Counting lunar eclipses using the Phaistos Disk

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This paper concerns itself with a unique fired-clay disk, found by Luigi Pernier in 1908 within the "palace" of Phaistos (aka Faistos). Called the Phaistos Disk, its purpose or meaning has been interpreted many times, largely seen as either (a) a double-sided text in the repeated form of a spiral and outer circle written using an unknown pictographic language stamped in the clay or (b) as an astronomical device, record or handy reference. We provide a calendric interpretation based on the simplest lunar calendars known to apply in Minoan times, finding the Disc to be (a) an elegant solution to predicting repeated eclipses within the Saros period and (b) an observation that the Metonic is just one lunar year longer, and true to the context of the Minoan culture of that period.

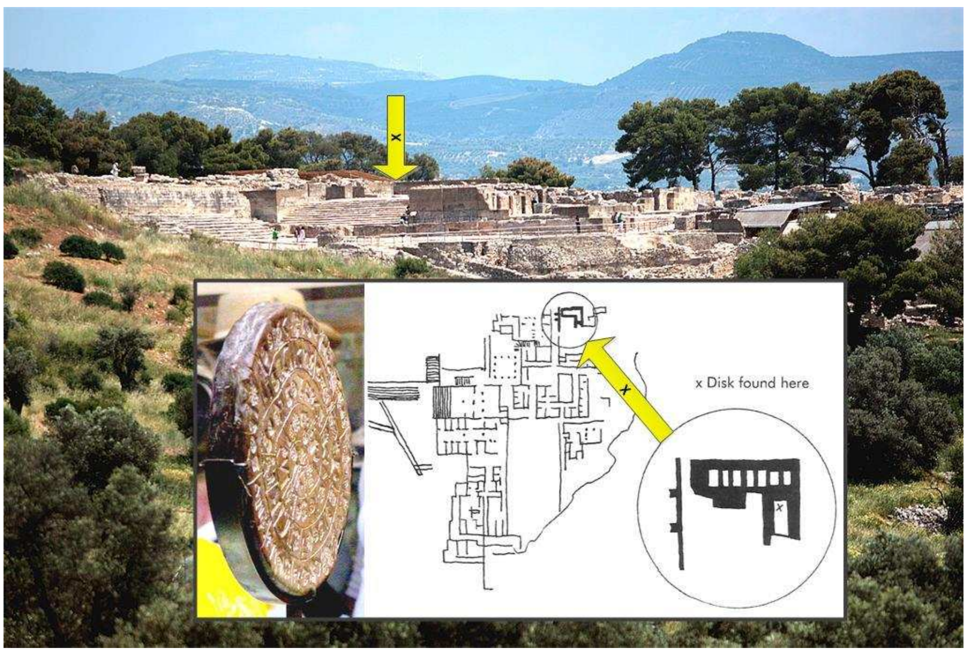

Figure 1. The location of Phaistos Palace atop a commanding hill in the middle of the fertile Massara valley in southern Crete. The Phaistos Disk was discovered in 1908 in chamber 8 of the northeast wing of the "Old Palace" (pre-1700 BCE) as per above diagram inserted from Balistier, 2000, 5.

Scholarship does not see the Minoans maintaining a solar calendar. It was only by the end of the Archaic period that Greek cities might have developed a **lunisolar calendar** [Stern 2012, *49-52*]. If it existed, this type of calendar would have been an adapted lunar year calendar based upon twelve named months, each a 'hollow' 29 days or a 'full' 30 days long. By this means and three 30 day intercalary months, later Greeks were able to re-synchronise their lunar year over eight solar years. An eight solar year calendar (*octaetaris*)[1] produced an agricultural calendar, following the seasons of the solar year, by slighting the sacred lunar calendar. Some such synchronisation is typical within the fully-settled agrarian societies surrounding small cities, because ancient Greek populations still followed a sacred calendar based upon lunar months.

A lunisolar calendar using hollow, full and extra months lost *exact* knowledge of the phase of the moon for the first time since the stone age, but one could look at the moon in the sky. The lunar calendar is drifting within a lunisolar calendar, only to be reset after 99 lunar months at which point month names have been displaced to suit the solar year. This would also have destroyed the meaning of the counting regime within the Phaistos Disk.

The modern calendar of Julius Caesar (January, 45 BCE) refined by Pope Gregory XIII (October 1582) totally lost track of the moon, requiring modern maths, published calendars or direct observation to catch up with the moon's phases. A reversal has taken place: whilst a Minoan's knowledge of the solar year had been *ad hoc*, modern knowledge only knows the phase of the moon in an *ad hoc* fashion. Harmonising the two luminaries within a common calendar has been a challenge since the Stone Age first quantified the month [Marshack, 1991].

The Old Minoan Calendar

The phase of the Moon was, in pre-1700 BCE Crete, a necessarily calendrical object; not least because it was emblematic of (a) women because of their menstrual cycle and the many beliefs surrounding that[2] and of (b) the goddesses forming at the heart

[1] "This is the octennial cycle: 8 x 365.25 = (8 x 354) + (3 x 30). The intercalations (of 30 days) then fell at successive intervals of 3, 2, and 3 years - for example, in the third, fifth and eighth years. In the historical period we hear of four festivals celebrated in every ninth year…" [Thomson, George. 1943. *58-9*.] Note that this system uses approximate lunar years of 354 days made up of months alternately 29 and 30 days long, the real lunar month being their average, 29.5 days whilst the true average lunar month is 29.53059 days long and the lunar year 354.367 days long.

[2] "It is important to observe that the magic of human fecundity attaches to the process, not to the result – to the lochial discharge, not to the child itself; and consequently all fluxes of blood, menstrual as well as lochrial, are treated alike as manifestations of the life-giving power inherent in the female sex. In primitive thought menstruation is regarded, quite correctly, as a process of the same nature as childbirth." [Thomson, George. 1947. *205*.] and "Red is renewal if life. This is why the bones from upper paleolithic and neolithic interments are painted red" [*210*]

of an inherently matrilineal or even matriarchal society[3] based on pastoralism. Their simple and direct counting of lunar months enabled the development of a sophisticated eclipse calendar, lost to near eastern civilizations. The Phaistos Disc appears to have described and facilitated a reliable method of predicting eclipses through counting lunar months.

Creating the Phaistos Disk made it easier to predict the repeat of a *similar* eclipse 223 lunar months after an eclipse, a period now called the Saros. The alternative, of counting the years or days within the Saros (assuming one knew it was 18 solar years and 11 days or 6585 days) would have required a very large count and a corresponding numeracy to support that. The creators of the Phaistos Disk could avoid large numbers by counting lunar months and years, exploiting the fact that eclipses occur only at full or new moon in a repeat pattern. The lunar months of the Semitic lunar calendar, found anciently in the eastern Mediterranean and Near East, inherently provided the ideal unit of time with which to build an eclipse calendar and in turn, the Phaistos Disk represents a fulfilment of late Stone Age notations of the lunar month and year, then on bone and softer stones [Marshack, Alexander. 1972 & 1991].

Figure 2 The two sides of the Phaistos Disk

The same arrangement of textual elements is found on both sides of the Disk, an outer rim of twelve units and an inner spiral of eighteen units. The Disk was probably

[3] "Emanating as it did from the sexual life of women, moon-worship became involved with their social functions. It was their task to draw water [and] tend the plants, … The moon was accordingly regarded as the cause of growth in vegetation … The Egyptian moon-goddess Nit was the inventor of the loom, and in European folklaw the moon is still a spinner. These too are women's tasks … [as too] grinding corn, making pots or cooking." [Thomson, George. 1947. *212*.]

made in three parts, a blank sandwiched between two disks, pre-decorated on a single side, then fired to form a permanent object. [Balistier. 2000. 37-38.] The result is a slightly oblate biscuit of clay, impressed using stamps of pictograms held within scored rectangular boundaries. Each side has,

1. An anticlockwise spiral of **eighteen** groups of pictograms, expanding from the centre of the disk.
2. **Twelve** groups around the rim
3. Collocated **gaps** on either side, punctuating the rims' groups of twelve, which corresponds with the end of the spiral groups of eighteen either side.

In a previous article [Heath, 2016] I offered a practical counting method adapting Reczko's insights into the Disk [Reczko, 2009]. There I interpreted the disk as counting the solar year as 12 1/3rd lunar months, eighteen times, to reach 222 lunar months (6 x 37), then one month short of the 223-month Saros period of near-identical eclipses. Such a count corresponded with other pieces of Neolithic art and monuments I have analysed[4] and interpreted. This scheme of counting (3 x 12.3333 = 37 x 6 = 222) is only one way of counting the Saros period in antiquity using lunar months. This article expresses a simpler counting process based on counting lunar months and lunar years, and this can answer to the repeated structural form on both sides of the Phaistos Disk.

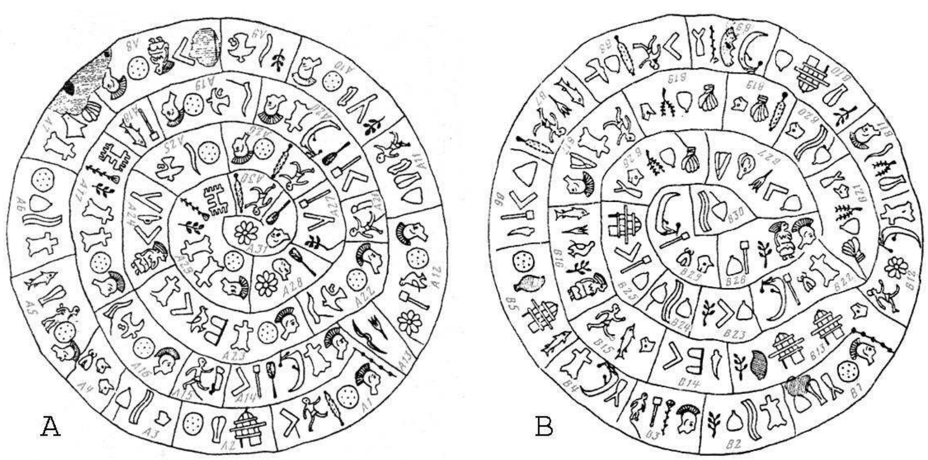

Figure 3. Pernier's drawing of the Phaistos Disk

[4] some of which are;

- Thornborough Henge as the Moon's Maximum Standstill
- What stone L9 might teach us and
- Diagram of the Saros-Metonic Cycle
- Astronomical Rock Art at Stoupe Brow

Numerical simplicity within lunar eclipse calendars

The B side of the Disk showed the relationship of the Saros eclipse period to the nineteen year repetition, called the Metonic period[5], through a simple counting of the *lunar* year and its twelve months. This explains why the Phaistos disk has two structurally similar sides: *side A defining the Saros and side B relating the Saros to the Metonic*.

The Disk can be assumed a calendrical object of the Minoans. They lived in a mythic time-world focussed upon lunar months and lunar years. Lunar months are easily noted being highly visible and, as we have said, they present the ideal time-unit for counting between eclipses: months are large enough to enable lunar counting between repeated eclipses using relatively small numbers and; these eclipses only involve exactly full or exactly new moons that are exact conjunctions of the sun, moon and earth when an eclipse occurs. It seems likely that lunar eclipses had prompted the Disk's development since (a) lunar eclipses are more frequent than solar eclipses and (b) they can be observed from half the surface of the Earth whilst solar eclipses are less frequent and only locally visible - making solar eclipses far less suitable for any ancient study of eclipse repeat patterns.

The rim of both sides of the Disk present twelve lunar months, which could be used to count the months of a lunar year calendar. After the 12th month of each counting cycle (a) a spiral count of eighteen lunar years moves outwards, and (b) the lunar year count is reset to the 1st month. This allowed the spiral count to collect up to eighteen lunar years or 216 lunar months, just seven short of the Saros, of 223 months between similar eclipses[6].

Side B presents the Lunar year of twelve months around its rim *after* an eclipse repeat, since the Metonic period ends exactly twelve months after a repeat eclipse. Observationally, the Metonic is far from obvious: Saros periods become observable because eclipses are observable, whilst the Metonic period is obscure outside a context where repeated eclipses are being counted using lunar months. Once noticed, every full moon was seen to occur exactly 19 solar years after a previous one, nineteen years before, and hence, after an integer number of 235 months. This *knowledge* of the Metonic cycle subsequently became independent of

[5] when any starting configuration of the sun, moon and stars is repeated.

[6] the reader should be aware how astronomically *short* the duration of the Saros is: A similar eclipse occurs so early because in that time, a triple rotation of the lunar orbit's perigee nearly meets both the sun and the same lunar node after eighteen years, so forming a similar eclipse.

the lunar calendar and, in reverse, became useful to solar calendars in harmonising the lunar to the solar calendar.

Side A: Counting the Saros

Side A functioned as a counter of the eighteen *whole* lunar years within the Saros of 223 months, the lunar year being defined as twelve lunar months. Once repeat eclipses had been grasped, the possibility of tracking multiple intertwined Saros eclipses emerged: *of reusing side A via the use of an external notation referencing the Disk*. It is conceivable that Room 8 of the Old Palace was for recording and storing counts, perhaps onto unfired tablets using stamps. Only the fired Disk then survived intact. 'It lay at a slant. Tipped northward, in the midst of pottery chards and other rubble, approximately 50 centimeters (19.7 inches) above the stone floor. At the center of the disk was a symbol resembling a rosette.' [Balistier, 2000. *5*.] covered over some 3600 years before.

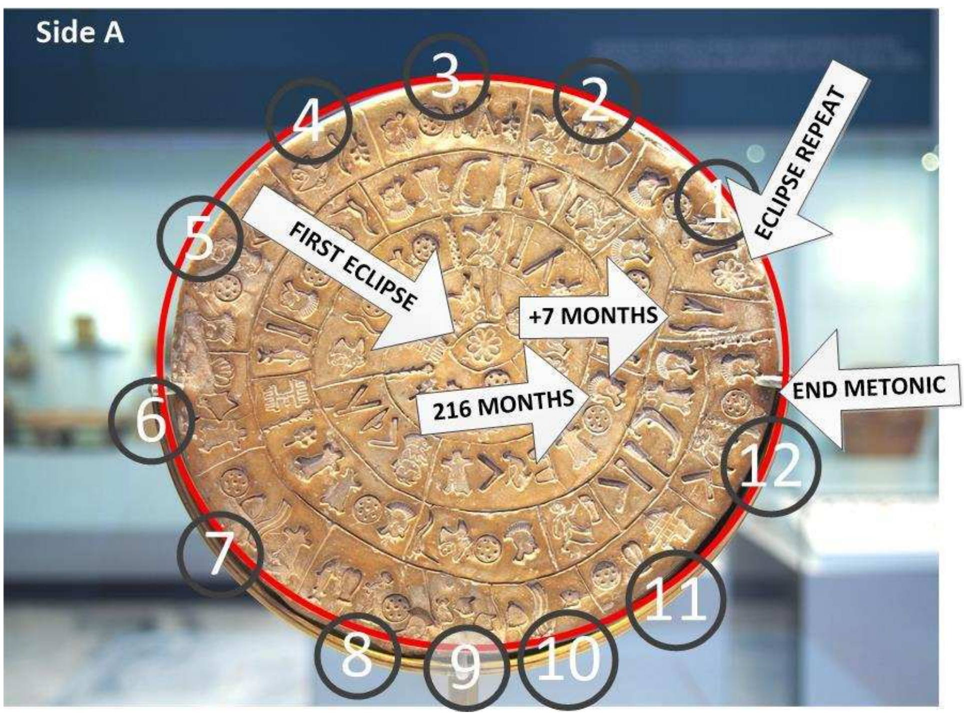

Figure 4. A Diagram of how Side A might have structured time to count 223 lunar months

In the first month after an eclipse, shown as 1 in figure 3, the central unit of side A (the flower or rosette) is marked as the current lunar year - both these 'field dividers' display the pictogram for a flower. The symbol for the eclipse could be this famous flower, the first stamped mark observed when the disk was found in 1908. However, the disk was probably not used like a board game, using markers to store the current state of the count[7]: both the current month and current year were probably transcribed as mentioned above (with ink on papyrus or stamps on clay) thus *employing the symbols given on the disk to record the count*.

Using modern numbers for convenience, one can notate the counting process as [year in the spiral)] / [month on the rim]. The spiral count would proceed as 1/1 to 1/12, then 2/1 to 2/12, etc. until 18:12 whereupon 216 lunar months would have been counted at the end of the 12th month of the 18th lunar year. The 19th spiral division, which touches the rim, is then counted 19:1 to 19:7, the extra lunar months to complete the count to 223, the Saros eclipse repeat. The count has again reached the flower symbol on the first month of the outer rim.

An eclipse can occur within any month within a lunar year with named months. A Saros count dislocates the lunar year by eight months, implying that only the starting month name needs to be noted to locate a given Saros count and the current month name would be general knowledge. On this basis, it seems likely that the pictograms found within each lunar month division and each lunar year division are either (a) identifiers for recording the state of the count, (b) notes on the counting process or (b) remarks on the significance of different time periods, after the start.

To recap: side A proceeded from an eclipse that starts any Saros, shown as the flower at the centre and at the start of the anti-clockwise rim count of months. Counting continued for eighteen lunar years and then a further seven months (the rim gap) to arrive at the end of the Saros (223 lunar months) as the flower of the first month.

Side B: Reaching the Metonic

Side B is a structural repeat in form but not in pictographic content. Another common feature is the flower appearing at the first month of the lunar year's rim count. The spiral again holds eighteen elements with a gap element next to that first month. A "walker" has been prefixed to the flower, which might mean "having counted to the Saros repeat", the counting of a lunar year of twelve around the rim will arrive at the Metonic repeat of 235 lunar months. *Thus side B could repeat the form of side A whilst presenting a further astronomical fact.*

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[7] a marker can be disturbed and the count lost but making notating marks or pictograms in additional media is more reliable and generates persistent documentation that can be referred to.

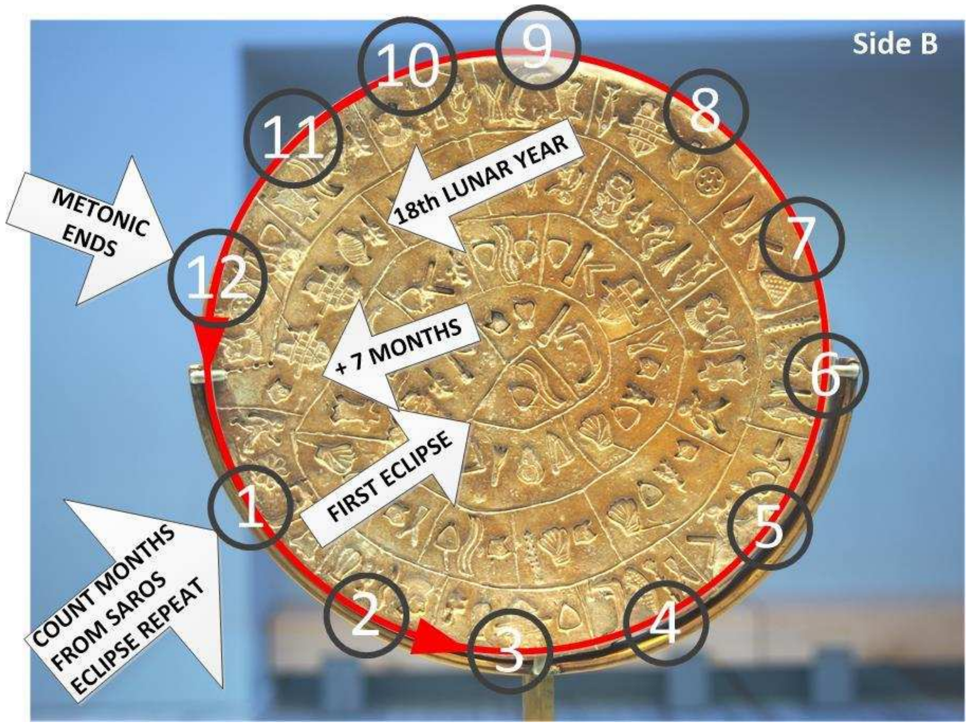

Figure 4. A diagram of Side B as showing twelve months separate the Saros and Metonic periods

In my view, this is the conceptual beauty of the Phaistos Disk. It was arrived at because every eclipse event is the start of a Saros period, which period is also the practical anchor also for understanding the Metonic period. Everything revolves around the lunar eclipse, and each eclipse triggers both the Saros of 19 eclipse years and the Metonic[8] of 19 solar years. And the first lunar year both starts a new Saros count and ends a completed Metonic count.

How the Numbers Work

We see that twelve months around the outside rim can be both a counting system for the eighteen lunar years in the spiral (side A) and the lunar year separating the Metonic from the Saros (side B). There are then 223 = (18 x 12) + 7 months before the Saros repetition of an eclipse and a further 12 months before the Metonic repetition. The sum is 7 + 12 = 19 and here one sees the numerical order emerging from counting using lunar months. There are 19 eclipse years in the Saros and 19 solar years in the Metonic.

After 19 *lunar* years, 19 x 12 = 228 + 7 = 235 lunar months of the Metonic period. And we know that the astronomical Megalithic Yard is 19/7 feet so, when counting

[8] 19 solar year anniversary of sun-moon and stars is just over 20 eclipse years long)

using solar years as 12 (the lunar year) plus 7/19th megalithic yards, the excess over the lunar year of 12, within a single solar year, resolves metrologically as Robin Heath has shown [Heath. 1998. *85*.]:

1. The excess of the solar over the lunar year is 7/19 lunar months which is 7/19 x 19/7 = 1, the English foot whilst
2. the excess of the solar year over the eclipse year is 12/19 lunar months which is 12/19 x 19/7 = 1.7143 feet, the Royal cubit of 12/7 feet.

It is interesting that the spiral, and final twelve months are both initiated by a flower of side A and ended by the head ("scribe"), the person who must recognise the end of such periods during month-counting.

Conclusions

The sun, moon and earth exhaust their ensemble of mutual aspects, relative to each other, within nineteen years and such ensembles are symmetrical, mirroring each other[9]. This is what made the identical pattern of sides A and B a meaningful act, intuiting the inherent symmetry of the Saros and Metonic.

The Phaistos disk was and still is a calendrical artefact whose purpose is easily overlooked in favour of a literary interpretation, epigraphy having been such a powerful and successful skill set in studying the ancient world. It is important to strengthen our understanding of the astronomical patterns relevant to pre-archaic Greek society before assuming the Phaistos Disk a literary device.

Minoan culture evolved out of the late stone age and the type of astronomy proposed for the Phaistos Disk relates well to the megalithic monument building of western Europes neolithic. Crete was too geographically small to form a state on a par with Egypt or Old Babylonia and, being an island with limited scope for large-scale agriculture, pastoralism was natural to Crete and the matrilineal clans of subsistence farming. Women rather than men gave their names to children in matrilineal tribes whilst the fathers are from other clans, a common circumstance until invasions by

[9] *** the Mirror Theorem developed by Roy and Ovenden [see Roy, 2005] that; "If n point masses are acted upon by their mutual gravitational forces only, and at a certain epoch each radius vector from the centre of mass of the system is perpendicular to every velocity vector, then the orbit of each mass after that epoch is a mirror image of its orbit prior to that epoch. Such a configuration of radius and velocity vectors is called a mirror configuration." [Celletti & Perozzi, 2007] These conditions being met for both the Saros and the Metonic and hence time-symmetric repeat cycles.

patrilineal tribes. Minoan society had grown instead through sea-faring trade, with its colonies in the Aegean and the Greek mainland, and with the near-eastern empires.

The general form of the disk, whilst a conceptually a model of the Saros, was probably used as a practical codex for keeping astronomical records during counts, enabling continuous eclipse prediction. Written notes referencing side A could save the counts for more than one Saros ‘series’, in parallel. If side B conceptualised the subsequent completion of the Metonic relative to the Saros, this was there as a permanent reminder which could share the form of a side A used for counting. Notes could be encoded during counting and decoded when reading records made, using the pictographic codes.

My interpretation should be seen in the light of three related anachronisms,

A. The Metonic period was memorialised in the myth of Apollo visiting his temple in Hyperboria once every nineteen years, a calendar synchronizing solar years with lunar months and eclipses. The myth could have been pointing towards Greek links to the megalithic astronomy of western Europe which had the methodology to count cyles such as the Saros and Metonic periods.

B. We know that the Callippic cycle of four Metons and the alternation of 12, 12 and 13 (=37) month years was used in the ancient Near East, and in western Christianity in calculating a date for Easter, Christianity's moveable feast.

C. The key numbers of the Saros and Metonic (223 and 235) have been found within the gear wheels of a bronze age "clock". The Antekythera Mechanism was recovered from the 18 BC wreck of a Roman treasure boat just north of Crete. "On the back of the mechanism, there are five dials: the two large displays, the Metonic and the Saros, and three smaller indicators, the so-called Olympiad Dial, which has recently been renamed the Games dial as it did not track Olympiad years (the four-year cycle it tracks most closely is the Halieiad), the Callippic, and the Exeligmos." [Wikipedia 2]

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Reczko's 2009 interpretation was similar in attributing the central spirals of eighteen as signifying years. He did not there comment on the twelve around the rim except to point to the lunar year of twelve lunar months was the most likely. Reczko then analysed the duplicates in the Minoan hoeroglyphics and deduces a specific pattern matching the eclipses in -1370s and -1360s Saros period, thus making his interpretation a specific observational record for a given Saros.

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