‡2 A Mayan Table of Eclipses

by Hugh Thurston[1]

A The Dresden Codex

A1 The Dresden codex (Dc) contains eight pages which have long been recognized as some kind of table of eclipses.

A2 This codex, which dates from fairly late in Maya history, probably not far from 1000 A.D., is one of the very few Maya documents to survive the ravages of time and the depredations of the Spaniards and the Catholic Church. It is painted, mostly in black and red, on tree-bark beaten as thin as paper.

A3 Each of the eight pages, which have been numbered 51 to 58 by modern historians, is divided into a top half and a bottom half. The tops of the first two pages contain an introduction; the table itself starts with the top of Dc page 53, which is followed by the tops in order and then the bottom halves. On page 31 of this paper is displayed Dc page 54 (taken, by high-contrast photography, from [1]); its top half is the second half-page of the table, its bottom half the tenth. You can see the whole table in [1].

B Interpretation

B1 It is the numbers that are important, not the text, which is concerned with mythology rather than astronomy, and does not explain the numbers. We have to do some detective work to interpret them.

B2 The Mayas used a dot to stand for 1, a bar for 5, and a shell for 0. So the combination of one bar plus two dots stands for 7. The units of time are

uinal = 20 days
tun = 360 days
katun = 20 tuns

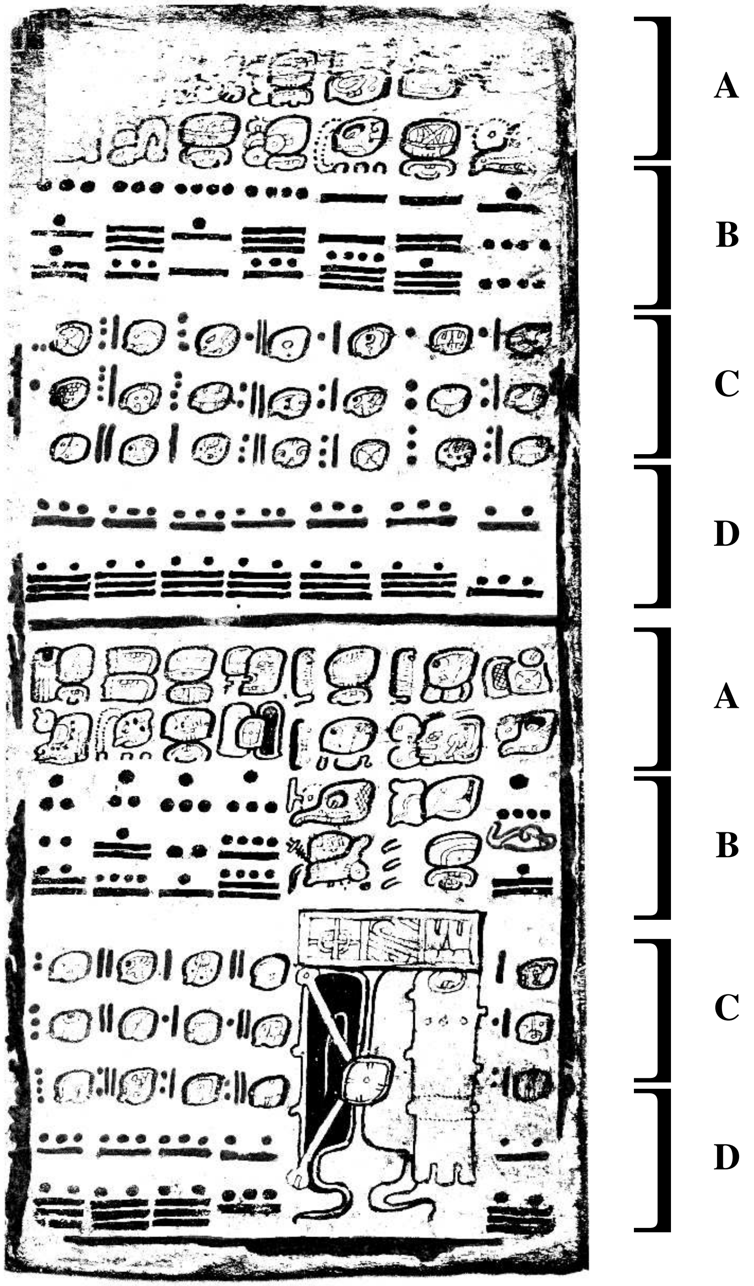
and higher units that we don't need here. So

2 katuns 0 tuns 3 uinals 5 days

amounts to 14465 days. In the codex the units are not written, so this time interval would appear as

2 0 3 5

(written in a column).



Page 54 of the Dresden codex (Dc)

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[1] Hugh Thurston has made his mark as mathematician, cryptographer, & skeptic. Bios of him are found at, e.g., *DIO 4.2* and *J.Hist.Astron 26.2*.

B3 Each half-page of the table consists of: two rows of text, which I have labelled A; a row of numbers, B; a triple row, C, which I will explain later; and a row, D, of numbers.

B4 The numbers in row D are all 177 (sixty altogether) or 148 (nine altogether). You can see (page 31 here) three 177s, a 148, and another 177 along the bottom of Dc page 54. Each 148 in the table is followed by a picture.

B5 On average, 177 days amount to 6 months; 148 days amount to 5 months. This inevitably reminds us of Babylonian tables of eclipses, which consist of a list of dates, given in years and months. Each entry is either 5 months or 6 months after the previous one, and the intervals appear in a strikingly regular (saros-length) pattern, namely

66666665666666566666665666666656666665

repeated over and over again every 223 months. (The numbers of successive 6-entries are seven, six, seven, seven, six.) You can see a transcription of one of these tables in [2]; another table, ACT 60, two hundred years later, carries on the same pattern. (See [3] page 525; and [4] volume 1 pages 106-109 & volume 3 page 38.)

B6 We know how these tables were constructed. The Babylonians had ephemerides which tracked the latitude of the Moon and which display an eclipse magnitude whenever they regarded the latitude at Full Moon or New Moon as close enough to the ecliptic. The dates when this happened were excerpted from an ephemeris for Full Moons (or for New Moons) to form an eclipse table. The underlying mathematical theory of the motions of the Sun and Moon make the entries occur in the regular pattern.

B7 As far as we know, the Mayas did not track the Moon's latitude, or indeed any latitudes or longitudes. The only data in codices or inscriptions are times, not angles.

B8 Without a theory of latitudes, how would anyone ever light on 5-month and 6-month intervals? It is easy enough to say glibly that these are good eclipse intervals (I have been guilty of doing this) or, as Otto Neugebauer has said more specifically, "It is a well-known rule of thumb in antiquity that eclipses can occur at 6-months distance or occasionally at 5-months intervals" ([3], page 504). But lunar eclipses at a 5-month interval are possible only under conditions which Neugebauer himself admitted are "very special" ([3], page 130). So the 5-month intervals would be particularly hard to find from mere observation. [See here at ‡1 §H4.]

B9 Let us look at an example. It is no use taking eclipses from Oppolzer, Meeus-Mucke, or Liu-Fiala because these modern compilations list eclipses visible anywhere on Earth, and we need eclipses visible to the person who is compiling the table. No table of eclipses visible from a Mayan site is readily available, but [5] lists eclipses of the Moon visible at Babylon, and any other site will show a broadly similar pattern.

B10 For eclipses in one sixty-year period (I happened to choose page 146 in [5]) the intervals between successive eclipses are 6 months (which occurs twenty-seven times), 11 months (once), 12 months (ten times), 17 months (three times), 18 months (twice) and 23 months (six times). No 5-month intervals. However, we might reason as follows. The commonest interval is 6 months. It can be doubled, but (for this period) once out of about eleven times one of the 6-month intervals is replaced by a 5-month interval. If it is trebled, it incorporates a 5-month interval more often than not. If quadrupled, it incorporates a 5-month interval every time.

B11 The Mayas may even have thought that there was something occurring fairly regularly without which there could not be an eclipse but with which there could be. This is no more fantastic than the celestial dragons *rahu* and *ketu* which Vedic astronomers thought caused eclipses and which later Indian astronomers identified with the nodes. A dragon at the node could swallow the Sun.

B12 This reasoning is reinforced if we compute the intervals between every pair of eclipses, not just successive eclipses. The intervals, in months, that occur more than once between the eclipses listed on page 146 of [5] are:

(no fives)	6	12	18							
(one five)	11	17	23	29	35	41	47	53	59	65
(two fives)	64	70	76	82	88	94	100	106	112	118
(three fives)	111	117	123	129	135	141	147	153		
(four fives)	158	164	170	176	182	188	194	200		

etc. The longer the interval, the more fives are needed. This could easily give rise to the idea that intervals between eclipses should be based on 6-month intervals with occasional 5-month intervals.

C Reconstruction

C1 We can deduce some details of how the Mayas might have constructed their table if we look at the table itself in a bit more detail.

C2 The numbers in the top half of Dresden codex page 54 (reproduced[2] above at page 31) are:

B:	1211	1388	1565	1742	1919	2096	2244
D:	177	177	177	177	177	177	148

The numbers in row B are a cumulative total of the numbers in row D: to get a number in row B, add the number in row D to the previous number in row B. But six times in the full table the number added is 178, not 177. What has happened? Should the number in row D be 178, or is there a mistake in addition? This is where row C helps.

C3 The glyphs in row C are the days of the Mayas' "sacred round". These days, like our days of the week, are repeated in fixed cycle independently of the date, but unlike our days of the week they form a long cycle of 260, not a short cycle of 7. [See §C9 & fn 3.] The three days in the first column of the top of Dc page 54 are the 78th, 79th and 80th in the cycle.[3] In fact, throughout the table, each column of row C shows three successive days. The days in the middle of row C of Dc page 54 (read across) are obtained by adding successive numbers in row D (§C2) to the one before (and, if the total is more than 260, subtracting 260):

C:	79	256	173	90	7	184	72
D:	177	177	177	177	177	177	148

Where the cumulative total (row B) increases by 178, the number of the day in the sacred round (row C) also increases by 178 (or by 178 minus 260), so the addition is correct and the compiler of the table has, for some reason, not entered the 178 in row D.

C4 Most early astronomers had a figure for the average number of days in a month. The Chinese *San Tong* calendar of 7 B.C., for example, used the relation 81 months = 2392 days. Ptolemy quoted "the ancients" as knowing that 669 months = 19756 days. [See here at ‡1 fn 83.] The Mayas had similar figures. From inscriptions that gave the age of the Moon at various dates, which must be calculated not observed, because some of the dates are mythical, John E Teeple [6] deduced that the Mayas were using 81 months = 2392 days at Palenque and 149 months = 4400 days at Copan.

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[2] Note: there are several scribal errors in our illustration of Dc page 54. (E.g., 1742 is miswritten as 1748.)

[3] An explanation of how to deduce these numbers from the glyphs is given in, e.g., Hugh Thurston *Early Astronomy* Springer 1994 pages 196 & 201.

C5 The total number of days covered by our table (the last accumulated total in row B) is 11958. The total number of months (sixty 6-month periods plus nine 5-month periods) is 405. Both these numbers are divisible by 3. And the numbers 3986 and 7972, which are, respectively, one-third and two-thirds of 11958, both occur among the cumulative total in row B. So the table breaks cleanly into three parts, in each of which

$$135 \text{ months} = 3986 \text{ days}$$

My suggestion is that the table was based on this figure, which is reasonably similar to the figures at Palenque and Copan. (We do not know for certain where the Dresden codex came from, but it was not from either of these cities.)

C6 The question that faced the table's constructor is: how can we build an interval of 135 months out of 5-month and 6-month intervals, with substantially fewer 5-month intervals than 6-month intervals? There is only one way: twenty 6-month intervals plus three 5-month intervals. Then there should be three 5-month intervals in each third of the table. There are.

C7 If each 6-month interval is 177 days and each 5-month interval is 148 days (as they will be if 135 months = 3986 days: §C5), there will be a total of 3984 days. Two days short. So twice in each third of the table the cumulative table should increase by 178 instead of 177. And this is just what happens. It looks as though the person who discovered this slipped the extra days in without telling the scribe who painted the table, and who innocently filled in all the 177s along the bottom without checking the addition.

C8 The distribution of the 177-day, 178-day and 148-day intervals is shown below. The top row shows the first third of the codex, the middle row the middle third, and the bottom row the last third. (There are twenty-three intervals in each row, thus sixty-nine intervals in all.)

177 177 177 148 177 177 177 178 177 177 177 177 177 148 178 177 177 177 148 177 177 177 177

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177 177 177 148 177 177 178 177 177 177 177 177 148 177 178 177 177 177 148 177 177 177 177

C9 There is another interesting point about the numbers in row C. If we list them, we find that they are far from evenly distributed: they clump into three sectors of the 260-day cycle. There are none from day 12 to day 52; twenty-three between days 53 and 91 (inclusive); none between days 92 and 149; twenty-three between days 150 and 184; none between 185 and 236; twenty-three between 237 and 11 (equivalent to 271 in the 260-day round cycle). This is what should happen if the dates are in fact dates of eclipses. The reason is that an eclipse cannot occur unless the Sun is near a lunar node. The average time for the Sun to travel from one node to the next is (and was) 173.31 days.[4] If the Sun is at a node on day 72, then it will be at the other node on day 245 (or perhaps 246), back at the first node on day 159 (or 158) and back again at the second node on day 72. Since eclipses occur only when the Sun is near a node, they will cluster around these dates. I chose day 72 as the middle of the first occupied sector of the 260-day cycle. Days 245 and 159 are in the other occupied sectors.

C10 The Mayas undoubtedly knew of this. They placed vastly more importance on their sacred round than we do on the days of the week. (The best we can do is a rhyme like "Monday's child is fair of face . . ." or a general belief that Friday is an unlucky day for a wedding.) Victoria and Harvey Bricker have an ingenious and complicated theory showing how the Mayas could have used sacred-round entries to turn the table into an efficient table for warning of the possibility that an eclipse might be imminent: the table spans 405 months (§C5), and only on the 69 months listed could an eclipse occur. I recommend their paper [7] for further reading. Of all the theories that I have come across about the use of the table, this is the only one that has any degree of plausibility. The statement, made all too often,[5] that the Mayas could predict eclipses is definitely false.

References

[1] J E S Thompson, *A commentary on the Dresden codex*, Washington, 1972.

[2] A Pannekoek, *A history of astronomy*, London, 1961, page 61.

[3] O Neugebauer, *History of ancient mathematical astronomy*, New York, 1975.

[4] *Astronomical Cuneiform Texts* [ACT], ed. O Neugebauer, London, 1955.

[5] M Kudlek, *Solar and lunar eclipses of the ancient near east*, Neukirchen, 1971.

[6] John E Teeple, *Mayan astronomy*, Washington, 1930, page 65.

[7] Harvey and Victoria Bricker 1983, *Current Anthropology 24*:1-18.

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[4] [Note by DR: $173^{\mathrm{d}}1/3$ is precisely one-third of two rounds, thus it has been reasonably (if controversially) speculated that the Mayas may have chosen their 260-day round-interval out of interest in eclipses.]

[5] [Note added 1995.] E.g., *Lost Civilizations* (Time-Life) nationally broadcast on 1995/7/9 the explicit claim that the Mayas could predict *solar* eclipses.