George Bevan – Daryn Lehoux – Richard Talbert

Reflectance Transformation Imaging of a 'Byzantine' Portable Sundial

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REFLECTANCE TRANSFORMATION IMAGING OF A 'BYZANTINE' PORTABLE SUNDIAL

The British Museum's Department of Medieval and Modern Europe acquired a portable bronze sundial of obscure provenance in 1997, which was published six years later by Silke Ackermann.[1] Because it was meant to be portable, the dial is only 110 mm (approx. 4 ¼ inches) in diameter. It is inscribed radially on its reverse with a list of 36 place names and their latitudes, arranged by order of latitude. The front face has one quadrant divided into latitude degrees (in three-degree increments), and includes a calendrical scale in the Julian calendar. To use the dial, one would have aligned the front face vertically according to the degree-value for one's current latitude (as read from the place-name list on the reverse), and then aligned the gnomon (no longer extant) according to the calendrical inscription.

Ackermann's *editio princeps* of the sundial was no mean accomplishment given the small size and current state of the instrument's reverse face. The accretion of bronze corrosion products has significantly reduced readability and makes the accurate photographic reproduction of the object nearly impossible. First-hand inspection of the object with raking light was hitherto the best way to make out many of the names and numbers. The present study republishes the sundial with new readings derived from the use of Reflectance Transformation Imaging, a relatively new and inexpensive technology with significant implications for the study of ancient inscribed materials.[2] A team of three, two of whom were students, were given permission to photograph both sides of the sundial for RTI on 22 February 2012 under the supervision of Dr. Louise Devoy, the then-curator of European and Islamic Scientific Instruments in the Department of Prehistory and Europe.[3]

Reflectance Transformation Imaging (RTI) was first developed by Hewlett-Packard Labs in 2000/2001 by Tom Malzbender in the form of Polynomial Texture Mapping.[4] The technology saw rapid adoption by epigraphers working in cuneiform, and increasing adoption within archaeology and art conservation.[5] In a nutshell, the object of interest is photographed using a standard digital single-lens reflex camera anywhere from 15 to 60 times, with the light placed in a different position along a notional hemisphere for each shot. A black sphere placed adjacent to the object has a highlight cast on its surface by the flash in each instance: a small, bright speck that allows the software to calculate the direction of light for each shot. This data allows the RTI builder to construct a composite image that can be dynamically relighted, and the 3D features of the surface are then enhanced by a number of filters. This technique has very considerable advantages for the epigrapher. First, the software to build and view RTIs is free. Second, when compared to other forms of 3D scanning, the file sizes are quite small (<200mb) and can easily be shared. Third, and most importantly for our present purposes, the combination of relighting, zoom, and filtering in RTI can in many cases render otherwise illegible text partly or wholly legible.

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1 Ackermann 2003.

2 See Bevan and Lehoux, forthcoming, on a simplified and reliable workflow for producing RTI images in field and museum conditions.

3 The authors would like to thank Cat Machado (Queen's University) and Fraser Reed (University of Edinburgh) for their assistance in completing the RTI at the BM. Permission for the photography was given by the Scientific Dept. and the Keeper at the BM.

4 Malzbender et al. 2001. The technique has seen very considerable advancement in the hands of Cultural Heritage Imaging, a non-profit corporation, in San Francisco, California: culturalheritageimaging.org. The latest RTI Viewer and Builder are available for free download thanks to the efforts of CHI and their collaborators.

5 Earl et al. 2010a, 2010b and 2011.

New edition of the dial’s latitude face

	RTI		Ackermann	
	Μ̲ΕΡ$^{\underline{\mathrm{O}}}$ΗΣ	Ις	---ΗΣ-	
	ΣΟΗΝΗΣ	ΚΔ̲	ΣΟΗΝΗΣ	ΚΔ
	Θ̲Η̲ΒΑΤΔ̲	ΚΔ	ΘΗΒΑ[ΙΔΟΣ]	ΚΔ
	ΛΙ̲ΒΥΗΣ	ΚΔ	ΛΙΒΥ[ΗΣ]	ΚΔ
	ΑΙΓΠΤΟΥ	ΛΑ	ΑΙΓΠΤΟΥ	ΛΑ
	ΑΛΕΞΑΝ̲Δ	ΛΑ	ΑΛΕΞΑΝΔ	ΛΑ
	ΠΑΛΑΙΣΤ	ΛΒ	ΠΑΛΑΙΣΤ	ΛΒ
6:00	ΠΕΝΤΑΠ	ΛΒ	ΠΕΝΤΑΠ	ΛΒ
	ΑΦΡΙΚΗ̲	ΛΔ	ΑΦΡΙΚΗ	ΛΔ
	ΚΡΗΤΗΣ	ΛΔ	[ΚΡ]ΗΤΗΣ	ΛΔ
	ΚΥΠΡΟΥ	ΛΕ	ΚΥΠΡΟΥ	ΛΕ
	ΚΟΥΛΗΣ	Λς	ΚΟΥΛΗΣ	Λς
	ΣΙΚΕ̲Λ[Ι]Α	Λς	ΣΙΚΕ[ΛΙΑΣ]	Λς
	ΠΑΜΦΥΛ	Λς	ΠΑΜ[ΦΥΛΙΑ]	[...]
	ΑΧΑΕ̲Ι̲ΑΣ	ΛΖ	ΑΧΑΕΙΑΣ	ΛΖ
	ΤΑΡΣΟΥΣ̲	ΛΖ	ΤΑΡΣΟ[ΥΣ]	ΛΖ
9:00	ΣΠΑΝΙΑΣ	ΛΗ	ΣΠΑΝΙΑ[Σ]	ΛΗ
	ΑΝΤΙΟΧΟ̲	[Λ]Θ	ΑΝ[ΤΙ]Ο[ΧΙΣ]	ΛΘ
	ΠΕΛ[ΟΠ]Π̲Ο̲	[..]	[...]	[...]
	ΘΕΣΣΑΛΟ	Μ̲[	ΘΕ[ΣΣ]ΑΛΟ	Μ-
	ΡΩΜΗ̲Σ	ΜΑ	[ΡΩΜΑΣ]	ΜΑ
	ΘΡΑΚΗΣ	Μ̲Α	ΘΡΑΚΗ[Σ]	ΜΑ
	ΒΙΘΥΝΙΑ	ΜΑ	ΒΙΘΥΝΙΑΣ	ΜΑ
	ΑΒΥΔΟ̲Σ	ΜΑ	-ΚΥΛΗ-	ΜΑ
	ΔΑΛΜΑΤ	ΜΒ	ΔΑΛΜΑΤ-	ΜΒ
12:00	Κ̲Α̲ΠΠΑ̲Δ	ΜΓ	-ΠΡ-Δ	ΜΓ
	ΙΤ̲Α̲Λ̲ΙΑΣ	ΜΓ	Ι[ΤΑΛ]ΑΣ	ΜΓ
	ΚΩΝΣΤΑ	ΜΓ	ΚΩΝΣΤΑ	ΜΓ
	Γ̲ΑΛΛΙΑΣ	ΜΓ	-Α---	ΜΓ
	ΑΣΙΑ	ΜΓ	Σ-Λ----	ΜΓ
	Ν[Ε]ΟΚΑΙΣ̲Ο̲	ΜΔ	----ΑΓΙΣΟ-	ΜΔ
	ΑΡΜΕ̲Ν[Ι]Α	ΜΔ	ΑΤΙΚΑ--	ΜΔ
	ΣΑ̲[Ρ]Μ[ΑΤΙ]Α	ΜΕ	ΣΠ-----	ΜΕ
	ΠΑΝΝΟΝΙ	ΜΕ	ΠΑΝΝΟΝΙ	ΜΕ
3:00	ΜΕΔΙ̲ΟΛΑΝ	Μς	ΜΕΛ---	Μς
	ΒΡ̲Ε̲ΤΤΑΝ	Ν̲[	ΒΕ----	[...]

Meroe	16
Syene	24
Thebaid	24
Libya	24
Egypt	31
Alexandria	31
Palestine	32
Pentapolis	32
Africa	34

Crete	34
Cyprus	35
Coele (Syria)	36
Sicily	36
Pamphylia	36
Achaia	37
Tarsus	37
Spain	38
Antioch	[3]9
Peloponnese	[..]
Thessalonica	4[
Rome	41
Thrace	41
Bithynia	41
Abydos	41
Dalmatia	42
Cappadocia	43
Italy	43
Constantinople	43
Gaul	43
Asia	43
Neocaesarea	44
Armenia	44
Sarmatia	45
Pannonia	45
Mediolanum	46
Britain	5[

Notes on the edition

Our line numbers differ from Ackermann’s insofar as she counted from her lowest legible latitude (Syene: 24°), whereas we are now able to read one latitude lower than this (Meroe: 16°). We have also included clock-face values to orient our line numbers with the positions of the place names as they appear on the RTI, which we hope to publish online.

The list of place names and latitudes on the dial proves exceptionally hard to read due to corrosion and wear. Corrosion is particularly bad from about line 24 through to line 1 (from Abydos through to Britain and then Meroe, which because of the circular nature of the dial are sequential). Using RTI, and the underlying algorithms of Polynomial Texture Mapping (PTM) and Hemispherical Harmonics (HSH),[6] it has been possible to improve considerably on Ackermann’s (very good) naked-eye edition, particularly through this damaged area. As is often the case, we have relied most heavily on specular enhancement within the RTI viewer, a filter that can completely eliminate distracting colour and give a high-contrast rendering of only physical surface variation.[7] The inscription is thus made to look as though it were incised into chrome, and even minute surface details, largely obscured to the naked eye, become visible. Nevertheless, the default rendering in the RTI viewer (essentially a colour photograph with a moveable light source) has also been very useful: the A in Abydos is a particularly good example of its application (see figure 1).

[6] Described in Mudge et al. 2008.

[7] For discussion of this filter and others for weathered and damaged surfaces, see, e.g., Mudge et al. 2005, 2006 and Rabinowitz et al. 2010; for a striking use of specular enhancement on the corroded bronze inscription of the Antikythera Mechanism, see Freeth et al. 2006.

Diffuse gain, a rendering filter which amplifies changes in slope on the three-dimensional model, was also used frequently. We cross-referenced all our readings between a PTM rendering and a HSH rendering of each face. We have provided some sample photographs taken from the RTI's (figures 1–8), although it must be said that the ability to move the light source around in the RTI viewer makes virtually all readings much clearer in the actual viewer than these still images can portray them.[8]

We note that there are a handful of spelling errors in the place names on the dial. The missing upsilon in Αἰγ⟨ύ⟩πτου (line 5) was noted by Ackermann, and we can add the tau in place of iota in what should be Θηβαίδος at line 3 (see figure 2). We also note what appears to be a correction in line 1, the addition of the small superscripted O in Μερόης.

We have found three latitudes that were previously unreadable: 16° for Meroe (see figure 5), 36° for Pamphylia, and 50° or higher (if there was originally a second digit after the N) for Britain.

One should note that Ackermann did not mark as uncertain any letters in her edition, and so it is difficult to know how confident she was of any given reading. We have chosen to underscore any letter that could bear more than one reading, even when the place name is otherwise certain (as the N in Alexandria at line 6, for example). In many lines, particularly from Bithynia around to Syene (lines 23 through to 2), RTI has revealed considerably more text than is clear to the naked eye. Excepting this particularly damaged section, however, there are very few cases where Ackermann reported a letter that we now disagree with. A few comments on the most prominent of these, however, may be in order.

At line 32, we read APMEN[I]A for Ackermann's ATIKA--. That she saw the descender and the top line of the rho as a partial T seems clear. We believe that she also saw the left-hand descender of the M as standing alone, and thus as an iota, and that she then combined the right-hand descender of the M with the lunate body of the E to form an apparent K. Her final A would then have been the two leftmost strokes of the N with no crossbar apparent. At line 26, she read –ΠP-Δ for our KAΠΠAΔ. It is difficult to know from her edition how many missing letters she supposes at the beginning of her word, but we believe she was seeing the second Π as a P, a plausible reading under some lights, though we are now confident that it is in fact a Π (see figure 3).

In two place names there seem to be omicron endings where they do not properly belong (ANTIOXO and N[E]OKAIΣO, lines 18 and 31). In both cases the traces are very faint, and we therefore underscore them as uncertain here.

Commentary

During the decade since Ackermann's publication of this sundial in 2003, further examples of more or less similar objects have surfaced,[9] and an initiative has been launched to analyze the place names and their associated latitude figures for the insight they can provide into contemporaries' geographical thinking and worldview.[10] In view of such ongoing activity,[11] it is appropriate that this presentation for the most part confines itself to concise appreciation of the significance of those place names and associated latitude figures on the British Museum sundial newly revealed by use of RTI.

Four of the new place names appear for the first time on any portable sundial known to date.[12] Each in its own way is a notable choice on the part of whoever drew up the list of 36 place names (the highest known total, matched only by the Memphis sundial).

[8] The problem is exactly analogous to the traditional publication of a single photograph in place of the epigrapher's actual moving light source – the former can never quite capture the dynamics and quality of the latter.

[9] See Hoët-van Cauwenberghe, Binet, and Thuet 2008; Hoët-van Cauwenberghe and Scholz 2013.

[10] Note especially Talbert 2010. With Eva Winter, Talbert also has a book-length study in preparation provisionally entitled *The World Reflected in Roman Sundials: Space, Culture, and Imagination*.

[11] Note the exhibition record *Le Temps des Romains: Perception, Mesure et Instruments* (Amiens: Musée de Picardie, 2012), and two works in preparation: Bonnin (forthcoming); and Winter (forthcoming).

[12] See Ackermann's table (p. 18) and bibliography. She overlooked two further Latin examples. The first, unearthed at Berteaucourt-les-Dames/Vignacourt and briefly published by Massy 1985, is re-examined by Hoët-van Cauwenberghe 2013. The second, a random find, was published by Arce 1997 [reprinted in Arce 2002, p. 215–26].

In itself Peloponnese is hardly a surprising choice, but still it might not be expected here when Achaia latitude 37 is also included. Moreover, the latitude figure – missing, but presumably 39, 40 or 41, to judge by the placement of the name in the list – appears rather high. Ptolemy's figure (*Geog.* 3.16.5) for the latitude of Rhion Akron (*Barrington Atlas* 58 B1), almost the most northerly point of the Peloponnese, is 37 10, and the actual latitude is approximately 38 20.[13] Peloponnese and Pentapolis stand out here as the only two regions within the Roman empire chosen for inclusion whose names reflect a sense of geography rather than awareness of Roman province names.

Mediolanum, too, is not a surprising choice in itself, but it is notable as the first attested occurrence of this Late Antique capital on portable sundials (*BAtlas* 39 E3); and in this list – with its token coverage of the Western empire – it is the only city west of Rome chosen for inclusion. The latitude figure 46 compares well with the correct 45 30.[14] A fraction of a degree could in any case not be reflected in view of the evident decision to limit all the latitude figures here to whole numbers (whereas fractions are recorded on several other portable sundials).

The choice of Abydos (*BAtlas* 51 G4) reinforces the marked attention to Asia Minor that the list demonstrates, and the latitude figure 41 compares well enough with the correct 40 20.[15] This is another choice that reflects a sense of geography. Abydos was best known as a crossing-point from Asia to Europe where the Hellespont is at its narrowest.[16] For that reason no doubt, Abydos was chosen for inclusion here, evidently in preference to any of the great cities of western Asia Minor such as appear on the Samos sundial: Chalcedon, Cyzicus, Ephesus, Laodicea, Miletus, Nicaea, Nicomedia.[17]

In fact it would seem that only two cities in Asia Minor appear in the British Museum sundial's list. The first, Antioch, may reasonably be reckoned as Antioch in Pisidia (*BAtlas* 62 F5) from its associated latitude figure 39 (actual latitude 38 20).[18] The second, Neocaesarea, may be considered by no means an obvious choice. That a city of this name in Asia Minor is meant cannot be taken for granted, to be sure, but its occurrence in the list between Asia and Armenia increases the likelihood, and the only known Neocaesarea elsewhere (in Syria) is improbable.[19] Of the two known cities in Asia Minor so named, the one that was *metropolis* of Pontus Polemoniacus[20] (actual latitude 40 30) might be more readily expected. The other is not attested before Late Antiquity, and remains unlocated somewhere between Daskylion (52 D4) and Hadrianoi (62 A2).[21] Even so, this unlocated Neocaesarea cannot be ruled out; it must have been situated approximately between latitude 40 00 and 40 30. Irrespective of which Neocaesarea in Asia Minor is meant, therefore, the sundial's associated latitude figure 44 is puzzlingly high, and it can hardly be an engraver's error when preceded by Asia 43 and followed by Armenia 44. Ptolemy's figure of 41 50 for Neocaesarea in Pontus (*Geog.* 5.6.10), while likewise high, is nowhere near so extreme.

Three of the place names already read by Ackermann might also be thought to appear for the first time on any portable sundial known to date, but in each instance that perception must be qualified. First, the self-standing Κούλης (= Coele, for Coele Syria) is indeed unique, but Syria appears on four other sundials, and Phoenice (also self-standing) on yet another.[22] Second, although Achaia latitude 37 – already mentioned

[13] n. b. All 'actual' latitudes stated are to be regarded as rounded approximations. For Ptolemy's latitude figures, I follow the edition of the *Geography* by Stückelberger and Grasshoff 2006.

[14] Ptolemy's figure is 44 15 (*Geog.* 3.1.33).

[15] Ptolemy's figure is 41 15 (*Geog.* 5.2.3). The sundial's same figure 41 for the latitude of Thrace appears low, however.

[16] Abydos is not included in Ptolemy's *Canon Urbium Insignium*, although Sestos on the opposite shore of the Hellespont is (9.6, p. 168 in Stückelberger and Mittenhuber 2009).

[17] See Tölle 1969; Schaldach and Feustel 2012. Observe that this sundial in turn omits Smyrna.

[18] Ackermann 2003, p. 20, assumes without discussion that Syrian Antioch (*BAtlas* 67 C4; actual latitude 36 10) is meant, but the inclusion of Coele (Syria) latitude 36 earlier in the list serves to suggest otherwise.

[19] See *BAtlas* 68 F2 (Athis/Neocaesarea), and *Brill's New Pauly* (2006), s.v. Neocaesarea.

[20] Kabeira/Neocaesarea/Diospolis/Sebaste/Hadriane, modern Niksar (*BAtlas* 87 B4). It, too, is not included in Ptolemy's *Canon Urbium Insignium* (Stückelberger and Mittenhuber 2009).

[21] *BAtlas Directory*, p. 970.

[22] See Talbert 2010, p. 266.

above in connection with Peloponnese – is also unique on a portable sundial, the name does occur (without latitude figure) in the 'pillbox' type of portable sundial held by the Kunsthistorisches Museum, Vienna.[23] Third, Libya latitude 24 might be considered unique, but it is fact now matched by Libya (with latitude that may fairly be reckoned as 23) on the sundial from the Balkans awaiting publication.[24] Both 23 and 24 are very low latitude figures.[25] Thus in the case of the British Museum sundial, where the regional names Thebaid, Egypt, Pentapolis and Africa are also listed, 'Libya' is perhaps intended to signify very generally the interior of the African continent west of Egypt.

Three observations in conclusion: first, it is evident that overall – for whatever reason – there is substantial variation in the accuracy of the latitude figures associated with the names chosen for inclusion on the British Museum sundial, even when allowance is made for the need to limit a region or province with an extensive north-south dimension to just a single figure. Second, whether it is justifiable to regard Neocaesarea as so distinctive a choice for inclusion that the compiler of the list can be thought to have lived there, or to have forged some special link with the city, could fairly be matter for speculation. Third, despite the valuable contribution that the new readings achieved by RTI make to our appreciation of other aspects, they still hardly enable us to refine Ackermann's cautious dating of the sundial "between the fourth and seventh centuries" (p. 21). Inclusion of Constantinople among the names rules out any date earlier than the fourth century. No doubt it becomes increasingly unlikely that a list compiled sometime after that century would include Britain in particular. However, the names on a sundial made later than the fourth century could still be those of a list drawn up earlier, which – either deliberately or out of lack of concern – underwent little or no revision.

Figure 1. Abydos (line 24), specular enhanced PTM still with default view superimposed (upper left); light slightly north-west of centre

Figure 2. Thebaid (line 3), specular enhanced PTM still, with light very slightly west of overhead

23 See Talbert 2010, p. 269.

24 Hoët-van Cauwenberghe and Scholz 2013, with thanks to the former for so generously sharing this information.

25 For comparison, Syene (*BAtlas* 81 C1) and Berenice (*BAtlas* 81 F2) at the far south of Roman Egypt are both at approximately latitude 24 00.

Figure 3. Cappadocia (line 26), diffuse gain PTM still, with light slightly south of centre

Figure 4. Mediolanum (line 35), diffuse gain PTM still, with light west of centre

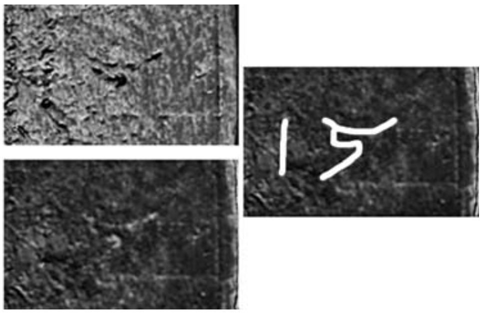

Figure 5. 16° latitude value of Meroe (line 1), specular enhanced and diffuse gain PTM still, with light north of centre, contrast enhanced

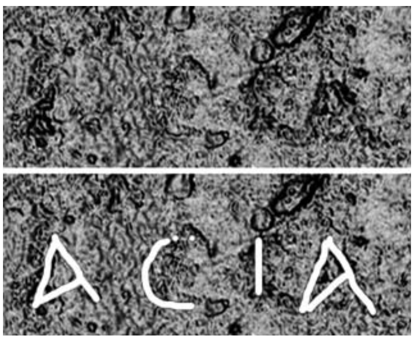

Figure 6. Asia (line 30), specular enhanced PTM still, with light north-west of centre

Figure 7. Rome (line 21), diffuse gain PTM still, with light west-north-west of centre, contrast enhanced

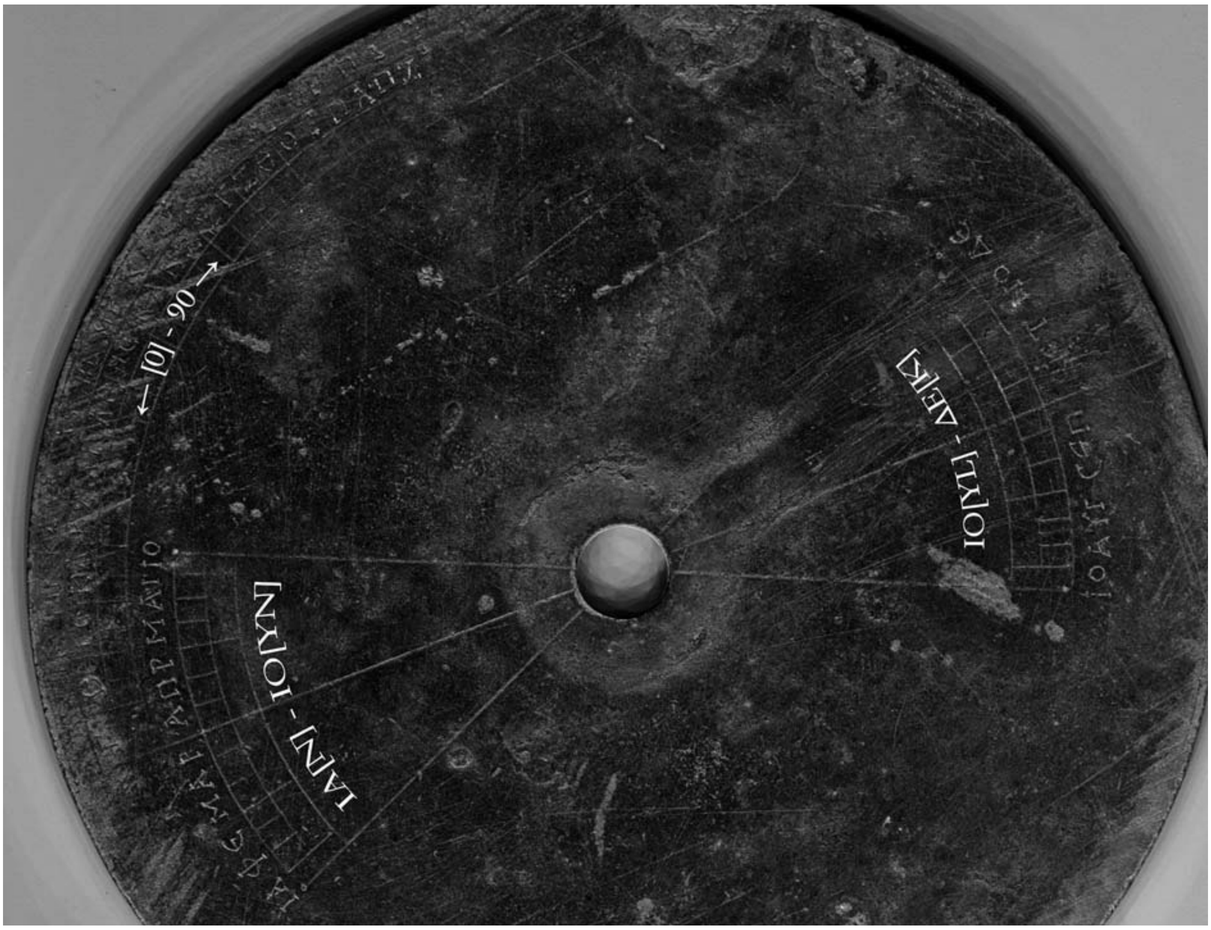

Figure 8. The front face of the dial under visible light, labelled

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George Bevan, Queen's University, Department of Classics
bevan@queensu.ca

Daryn Lehoux, Queen's University, Department of Classics
lehoux@queensu.ca

Richard Talbert, The University of North Carolina at Chapel Hill, Department of History
talbert@email.unc.edu