REPORT ON THE GREEK DIAL FROM DELOS STORED IN THE LOUVRE (Ma 4823)

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In June 2012, John Davis asked if it was possible to identify and find two dials drawn by C.R. Cockerell in 1810. The conclusion of this enquiry was published in the September 2012 *Bulletin*.[1] The aim of this second paper is to provide up-to-date information about the Delos dial which is stored in the Louvre. On 5 September, thanks to the valuable help provided by Ludovic Laugier, we were able to study this very special dial in detail. Jérôme Bonnin carried out the historical research work and Denis Savoie made the mathematical study.

History of a (Re)Discovery

This dial is the only one from Delos not conserved *in situ*. In all likelihood, as C.R. Cockerell drew it in 1810, the time of the discovery of this instrument can undoubtedly be set at this year. The dial remained on the island after Cockerell's departure. In 1811 or 1812, a Capuchin monk called P. Urbain and living in Mykonos gave the instrument he had found "amongst the ruins of Delos" to a French architect, A.-F. Mauduit (1778-1854).[2] After that, Mauduit brought the sundial to France and asked the astronomer J.-B.-J. Delambre to study it. Delambre produced three similar articles on the object.[3] Then, Mauduit gave it to the 'Cabinet des médailles' in Paris[4] where the dial was displayed in the 'salle du zodiaque'. In 1929, the dial was given to the Louvre, where it is still stored to this day, in the storage rooms to be precise, under the inventory number MND 1580 / Ma 4823.

This is not the place to present a complete description of the dial. Delambre gave a very good account two centuries ago in the introductions to his studies. Those studies can be found nowadays on the internet free of charge. Nevertheless, we would like to communicate considerations about the original setting of the dial and additional information about the object itself.

The Temple of Apollo at Delos

The information about the real location of the discovery of the dial is not very precise. Cockerell's drawing shows that the dial was no longer in its original environment when it was discovered. It was reused, probably in late Antiquity, inside a sort of dry-masonry construction. But according to Cockerell and Mauduit, it can be assumed that it was dug up not far away from the 'Temple of Apollo'. Nowadays, this term is used for three temples found inside the sanctuary of Apollo. But in 1810, it could only be the 'Great Temple', the peripteral hexastyle temple built between 475 BC and the 1st century BC. For some unknown reason the

Fig. 2. Close-up of the hour lines and gnomon hole.

Fig. 1. The Delos dial, photographed in The Louvre.

temple was never finished. What the link was between the instrument and the Temple, or even if this link ever existed, are questions which we cannot answer. But we can present an hypothesis based on other cases of sundials found inside sanctuaries, near Temples of Apollo. Indeed, sundials are quite often linked with Apollo (or other Gods) in Antiquity. Here are two examples among many others: (a) the British Museum holds a miniature dial found inside the Temple of Apollo of Naucratis, Egypt (inv. n° 1909 2-16 10); (b) in front of Apollo's Temple of Pompeii, a sundial was displayed on a column. Unfortunately, the reason why sundials were placed inside sanctuaries is not totally understood. Undoubtedly, the link between Apollo and the Sun is of importance. But the question is whether the dial had a defined function for the cult ceremonies or whether its function was solely that of a timepiece for passers-by.

Additional Information on the Sundial

The instrument is in an average state of preservation (Fig. 1). The base of the dial is the only damaged part. The cylindrical gnomon is missing. Traces of red pigment are visible along the hour and calendar lines (Fig. 2). These seem to be rather modern (maybe from the 19th century). The marble disc is 56 cm in diameter. It is nearly circular and has a rectangular foot at its base. The centre of the instrument still has the remains of the hole used by the craftsman to draw the circular shape of the dial. On the upper part of the circular surface of the dial, above the gnomon hole, we have noticed some graffiti. It seems to be inscribed in Greek '(ρ)ολ(ο?)' or 'Pol(o)' in Latin. This inscription is modern (19th century) and does not date back to Antiquity. The word 'polos' in Latin (or in Greek 'πόλος', not 'ρόλος') was indeed used in the 19th century and even the beginning of the 20th century in order to design any type of sundial. Two barely visible small marks on the horizon line could be the remains of a construction guide for the craftsman. The back of the stone is plain, without any inscription or trace of another dial. It just shows three circular holes, one being the end of the gnomon hole of the dial, the other two being the remains of a fixing device to a vertical surface (a wall most probably). To conclude with the shape of the dial, it belongs to a very rare typology with only one other example, from Grottaferrata. It could be the *discus in planitia* mentioned by Vitruvius.

Gnomonic Study (Denis Savoie)

It is a vertical sundial that functions when oriented exactly towards the East. It is thus a vertical oriental sundial, operational in the morning, from sunrise until approximately the sun's passage into the sundial plane, *i.e.*, before solar noon.

The five hour lines are not labelled; the indicated time is in temporal hours [seasonal or temporary]. The sundial possesses two arcs for the solstices (the lower one for the summer solstice, the upper one for the winter solstice) and a line for the equinoxes. The straight stylus, *i.e.*, the horizontal gnomon (perpendicular to the plane of the sundial) that casts a shadow on the sundial and whose tip alone gives the time (and date), is set at the intersection between the equinoctial line and the horizontal straight line (which corresponds to the moment of sunrise). One can notice a very tiny offset between the setup hole and the equinoctial line.

To determine the latitude for which this sundial is intended, one has to measure the angle between the equinoctial straight line and the horizontal line passing by the base of the gnomon. This angle is equal to $(90° − \phi)$, where ϕ is the latitude. Several measurements[5] give an angle of 59° with an uncertainty of 0.5°, and thus a latitude of 31° ± 0.5°. Note: the true latitude of Delos is 37° 23′ while Alexandria is at 31°. There is thus a difference in latitude of at least 6°.

On the equinoctial line, one has to measure the distance r between the hour line and the point at which the gnomon is set. This gives the length a of the gnomon through the trigonometric relation: $a = r \tan H$, where H is the equinoctial hour angle ($H = 15°$ for hour line 1, 30° for hour line 2, etc.).

For H = 15°, we measure r = 9.2 cm and thus a = 2.5 cm.

For H = 30°, we measure r = 4.3 cm and thus a = 2.5 cm.

For H = 45°, we can measure directly a = 2.6 cm.

For H = 60°, we measure r = 1.5 cm and thus a = 2.6 cm.

Note that a 1 millimetre error (due to measurement error, to the thickness of the engraved line and/or to the slight eccentricity of the hole) translates into an error of ±1 mm in the length of the gnomon. The values seem closer to 2.6 cm when estimating the sundial in a modern way.

Assuming an obliquity of the ecliptic of 24° (in the second century BC, its exact value was 23° 43′), modern calcula-
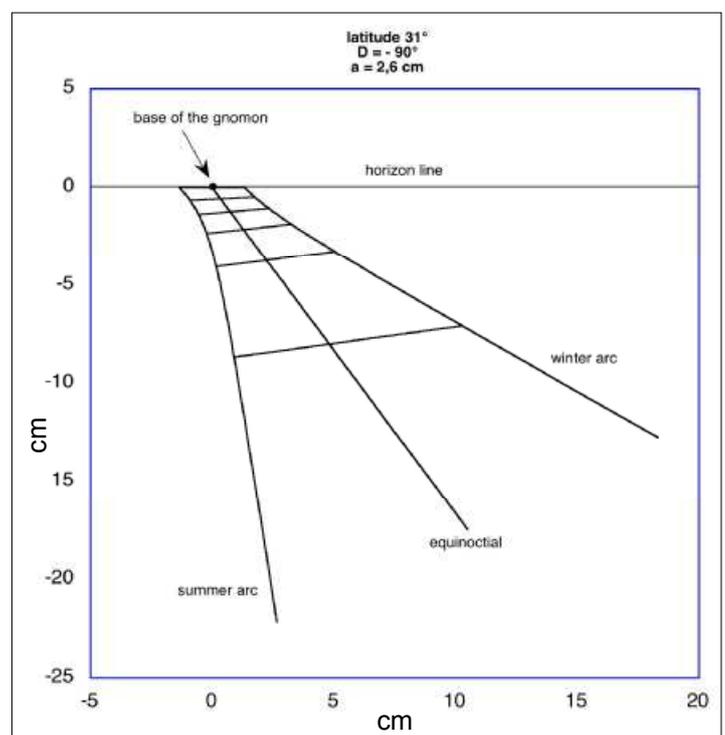

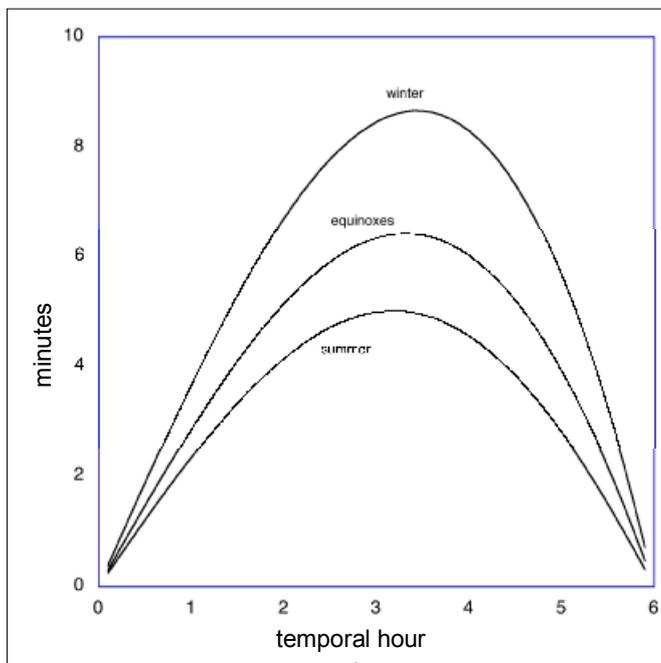*Fig. 3. Sketch of the Delos dial as it would have originally been delineated.*

Fig. 4. Error in the hour reading due to the displacement in latitude.

tion[6] (with parameters $\phi = 31°$, $a = 2.6$ cm) shows that the summer hyperbolic arc is very accurately estimated in its upper part, that is from the horizon line up to temporal line 5. But then it goes down too abruptly, going as far as crossing again the vertical, passing the setup point, which is not normal. The temporal hour lines between the summer arc and the equinoctial line are fully accurate.

By contrast, the hyperbolic winter arc is totally erroneous; its distance to the equinoctial line is much too large. In addition, one can notice a pronounced break in the autumn-winter hour lines on the equinoctial; it is not only the arc that is erroneous, but also the lines are too steeply inclined and should be in the continuation of the spring-summer lines.

We note that the sundial's displacement in latitude (intended for a 31° latitude but set up at a latitude of 37° 23′) results in a maximum error of 9 minutes in temporal hour (in absolute value) during winter (Figs 3 & 4). As a matter of fact, the most blatant error (which must have been clearly visible) was that the extremity of the gnomon's shadow would not fall on the arcs of the solstices and on the equinoctial straight line at the correct date.

Conclusion

To conclude, we could say that, in many respects, this sundial is exceptional. First of all, the typology, place and circumstance of its discovery are quite uncommon. This sundial, despite its surprising computation, belongs to the very small number of Greek dials from Delos. We are also very lucky to have Cockerell's drawing and a modern mathematical study of it. Sundials with such well-documented and complete study are very rare. There still remain a few puzzling questions about it (in particular, its original location, the reason for its creation and the method of its con-

struction). That is not the case for the other sundial drawn by Cockerell.[1] Searches carried out at the Kia/Ceos Museum were unsuccessful since the curator told us that no dials or fragments of dials were stored in the museum. This work has to be pursued in order to locate it.

REFERENCES

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6. D. Savoie: 'La Gnomonique', *Les Belles Lettres*, Paris, 2007.

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The tradecard of Walker and Hughes, 19th-century clock dial makers. Courtesy of the Guildhall Library, London.