in the horizontal roof plane; Ibid., p. 322, 325, plate 51.

[18] E. Buchner, *Aristomenes — Uhren in Samos*, Chiron 3, 1973, p. 119 - 129; *Römische Medaillons als Sonnenuhren*, Chiron 6, 1976, p. 329 - 348; *Solarium Augusti und Ara Pacis*, Mitteilungen des Deutschen Archaeologischen Instituts, Römische Abteilung, 83, 1976, p. 319 - 365; The last two works of E. Buchner are cited as examples of the graphoanalytical approach to sundials.

[19] C. Ionescu-Carligel, *Contributions à l'étude des cadrans solaires antiques*, Dacia XIV, 1970, p. 119 - 137.

[20] The so called meridian sundials are an exception. The ancient world had accepted the Babylonian division of the day into 12 equal parts. This was introduced by the ancient Egyptians and Greeks. The sundial from Serdica has non-standard hour-lines because they were not engraved as a fanlike network on the receiving surface. This peculiarity makes it a unique specimen among the hundred or so spherical sundials left from antiquity.

The difference in day duration is accounted for by the fact that the equatorial plane does not coincide with the plane of the earth's orbit round the celestial sphere – i.e. the ecliptic.[21] For the Northern hemisphere the sun is at its lowest point above the horizon on December 22, on the winter solstice when the shadow of the gnomon has its longest value at midday. It is at its highest point on June 22, on the summer solstice when the shadow of the gnomon has its shortest value at midday. The shadow maintains its mean value on the spring and autumn equinoxes – i.e. on March 21 and Sept. 23, respectively. Therefore three characteristic curves are traced by the tip of the gnomon's shadow on the receiving surface and are subsequently engraved across the fanlike network of hour-lines.

In order to project and then engrave this specific type of dial onto a flat or concave stone slab prepared in advance it was necessary to construct the so called *analemma.*[22] Vitruvius describes the construction of the analemma of a sundial with a spherical receiving surface belonging to the type, formulated as *hemicyclum excavatum ex quadrato ad enclimaque succisum.* Among the scientists who have contributed to restore or reconstruct the analemmas of sundials with varying types of faces are Gustav Bilfinger, Constantin Ionescu-Carligel, Edmund Buchner and others.[23]

Besides the obliquity δ of the ecliptic the graphoanalytical way of research requires also knowledge of the dimensions of angle ξ formed by the rays of sunlight at sunrise (or sunset) on solstice and equinox on the tip of the gnomon point. If δ is known, then ξ is computed, using the formula for the solar azimuth:

$$\cos A_{\odot} = \frac{\sin \delta}{\cos \varphi}, \text{ where } A_{\odot} = 90° - \xi \text{ or } \sin \xi = \frac{\sin \delta}{\cos \varphi}. \tag{2}$$

The quantity φ appears in the formula for ξ. It stands for the geographic latitude of the sundial in function. φ stands for the acute angle, formed by the equatorial plane and the direction of the plumb line at the original location or provenance of the functioning sundial. In ancient times the value of φ was expressed by a simple fraction, which had for a numerator the length of the vertical gnomon's shadow at midday on equinox and for a denominator the gnomon's height. The accepted ratio for Rome was 8/9, for Athens –3/4, for Alexandria – 3/5, etc.

The sundial under investigation which has a non-planar receiving surface can be analysed at two significant sections: across the midday line (a vertical cross-section along the length of the gnomon) and a horizontal section (a plane across the sunrise curve, the gnomon and the sunset curve).

[21] The angle, formed between them – δ was equal to 23°26′28″, 91 for 1984, 0 (*Astronomičeski kalendar*, Sofija 1983, p. 9) In 1100 BC its value was 23°54′ (Bonev, o.c., p. 224). When sundials were constructed in antiquity the value of δ was assumed to be a round 24° and represented 1/15 of the circle (Vitruvius, IX, 7, 4). The change in the value of δ was caused by the precession and the nutation of the terrestrial axis.

[22] Vitruvius IX, 7.

[23] G. Bilfinger, *Die Zeitmesser der Antiken Völker*, Stuttgart 1886, p. 34.

If we draw on tracin paper three intersecting straight lines (the rays of sunlight at midday – on the 6th hour; on the 12th hour of local apparent solar time on sol stices and equinox) and if the three lines intersect at a point, (which is the tip of the gnomon) with angles equal to δ, we obtain a constant pattern for all spherical, conical and cylindrical shadow receiving surfaces, analysed at a vertical cross-section.

To scale 1 : 1, on a straight or curved line, corresponding to the midday line on the dial under investigation we mark points t, w, e, and s, corresponding to the base of the gnomon tG and the points of intersection of the winter, the equinoctial and the summer curves with the midday hourline.

The pattern is then positioned on the projected vertical cross-section and its three rays are traced to intersect with points w, e, and s. Then we can graphically read the length of the gnomon tG. If the midday line of a conical or cylindrical sundial was parallel to the terrestrial axis at the time of construction, it is also possible to measure the geographic latitude of its original location or provenance in antiquity.

If we draw on tracing paper three intersecting straight lines, forming angles equal to angle ξ, computed by formula (2) at φ for the geographic latitude of the locality where the sundial was found, we obtain a second pattern for the specimen under investigation.

To scale 1 : 1 the sunrise curve is then traced, which switches into the sunset curve at point t. The curve is most often part of a circle or an ellipse. On the curve mark the points of intersection with the winter, the equinoctial and the summer curves, and start to move the second pattern along the axis of symmetry, beginning at point t, while at the same time we should be careful to keep to the medial straight line (i.e. the ray of sunlight at sunrise and sunset at the equinoxes) perpendicular to the axis of symmetry. The three straight lines are supposed to pass through points w′, e′, s′, and through points w″, e″, s″, respectively. The length of the gnomon tG can be read again. This is, in fact, the final test of the viability and fitness of the dial under investigation.

There is certainly another practical test, for which the sundial should be taken into the open, exposed to daylight and oriented by using a compass, so that the midday line will face North-South, the base of the gnomon will face North and the receiving surface will face South.[24] The stone body is perpendicularized, while a gnomon of length, obtained by graphic measurements is inserted horizontally. Then the shadow of the gnomon point at solstices and equinoxes should coincide with the winter, the vernal-autumnal, and the summer curves.[25]

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[24] Some sundial types are not mentioned here (conical sundials facing North, roofed spherical sundials, globes, etc.) since these types have not been found yet in the area of the Roman empire under investigation.

[25] Not all sundials have the three seasonal curves engraved on their faces. It is even rarer to have any other zodiacal curves engraved on them. Extremely interesting in this respect is the sundial fragment, found in Istropolis (Rumania) with calendrical (?) markings on the midday hour-line (cf. Gibbs, o.c., p. 158 and the references cited there).

Unfortunately most of the sundials from Graeco-Roman antiquity have been submitted to severe damage. Such was the plight of most of the sundials, mentioned in this paper and the sundial from Pautalia is even missing. It should be borne in mind, however, that during archaeological excavations one may come across small stone segments with engraved lines and curves, by which the gnomon length and the geographic lattitude could be analytically worked out, provided the fragment was part of an ancient sundial.[26]

*

During a period spanning from 1792 till 1978 archaeological excavations were carried out at a site situated 6 km from Montana (the present day town of Mihaylovgrad). The investigation focused on the Ancient Villa No. 2, presenting a sizable complex of three houses, three baths, three horeums, a tolos (area?), and some other farm buildings, pottery kilns, a stone-pit, an early Christian basilica and a necropolis with four mausoleums.[27]

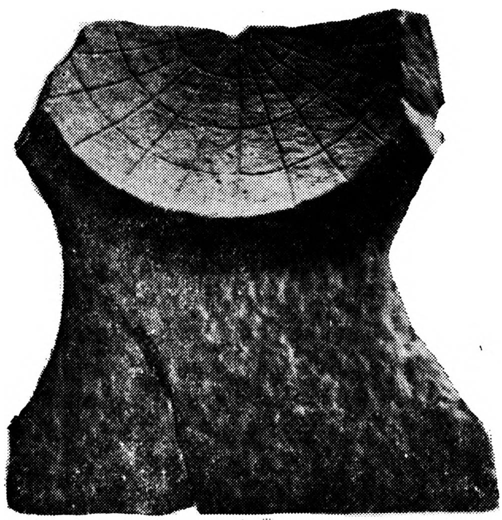

Fig. 3. Regio Montanensium. Ancient villa No 2. Horreum No 2. The marble sundial. Photograph by E. Georgiev

The second part of the paper discusses the marble sundial (Fig. 3), found in Horeum No 2,[28] concealed there together with a treasure trove of copper coins, minted during the period from the reign of Flavius Valerius Constantinus (known as Constantinus the Great; 306 - 337) until the reign of Julianus Apostata (361 - 363). The year 378 could be accepted as a reliable upper limit, since that was the year of the second invasion by the Goths.

The sundial was cut out of a marble slab and had the following dimensions: H (height) = 5 m, D_{max} (a maximum width) = 5 m and W (thickness) = 2.5 m, where m is equal to 1/5 of a Roman foot or 59.18 mm.[29] The silhuette, resembling the body of a female is shown on Fig. 4. The ratios of Db_{min}: Db_{max}

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[26] C. Ionescu-Carligel, o.c.

[27] G. Aleksandrov, *Antična vila No 2 kraj Montana* [*Ancient Villa No 2 near Montana*], IMSB 4, 1980, p. 9 - 64.

[28] Ibidem, p. 33 - 34; Aleksandrov, *Dva sl"nčevi časovnika ot Montana...* [*Two sundials...*], p. 33 - 38.

[29] The module *m* was deduced by the author in his thesis, headlined "Time measurements

(3 m : 5 m = 0.6) and R_f: (H $-$ R_f), i.e. 2 m : 3 m = 0.66 ... are almost at sectio aurea. These ratios visually approximate 0.618 after the sundial is mounted and fixed onto a high place.

Not much effort was employed on processing the marble. Greater emphasis was laid, however, on inscribing the lines and curves onto the shadow receiving surface. The eleven hour-lines originate from the base of the presently missing gnomon and extend towards the frontal edge. The midday line (for the 6th hour) had previously been marked on the frontal plane — a mark also common for a number of other specimens. The so called day or seasonal curves are three in this particular case: they may often spring up some surprising information for the specialists.

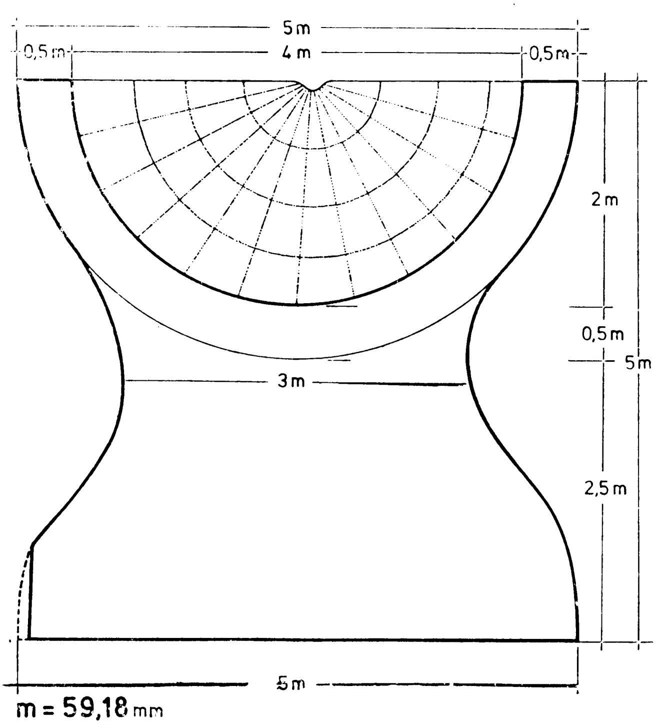

Fig. 4. The sundial from Montana. Silhouette outsulines. Drawing by P. Valev

Before undertaking this particular investigation it would be methodologically consistent to analyse the shape of the shadow receiving surface.

The frontal and horizontal sections of the sundial from REGIO MONTANEN-

in antiquity (based on direct sources and on archaeological finds from the lands of present-day Bulgaria)". It has turned out that even the details of the networks of lines and curves engraved on sundial receiving surfaces are divisible by the module *m*.

SIUM are semicircles and the midday hour-line is slightly concave, instead of being a straight segment. The actual horde tb (measured mean length of 163 mm) with an 8 mm arrow) moving to the left and upwards, i.e. remaining parallel to itself becomes gradually more and more tangent to the receiving surface. The receiving surfaces of all the sundials different from the quarter spherical ones and having semicircles for their vertical and horizontal sections are parts of *inclined elliptic*

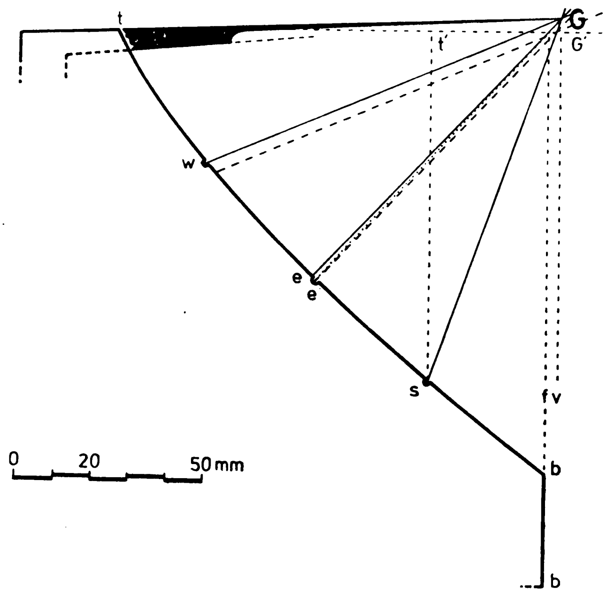

Fig. 5. The sundial from Montana. A verticle section across the midday line (meridian section). Drawing by P. Valev

cylinders. If the centres of the two sections coincide (which makes their radia equal in length) then the generator of the cylinder lying in the meredian plane will form an angle of 45° with the prime vertical of the sundial's provenance, i.e. only at $\varphi = 45°$ it will be parallel to the terrestrial axis. Since the diallers knew that the midday line of the inclined cylindrical dials had to be parallel to the terrestrial axis and respectively perpendicular to the equinoctial ray of sunlight, they used to cut it between points w and s (Fig. 5), so that the active part of the network of lines and curves would be in proportion (homeothetic) with the strip of the celestial sphere in which the sun moves throughout the year. The gnomon point is the homeothetic centre. It is an obligatory condition (providing the dialler had no other consideration in mind or had not made and error) for the gnomon point to be on the cylindrical axis and in this case, to coincide with the center of the two semicircles, perpendicular to each other. Having accomplished this elaborate point by using a pattern especially designed beforehand and some additional cutting in the vicinity of the midday line

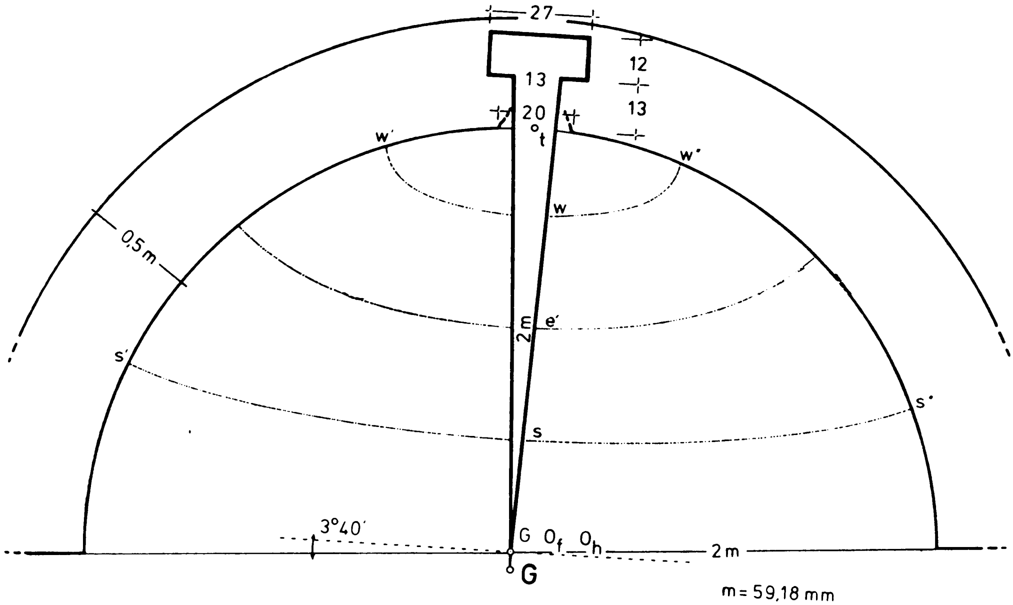

Fig. 6. The sundial from Montana. Projection of the seasonal curves onto the horizontal lane across the gnomon. Drawing by P. Valev

(at noon ws 'receives' the equinoctial ray of sunlight at a right angle),[30] the dialler accepted point t at the base of the gnomon for the centre of the day curves w, e′ and s.[31] This means that rays w, e′ and s will coincide with their intended curves w, e′ and s only around noon; during any other time of the day the shadow of the gnomon point will not coincide with them. (Fig. 6).

Thus, the great semi-axis of the elliptic cylinder, used as a dial face of the sundial from REGIO MONTANENSIUM is equal to 2 m (118.4 mm). The small semi-axis is obtained from the orthogonal isosceles triangle tbG′ : 2 m. sin 45° = 83.7 mm (Fig. 5). After engraving the midday line and smoothing the surface on both sides.

[30] The additional cutting might have been avoided if the generator of the inclined elliptic cylinder formed an angle φ with the prime vertical of the provenance. For this purpose it is required that points $O_f \neq O_h$, where O_h has been moved away from O_f in the direction of point t, – i.e. $tO_h = R_h$, $bO_f = R_f$, $R_h = R_f$, $R_f : (R_h + O_hO_f) = \mathrm{tg}\,\varphi$. Since O_hO_f has a small value in respect to $r_h\,(r_f)$, then practically the semicircles overlap as though their centres coincided. The midday line does not hollow out but receives the equinoctial ray of sunlight at a right angle, while the horizontal cross-section of the inclined elliptic cylinder remains a circle, although the horizontal plane does not intersect with it at a 45° angle.

[31] Apparently the dialler did not known the construction of the analemma described by Vitruvius and had not had the time at this point to trace the marks of the shadow point on the receiving surface on the days *w*, *e′* and *s*, which suggests that he had not been a citizen of Montana but a travelling dialler.

the small semi-axis is reduced to almost 1.5 m (88.8 mm, measured 91.7 mm). Having undergone this change, the receiving surface already becomes part of an inclined elliptic cylinder, whose great semi-axis is a constant (2 m), while the small axis varies from $2\,\mathrm{m}\cdot\sin 45°$ $(2\,\mathrm{m}\cdot 0.5)$ to $2\,\mathrm{m}\cdot\sin 48°35'$ $(2\,\mathrm{m}\cdot 0{,}75=1{,}5\,\mathrm{m})$ or $2\,\mathrm{m}\cdot\sin\alpha$, where $45°\leqslant\alpha\leqslant 48°35'$; $\alpha=45°$ for a horizontal and a vertical section, and $\alpha=48°35'$ for the equinoctial section.

Now let us try and find the degree of influence. exercised by the declination δ and the geographic latitude φ on some details of the receiving surface- significant for our investigation. Three cases can be distinguished (Fig. 7): a) – the actual declination of the sun approximately on March 21 in the year 325 A.D.[32], and the geographic latitude of the Ancient Villa No 2 at $\varphi=43°27'$ $(\lambda=-23°16')$;[33] b) – the rounded value of δ equal to 24° (1/15 of 360°) according to Vitruvius and at $\varphi=43°27'$; c) – δ_{max} of the year $325=\pm 23°39',5$ and the geographic latitude $\varphi'=\varphi-\Delta\varphi$, where $\varphi=43°27'$, and $\Delta\varphi$ is the correction which might be necessary if point e′ happens to be equinoctial and not different from the date of March 21.

Therefore it seems logical to assume that the sundial was constructed on the spot of its location and that point e′ regardless of the slight errors in the value of δ had been deliberately marked. Table 2 presents a comparison between some data read directly from the specimen under investigation and the results of computation.[34]

[32] The sundial could not have been constructed later than the year 378 A. D. when the villa was destructed during the time of the second invasion by the Goths (Aleksandrov, o.c., p. 38). The closest date of an equinox known for certain is March 21 in the year 325, when during the Nicaean council it was decided that the mobile spring point γ was just on March 21 (Bonev, o.c., p. 374). According to Newcomb's formula (cf. E. Buchner, o.c., p. 333, Note 47) in this particular ease we have δ_{max}. the year $325=23°27'8''$, 26 - 46″, 845. T – ...; T=the 4th century – 20 cent. $=-16$; $\delta=23°39'37'',78$ or approximately $23°39',5$.

[33] The geographic lattitude, expressed by a fraction is 18/19 or 9/9,5 ($\mathrm{tg}\,43°27'=0{,}9473$; $18/19=0{,}9474$). The interpolation of φ and λ was carried out by the *Academic Geographic Atlas*, Sofia, 1960, p. 72).

[34] The computations can be carried out in three variants by accepted theoretical values for the basic elements of the meridian section of the shadow receiving surface.

Variant I (Fig. 5 and Fig. 7a):

$tG=bG=2m=118{,}4$ mm $\qquad \delta_{max}=23°39',5$

$tb=2m\sqrt{2}=167{,}4$; $ws=82{,}0$ $\qquad \varphi=43°27'$

$\triangle wGs$: $wG=sG=\dfrac{41{,}0}{\cos 66°20'5}=102{,}2$; $eG=wG\sin 66°20',5=93{,}6$ mm

$\triangle sGb$: $sb^2=102{,}2^2+118{,}4^2-2\cdot 102{,}2\cdot 118{,}4\cdot\cos 19°47'5$; $sb=41{,}1$ mm

$\triangle tGw$: $tw^2=118{,}4^2+102{,}2^2-2\cdot 118{,}4\cdot 102{,}2\cdot\cos 22°53'5$; $tw=46{,}6$

$\triangle tGe$: $te^2=118{,}4^2+93{,}6^2-2\cdot 118{,}4\cdot 93{,}6\cdot\cos 46°33'$; $te=86{,}8$

$\triangle tGs$: $ts^2=118{,}4^2+102{,}2^2-2.118{,}4\cdot 102{,}2\cdot\cos 70°12'5$; $ts=127{,}5$

Variant II (Fig. 5 and Fig. 7b):

$tG=BG=2m=118{,}4$ mm $\qquad \delta_{max}=24°$

$tb=2m\sqrt{2}=167{,}4$; $ws=82{,}0$ $\qquad \varphi=43°27'$

It seems correct to have assumed that $R_f = R_h = 2$ m and 2 m is the most probable value of projection since the dimensions obtained by computation do not vary significantly from the measured ones.

It could be seen in Fig. 3 and Fig. 4 that the tip of the gnomon protrudes slightly beyond the space of the receiving surface and is a little above the horizontal plane. This can be accounted for by the repeated restoration cf points O_f, O_h and G during the construction of the sundial face and during the process of engraving the lines and curves of the dial.

Fig. 4. shows that the vertical plane of the cross-section is not perpendicular to the axis of the gnomon but deviates with 3°40′ from it.[35] A single explanation for the cause of that 'annoying' error can be offered: The clock (sundial) had been mounted and fixed onto a one-storey building with wrong orientation. Only after fixing the sundial the following procedures were undertaken to complete the task:

1. The North direction was determined through a method resembling the one

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$\triangle wGs$: $wG = sG = \dfrac{41{,}0}{\cos 66°} = 100{,}8$; $eG = 100{,}8.\sin 66° = 92{,}1$ mm

$\triangle sGb$: $sb^2 = 100{,}8^2 + 118{,}4^2 - 2.100{,}8 \cdot 118{,}4 \cdot \cos 19°27'$; $sb = 40{,}9$

$\triangle tGw$: $tw^2 = 118{,}4^2 + 100{,}8^2 - 2.118{,}4 \cdot 100{,}8 \cdot \cos 22°33'$; $tw = 46{,}2$

$\triangle tGe$: $te^2 = 118{,}4^2 + 92{,}1^2 - 2.118{,}4 \cdot 92{,}1 \cdot \cos 46°33'$; $te = 86{,}6$

$\triangle tGs$: $ts^2 = 118{,}4^2 + 100{,}8^2 - 2.118{,}4 \cdot 100{,}8 \cdot \cos 70°33'$; $ts = 127{,}4$

From the comparison with the results of Variants I and II it is evident that the values of the sun's declination have almost no influence on the elements on the midday line of the sundial.

Variant III (Fig. 5 and Fig. 7c):

$tG = bG = 2m = 118{,}4$ mm $\qquad \delta_{max} = 23°39',5 \qquad ee' = 2{,}0$

$tb = 2m\sqrt{2} = 167{,}4$; $ws = 82{,}0 \qquad \varphi = 42°13',5 \qquad eG = 93{,}6$

$$\sin \measuredangle e'Ge = \frac{2{,}0}{93{,}6}$$

$$\measuredangle e'Ge = 1°13'5$$

$$\varphi' = 43°27' - 1°13',5 = 42°13',5$$

$\triangle sGb$: $sb^2 = 102{,}2^2 + 118{,}4^2 - 2 \cdot 102{,}2.118{,}4 \cdot \cos 18°34'$; $\quad sb = 39{,}0$ mm

$\triangle tGw$: $tw^2 = 118{,}4^2 + 102{,}2^2 - 2 \cdot 118{,}4.102{,}2 \cdot \cos 24°07'$; $\quad tw = 48{,}7$ mm

The dimension obtained for tw excludes any possibility the sundial to have been constructed at a workshop in PAUTALIA ($\varphi = 42°18'$) or in PHILIPPOPOLIS ($\varphi = 42°10'$). No pattern for their geographic lattitudes could have been applied, either, since the curve for the winter solstice remains from 2,1 to 6,2 mm beyond the vicinity of the sunray on the winter solstice – the distance would become even larger if we worked out again the value for wG, resp. for sG. The rays wG = sG would become longer, since by reducing the value for φ the angle α in the formula for the small semi-axis of the elliptic cylinder should be increased by 1°13′,5.

[35] A deviation of the network of lines and curves engraved on the dial face is also visible in the sundial found at Durostorum. The deviation is 3° to the South-East. The azimuth of the Kazanlik tomb, for instance is 4°30′, (measured with a compass) and of the Pomorie tomb it is 4°17′ (worked out by observation of the sun). Thus, it seems that the precise orientation of the network on the sundial face or on any other place of worship was difficult to accomplish.

described by Vitruvius.[36] A vertical gnomon of 2 m height was raised from the middle of the frontal semicricle. A little before noon the position of its shadow point was marked. An arc was traced from the base of the vertical gnomon with radius equal to the distance from the base to the tip of the shadow. Then the diallers carefully watched for that particular moment after midday when the tip of the shadow would coincide again with the traced arc. The second point which had to be symmetrical to the first one was also marked. The axis of symmetry was the direction of astronomic North. The two points were connected by a horde, which was halved, the base of the vertical gnomon was connected to the obtained point by a straight line which was continued until it intersected with the semicircle of the horizontal section at point t. The gnomon hole was cut behind point t.

2. A pattern copy of the projection of the vertical section across the midday line was placed between the base of the vertical gnomon and the groove of the permanent horizontal gnomon; the points w e′ and s were marked at a calibre opening equal to tw te′ and ts; the curves w e′ and s were traced and engraved; then they were divided into 12 parts equal for each curve. The hour-lines were engraved and the pattern of the vertical section was applied again. Any small errors. committed so far were compensated for during the positioning of the metal gnomon. Finally lead was cast into the gnomon hole at its base.

Thus the evident transferrence of the whole network of lines and curves in the direction of the South-East compensates for the error of mounting and fixing the sundial onto a wall or a roof oriented 3°40′ to the North-East. Apparently in this particular case the most important activities of the dial construction – i.e. the tracing and engraving of the network of lines and curves was done only after fixing the sundial at its intended permanent location.

A number of hordes and arrows are listed below. They were used for computing the elements in Fig. 5 and Fig. 7:

detail:	*horde*:	*arrow*:	*radius*:	*theoretical value*:
tb	162 mm	8 mm	414 1 mm	414,3 mm = 7 m
R_f	205	60	117.6	118,4 = 2 m
R_h	80	7	117,8	118,4 = 2 m
R_h	154	30	113,8	118,4 = 2 m
R_h	192	51,5	115,2	118,4 = 2 m
w	80	39,5	40,0	
e′	154	72	77,2	

By analysing the so called day or seasonal curves, the project of the vertical section across the midday line has been deciphered.

Each day at noon a ray of sunlight intersects with the gnomon's point. We get

36 Vitruvius I, 6, 6 - 7.

a fan of sunrays flanked by the winter ray w and the summer ray s, lying in the vertical (meredian) plane across the gnomon, the midday line and the prime vertical of the locality. The crossing point of the equinoctial ray e is often marked on the midday lines of most sundials.[37]

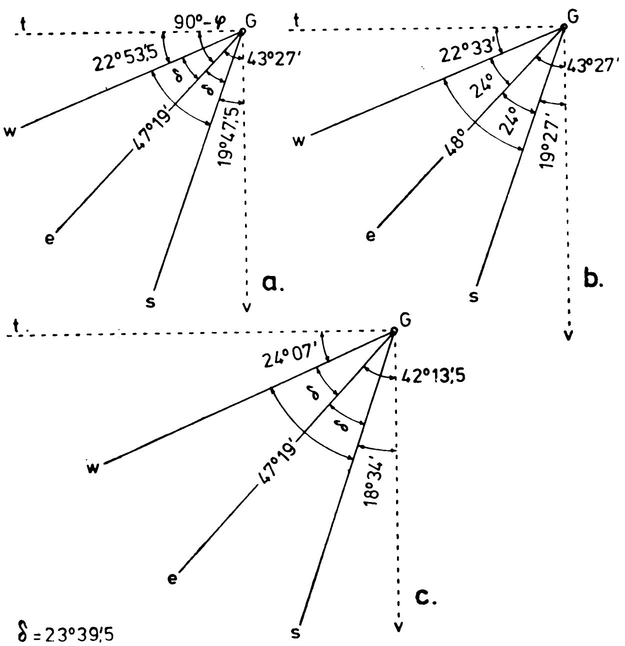

Fig. 7. Examination of the sundial from Montana. Three 5-ray patterns at different δ and φ across the meridian section. Drawing by P. Valev

The midday line between points w and s is parallel to the terrestrial axis and if point e. was supposed to mark the equinox, which at the beginning of the 4th century was on March 21, then we must have we′ = e′s. However, we have we′ = 42 mm, e′s = 40 mm (Table 1), i.e. point e′ marks a day different from March 21 at a positive declination of the sun. From triangle ee′G′ we get for angle eG′e′ : $\operatorname{tg}\delta_{e'} = \frac{2}{1{,}5\text{ m}}$, $\delta_{e'} = 1°17',5$. This declination corresponds to the date of March 24, about the year 325.[38] This was the first day of the cult festivities, dedicated to MAGNA MATER.

[37] The declination of the sun undergoes its fastest change at the point which is the closest to the equinoxes (March. 21 and Sept. 23). The shortening and lengthening of the gnomon's shadow around these days is visible, easy to compute and mark down, despite the relatively small dimensions of the sundial faces.

[38] *Astronomičeski kalendar* [*Astronomic Calendar*], Sofija 1978, p. 15.

Table 1

Some linear dimensions of the sundial from REGIO MONTANENSIUM (in mm)

De-tails	Measured by: GA	Measured by: PV midday line	Measured by: PV - EG arithm. mean	Measured by: PV - EG midday line	Arithmetical mean: arithm. mean	Arithmetical mean: midday line	Theor.	Decimal fractions from the module m
1	2	3	4		5		6	7
H	290	290,0	288,5	285,0	288,4		295,9	5 m
W_{max}	140	160,0			150,0		148,0	2,5 m
Db_{max}	285	280,0	290,0		285,0		295,9	5 m
Db_{min}	180		184,0		182,0		177,5	3 m
H_{sd}	150			145,0	147,5		148,0	2,5 m
D_{sd}	250							
bb′	27	30,0		30,0	29,0		29,6	0,5 m
R_f	(120)			117,6			118,4	2 m
R_h	(110)			115,2			118,4	2 m
r_w		42,0	(38,6)	40,0	41,0			
r_e'		83,0	(73,7)	77,2	79,4			
r_s		122,0	(102,0)	125,0	123,5			
tw		42,0		43,0	42,5			
tb		164,0	(164,6)	162,0	163,0			
we′		42,0	(42,4)	42,0	42,0			
ws		82,0	(82,3)	82,0	82,0			
wb					121,5			
e′s		40,0	(41,9)	40,0	40,0			
sb		40,0	(42,2)	39,0	39,5			
w		9,0	10,1	9,25	10,1	9,1		
e′		19,0	19,3	19,5	19,3	19,2		
s		26,5	26,7	28,5	26,7	27,5		
b			33,2	34,0	33,2	34,0		

NOTES: GA = G. Alexandrov; PV = P. Valev; PV – EG = P. Valev-E. Georgiev. The results in parenthesis were not taken into consideration for the arithmetic mean.

Assuming the sundial had been constructed around the year 200 A. D., the date would be March 25.[39]

On March 25 was the day of HILARIA. Besides,
On March 26 was Reguietio,[40]
On March 27 was Lavatio
On March 28 – precise name of the festivity unknown, but still connected with MAGNA MATER.

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[39] P. Herz, *Untersuchungen zum Festkalendar der Römischen Kaiserzeit nach datierten Weih- und Ehreninschriften*, I, Mainz 1975, p. 91.

[40] This festivity was introduced at the end of the 2nd century A. D. cf. ibid., p. 168; II, p. 479.

Table 2

Comparison of the directly measured details (in mm) of the sundial from Montana with the theoretically obtained ones

Details	Directly measured data	Computed (theoret., project) data		
		$\varphi=43°27'$		$\varphi=42°13',5$
		$\delta=\pm23°39',5$	$\delta=\pm24°$	$\delta=\pm23°39',5$
1	2	3	4	5
tw	42,5	46,6	46,2	48,7
te′	85,4	86,8	86,6	
ts	125,0	127,5	127,4	
tb	163,0	167,4	167,4	
we′	42,0			
ws	82,0			
wb	121,5			
e′s	40,0			
e′b	79,5			
sb	39,5	41,1	40,9	39,0
wG=sG		102,2	100,8	
e′G		93,6	92,1	
$tG=R_f$	117,6	118,4	118,4	118,4
$bG=R_h$	115,2	118,4	118,4	118,4

It seems perfectly natural for the inhabitants of a villa rustica to celebrate the supreme Phrygian goddess KYBELE, a symbol of Mother Nature, and possibly together with her spouse the God ATTIS – a symbol of the death and rebirth of Nature. March 25 was the day of the rebirth of Attis.[41]

According to G. Alexandrov the construction of the Ancient Villa No 2 where the sundial was found must be dated back to the period between the 2nd and 3d centuries A.D.[42] A number of coincidences, however, bear more illuminating evidence on this point. P. Herz supposes that the celebration of HILARIA (on March 25) was introduced by Antonius pius (138 - 161 A.D.).[43] One could add that this feast is in direct relation to the emperor's birthday – Sept. 19.[44] And moreover, Montana

[41] KBE [A Short Bulgarian Encyclopedia], I, 1963, p. 142: KBE 3, 1966, p. 19; Herz. o.c., p. 478.

[42] Aleksandrov, o.c., p. 38.

[43] Herz. o.c., I, p. 165.

[44] This conclusion was suggested by the fact that the declinations of the sun on March 25 and on Sept. 19 about the middle of the 2nd century A. D. were almost equal:

δMarch 24, in the year 325 = δMarch 25, in the year 161 = $+1°21'$ (HILARIA)

δSept. 19, in the year 161 = δSept. 20, in the year 325 = $+1°09'$, i.e.

δMarch 25. 161 = δSept 19, 161 A. D.

Antonius Pius (July 10, 138 – March 7, 161) was born on Sept. 19, in the year 86 A. D. in Lanuvium. The introduction of a festivity on a day, which is symmetrical to another day by the solstice is not an isolated case. This was probably a religious ceremony (although not obliga received its municipal rights in 161 A.D. – evidence that the growth of the city brought some qualitative changes. These facts, coupled with the deliberate marking of the date of March 25 on the shadow receiving surface of the sundial point to the conclusion that this particular time keeping device was constructed during the time of the villa construction work – some time before 161 A.D.

Three Latin inscriptions on marble tomb stones were found in Mausoleum No 1. By paleographic features they were dated back to the period between the 2nd and 3d centuries A.D. One of the inscriptions is about a liberated slave by the name of Anicetus, who had probably come from Asia Minor and had later become the steward of the mansion.[45] It seems plausible to assume that the festivities introduced by Antonius Pius and dedicated to the God ATTIS were most gladly accepted by the Asian steward and coded on the dial face.

In order to be consistent with the point of research, however, it should be mentioned that in the internal roofed yard (the cavedium) of the larger house in the middle of the southern wall a marble ara was found with a Latin inscription on it. It had been used as an altar to the God Silvanus, worshipped in the region of Montana.[46] The exactly dated Latin inscriptions, bearing the precise days of feasts, dedicated to Silvanus are quite regularly spread within a calendrical year:

Jan.	Feb.	March	Apr.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
8	–	3	3	1	4	2	3	4	2	–	–

One inscription with an exact dating is known from the lst century A.D., 21 from the 2nd and 7 from the 3rd century. Three inscriptions originate from Moesia Inferior – from 144, 178 and 191 A.D. Two or more inscriptions exist for the following dates: 4 for Jan. 13, 2 for Aug. 1 and 2 for Sept. 19. The last two inscriptions are from Rome (Sept. 19 152 A.D.) and Bonna (Germ. inf.; Sept. 19 190 A.D.).[47]

Taking these statistic data into consideration we are led to the conclusion that the worship of Silvanus became popular mainly during the 2nd century and at that time it must have spread over the region of Montana, too. Moreover that cult did not have a fixed data for celebration.

G. Alexandrov's conclusion that Silvanus was worshipped as a home deity at the Ancient Villa No 2 near Montana[48] neither contradicts nor excludes the hypothesized celebration of the God ATTIS, designated on the dial face. The identifica-

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tory!) which originated from Egypt and has been preserved even in the Christian calender. Naturally, the hypothesis, presented in the paper will be thoroughly studied and verified mainly by collecting the necessary facts.

[45] Aleksandrov, *Antična vila No 2 kraj Montana* [*Ancient Villa No 2 near Montana*], p. 47, 56 - 57.

[46] Ibidem, p. 14; G. Aleksandrov, *Latinski nadpisi ot Montana* [*Latin Inscriptions from Montana*], Vekove 5, 1977, p. 54, fig. 4.

[47] Herz, o.c., p. 273.

[48] Aleksandrov, *Antična vila No 2* (*Ancient villa No 2*], p. 14, 17, 56 - 57.

tion of the ancient Roman god Silvanus with the Greek Pan and the Phrygian Attis is a result of the tendencies for syncretism, characteristic of the pre-Christian era.

The paper is an attempt for the first time to make a complete inventory of all the ancient sundials found in the Thracian lands of present-day Bulgaria. The detailed study of the specimen found at Montana was not only phocused on the methods of construction, but on the significance of the date of March 25 marked on the shadow-receiving surface of the dial, as well. This is a date, which throws considerable light and brings into relief the spiritual atmosphere, in which the inhabitants of the ancient mansion used to live.