MAYA ECLIPSES AND THE CORRELATION PROBLEM

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Abstract

The Eclipse Table in the Dresden Codex implies that in the first millenium A.D. the Maya had kept long and accurate date-lists of lunar and solar eclipses. The table itself has been variously regarded either as a) a Solar Eclipse table or b) an Eclipse Warning table. Correlations converting Maya to A.D. dates are normally made to fit one of these alternatives. A test is now presented that seems to confirm the Early Warning hypothesis.

In the Codex there are over 30 specified Long Count dates, believed to be of astronomical observations; of the four such dates associated with the Eclipse Table at least one is assumed to be that of an eclipse. The Moon Age glyphs of the Long Count dates in the Codex prove that the dates are not randomly distributed in the four-week Lunar cycle, many are at New Moon (potential Solar Eclipse) and a few are at Full Moon (potential Lunar Eclipse). We here show that the dates are likewise not randomly distributed in the 173-day Eclipse cycle and that there is a cluster within a 38-day section. This section is assumed to include the eclipse moons and the 36-day period, centred on the node, when eclipses are possible. As the Eclipse Base itself —9.16.4.10. 8 12 Lamat— is not at the middle but at the beginning of this cluster, the Table is assumed not to be an Eclipse table but an Eclipse-Warning Table; the first three associated dates defining the beginning, middle and end of Eclipse Moons.

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The 12 Lamat base thus leads to a date-list of New Moons at the beginning of the eclipse half-year, as indeed were required for the Copan system of numbering. The lunar eclipses, and further solar eclipses, would be indicated by the date-lists generated from the second and third dates, respectively 15 and 30 days later.

This view so far is consistent with both the original Thompson (584 285) and the author's (615 824) correlations. The latter is 86.4 years or 31,541 days latter than the conventional 584 283 constant, and brings the Full Moon date into line with the *visible* 'node-passage' lunar eclipse of 842 March 30. We can find many other eclipse dates, some with glyphic evidence, some in connection with either the Venus table or the Maya lunar cycle of 4 x 819 days. A solar eclipse at sunrise in A.D. 847 might then explain the name of a ruler, New-Sun-at-Horizon, and the date of his inauguration at the so-called 'Astronomical Congress" timed two days before the predictable lunar eclipse of 849 Nov. 4. With the new correlation many of the eclipses listed in our table would have been conspicuous in Mayan longitudes. The conventional correlation (584 283) brings the Full Moon date two days off a lunar eclipse (in 755), but that eclipse was not visible in Mesoamerica.

Other correlations, if they differ from 584 285 or 615 824 by multiples of both 173.3092 and 29.53059, would nevertheless generate eclipse coincidences near the Long Count dates.

The so-called Spectrum of Time project (Schove, 1960, 1961, 1982) has led to a collection of eclipse records, and a special study of observed eclipses through the period A.D. 1-1000 has been carried out (Schove and Fletcher, 1984; Schove, 1955). It was not at first possible to include Mesoamerican eclipses in this survey or in the work of Newton (1972) because of the lack of agreement among scholars on the conversion of Maya dates, regarded by many as constituting a floating chronology.

Maya dates (Morley, 1961) are expressed very precisely in their own form so that it is simple to convert a date such as 9.16.4.11.3 into a Mayan Day Number (MDN = 1412 863): the difficulty (Aveni, 1980, p. 204) has been to find an agreed correlation constant to reach the Julian Day Number (JDN) and hence the A.D. date. The conventional Modified Thompson correlation, adopted in most books, uses a correlation constant 584 283; indeed this equation fits well several dates in the Colonial period of the sixteenth century, dates which Spanish explorers attempted to express in both Mesoamerican and Christian forms.

The Maya Sacred year or *tzolkin* of 260 days was in use in both Classic and Colonial times, and it was at first assumed from this apparent continuity that any correlation fitting the Colonial period would apply also to the Classic period of the first millenium A.D. A continuity principle was reasonable as a first assumption, but minor calendrical changes are known to have taken place, as Edmonson (1976 and personal communication; cf. Schove, 1978a) notes. Three such slippages are already evident — one vaguely about A.D. 1000, another in 1539 (when a change from terminal to initial dating of the Katun caused a shift of 80 days) and a third in 1752. On the first two occasions the year-bearers were changed by a disjunction between the 260 —and the 365— days (*haab*) years.

Various criteria for a satisfactory correlation constant have been listed and numbered by Kelley (1976, pp. 31-32). Several are based on the astronomical evidence (Lounsbury, 1978) in the Dresden Codex, and for the Classic period these criteria can be shown (Schove, 1981, 1983b) to be more consistent with the writer's equation, an equation that was one of two based originally on planetary evidence (Schove, 1977 and 1976):

$$\mathrm{MDN} + 615\,824 = \mathrm{JDN}$$

This makes the dates 86.4 years or 31,541 days later than conventionally given. We shall use dates converted by this equation here, but as far as our first problem is concerned —to determine which of Kelley's mutually exclusive tests 6 and 7 is appropriate— the conventional equation and our own are in agreement.

The Eclipse Table in the Dresden Codex can be used sucessfully for the prediction of eclipses over a 33-year period in any century, and various dates have been suggested for its 'initial eclipse' as follows: A.D. 477 (Smiley in ed. Aveni, 1975), 490 (Owen also in Aveni), 695 (Willson, 1924), 1128/1139 (Spinden, 1924) and 1181 (Thompson, 1972). Certainly the table must have been derived empirically from a long series of well-dated observed eclipses. There are three bases, specified by Maya dates, separated by 15-day intervals, and the dates are known to correspond to lunar phases as indicated below:

9.16.4.10.8	12 Lamat	New Moon	(Solar eclipse?)
9.16.4.11.3	1 Akbal	Full Moon	(Lunar eclipse?)
9.16.4.11.18	3 Etznab	New Moon	(Solar eclipse?)

There is a fourth base, incorrect as it stands, which ends in 7 Lamat and appears to link the Past and the Future. A 7 Lamat table is included in Columns B to H prior to these bases, as explained by Lounsbury, 1978 (p. 801) in an article we shall quote frequently. His reconstituted date 9.19.(18).7.8. 7 Lamat is therefore preferred to the alternatives given in the standard lists of Satterthwaite, 1964 and Thompson, 1972. The link with the Past of a 7 Lamat table is that its prototype, as explained below (see Fig. 1), would have yielded a base for the eclipse table; the link with the Present of a 7 Lamat date was that such a date would by that time occur 30 days —one lunar month— later than the third base. The date converts to A.D. 914 December 22, and Lounsbury's explanation makes it easy to see that the Maya might have expected a lunar eclipse about 45 days earlier (actually, there was an eclipse 47 days earlier, but it was not visible at Tikal), for they knew well that the 7 Lamat-type table in this period marked the end of the second moon of the eclipse half-year. However, for our immediate purpose we can ignore this fourth base.

At least one of the first three bases is generally believed to be that of an observed eclipse. The sixth criterion of Kelley (1976) is favoured especially by those astronomers who assume that the first New Moon base is that of a *Solar* eclipe. The seventh criterion is favoured especially by those who believe that the second or Full Moon date is that of an observed *Lunar* eclipse. A *Solar* eclipse at the first base (Criterion 6) makes the 12 Lamat series an *Eclipse table;* a *Lunar* eclipse at the second base (Criterion 7) makes the 12 Lamat series an *Eclipse Warning table*. The dates would then indicate a possibility of lunar eclipses a fortnight later, the 12 Lamat dates themselves marking the New Eclipse Moons, at the beginning of each eclipse half-year, occasional solar eclipses occurring either then or at the third (Etznab) base.

The node cycle or Eclipse half-year, of 173.309 days, determines when eclipses are possible: they can occur only within 18 days of node passage. The Maya were well aware of this and indeed their expanded tables imply that the node passage took place just one day earlier than their initial eclipse, at either 12 Lamat or 1 Akbal as the case may be; all subsequent dates in the 33-year series then being within the 18-day limit. The mutually exclusive criteria 6 and 7 respectively regard the first and second bases as an 'initial eclipse' near node passage.

There are frequent eclipse glyphs in the Codex; there are also

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many Long Count dates which are at either New or Full Moon. These two factors suggest that a proportion of the dates might plausibly have eclipse associations; and lie within 18 days of Node Passage. I therefore converted all the Long Count Dates to Mayan Day Numbers and divided them by 173.309.

This reveals that 12 of the 35 dates cluster as required within a 37-day portion of the 173 day cycle. This is not a high proportion as 8 such dates could occur within a random sample, but we can show that many of the dates so selected have internal evidence of eclipse associations and significant relationships to *visible* eclipses. The first base is at the periphery and the second at the centre of this cluster; correlations which pass Test 7 thus have more eclipse "successes" than those which pass Test 6.

Test 6 was favoured by Willson (1924) who long ago correctly recognized solar eclipse glyphs in the Codex. Apparent support for his view that node passage was near the first base came from a computer analysis by Kelley and Kerr (1974) which threw up a number of New Moon Maya dates separated by multiples of the eclipse half-year but which they regarded as statistically not very significant. Several scholars in the recent books edited by Aveni (1975, 1977) have adopted such a view, and in his important article 'Astronomical Tables and Inscriptions' Kelley (in Aveni, 1977, p. 70) himself suggested that 9.16.4.10.7, one day before the first base, was at Node Passage.

Test 7 is consistent with the 'Original Thompson' correlation constant of 584 285 (two days on from the Modified version in general use today). It is equally consistent with the writer's new 615 824 constant. It will likewise be consistent with any other constant differing from these by a multiple of 173.309 days.

All such correlations will bring a few of the Dresden Long Count dates into alignment with eclipses. The original Thompson constant thus makes the middle base coincide with the lunar eclipse of A.D. 755 November 23. That eclipse was noteworthy only over that half of the earth centred on India; but if we adopt the 615 824 correlation this 1 Akbal base coincides with the Atlantic lunar eclipse of A.D. 842 March 30; this was central between Mesoamerica and Africa, being recorded later the same night in Germany and in France (Annals of Fulda cf. Schove and Fletcher, 1984). Some of the dates in the expanded 12 Lamat table may well be Solar Eclipses, and Smiley (in ed. Aveni, 1975 cf. Aveni, 1980 Tables 18 and 19) claimed that for his period A.D. 477/510 in particular it could have successfully predicted every solar eclipse that occurred anywhere on earth without any false warning.

The 12 clustering 'nodal' Dresden dates have been grouped together in Table 1. Some extra dates have been added.

a) Two other Dresden dates that appear to have had eclipse significance for the Maya.
b) Additional Venus dates implicit in the Venus table of the Codex.
c) Several non-Dresden dates with glyphs thought to be associated with eclipses.

The two dates in category a) have been placed chronologically and are thus, respectively, before and after the 'nodal' cluster. They are 850.0 years apart, the first relating presumably to an observed eclipse and the second possibly to a predicted eclipse. The month of the first date is correct for the near total solar eclipse of 2 January 447 although, as explained below, the date itself appears to have been adjusted by 21 days to fit the Maya eclipse cycle. The prototype of the eclipse table may have been a fifth century version, but the extant form, as Lounsbury (1978, p. 800) explains, is that of the 1 Akbal node (Converting to 9th Century) modified after 9 rounds or 3 centuries of use to a 12 Lamat node (Converting to 12th century). The latest observation dates appear to be near the important eclipses of 1137/1140 and the final thirteenth century date must have been calculated (Lounsbury, p. 796) or contrived and is perhaps an unsuccessful prediction. The Maya of the Classic period would have known that the 12 Lamat dates would by then have been too late for an eclipse, but we have included it because of its apparent implication.

The internal evidence consists first of eclipse glyphs near some of the dates. We know, however, that the Maya used the 11,960 day eclipse cycle —the length of the Eclipse Table— and this interval connects our date in A.D. 447, 709, 742 and 774, suggesting that they adjusted the eclipse dates slightly. This cycle is involved also in the A.D. 769 date.

Lounsbury explains (*op. cit.*, p. 796) that the 13 Muluc day (Day 169 in the 260-day cycle, cf. Fig. 1) used then must have preceded the 12 Lamat (Day 168) day of the First Base (A. D. 842) over 70 years later, and adds 'Whether either of these two dates was the occasion of an eclipse observed by the Maya is not known'. In our chronology they are the new moons at the commencement of an

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eclipse half-year and preceding visible eclipses by 15/16 days. The knowledge of this eclipse cycle goes back to at least 808 and probably about 778 (DJS) at Palenque (cf. Lounsbury, p. 775 who explains that his own dates are conventional). There were in this century three near-total *solar* eclipses (A.D. 744, 790, 797) which must have made a great impression on the people, although even then what the astronomers watched for were the New Moons a fortnight before *lunar* eclipses.

The Maya also knew the luni-solar 19 year cycle, when the sun and moon return to almost the same position on the same day of the solar or tropical year. Curiously, Spinden (1924, p. 137) once noted at Copan the 19.00 year interval at dates in these years, two moons earlier on Feb. 16, but this may be a coincidence. Two astronomical dates at Palenque noted by Kelley and Kerr (1974) in their tables 3 and 4 convert to 508 December 13 and 521 December 14. These are New Moons and the 521 date precedes a solar (Dec. 15) and a visible lunar eclipse. Among our selected Dresden dates, those of A.D. 462 (Thompson's correction) 742 and 842 are almost at the same time of the tropical year as each other whatever correlation is adopted, and the difference between the first and last of this trio is twenty times this 'Metonic' cycle.

Several of the eclipses, as in 842 and 857 are almost at node passage; this suggests that they were used in revising the Eclipse Table. A fifth century origin (as suggested by Smiley in ed. Aveni, 1975) fits in with the Maya interest in numbering the days of the moon. Their first date so numbered 8.16.0.0.0, converts to 443 June 10 and is less than a day out, although the lunar half-year, beginning 25 days earlier, was not linked to the eclipse pattern used after 842. Curiously the 15-year interval between A.D. 447 and 462 is matched by a similar interval between A.D. 842 and 857, but this is not exact and is presumably accidental.

The 3 Chicchan dates (Day 185) are discussed by Lounsbury (*op. cit.*, p. 803) who points out the glyphic connection with the *visible* new moon. The date we convert to 352 July 2 certainly is a date when the moon was 4 days old; it has to be excluded from our table because the (small) visible solar eclipse did not occur until 25 days later. The other date, our 1058 August 25, is discussed by Lounsbury without reference to a specific correlation. He suggested that the date might be 18 days after a lunar eclipse (There was a near miss on August 8 and '3 days after' a date 'for a solar eclipse predicted surely, if not actually observed'). Indeed, there was a solar eclipse on August 22, although the Maya could not have seen it. Lounsbury (p. 803) further calculates that an intermediate implied Maya date is implied —10.5.16.12.8 2 Lamat 11 Tzec— and this converts to 1031 July 21, one day off a solar eclipse and 15 days before the lunar eclipse of August 5.

The Eclipse table was, in its ninth century form, a guide to both solar and lunar eclipses. The lunar eclipses came fairly regularly at the dates indicated by the second 1 Akbal base; solar eclipses could occur at dates (with errors up to two days) in either of the other bases. The Maya were especially interested in the New Moons preceding eclipses, as their recognition was needed, at least from A.D. 842, for the current numbering of their moons.

The secret of Copan moon-numbering indicated by Glyph C was long ago solved by Teeple (1930, p. 93) who showed that in addition to the 12 Lamat base (our 842 Mar. 15) the dates below were the beginnings of new half-years. We used an unpublished list of lunar eclipses at Tikal kindly prepared by Dr. M. Kudlek to check that a fortnight later there was a visible lunar eclipse in each case.

9.16.8.6.3	+ 15 days	=	842 Mar. 30
9.16.9.16.9	+ 14 days	=	847 Jul. 2
9.16.11.14.7	+ 15 days	=	849 May 11
9.16.12.5.4	+ 15 days	=	849 Nov. 4
9.16.13.4.7	+ 16 days	=	850 Oct. 24

Later astronomical dates in the same class include e.g.

9.17.12.17.5	+ 16 days	=	870 Mar. 21

Venus dates

The Venus table in the Dresden Codex has three bases, the principal one already included in the first part of Table 1, and two implied dates that fit the significant intervals of 9,360 days before and 11,960 days afterwards. These are eclipse intervals, and Smiley (like Spinden) therefore suggested that the dates in the Venus table and their expansions had eclipse overtones (Kelley in Aveni, 1977, p. 59). Indeed, all three Venus bases in the new correlation prove to be about a fortnight after visible lunar eclipses. Smiley's own correlation was less successful (Satterhwaite, 1962) in this respect. The lunar eclipses were central in longitudes 84° to 169° W. so that they were all conspicuous in Mesoamerica.

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Moreover, if we expand the table, adding 4.12.8.0 to the above dates (cf. Lounsbury, 1978, p. 783), we get three more visible eclipses. However, they rapidly decrease in intensity; the third although centred at 69° W. being so small as to be effectively invisible. Although the Maya had methods of correction to bring dates into line with both Venus and eclipses, we have included in Table 1 only the first of these three eclipses, that of 774, which is 33,280 days after the 3 Xul base.

819-day dates

An 819-day cycle was noted intermittently by the Maya between the 750s and 900 (cf. Lounsbupry, *op. cit.,* p. 811). This suggests an interest in lunar longitude: after 30 sidereal months the moon is back to the same position among the stars. Each return was associated with one of the cardinal points so that the complete cycle was 3,276 days or 120 sidereal months, that is, 111 lunations or one fortnight less than 19 eclipse half-years. There are only 14 examples know (List in Kelley in ed. Aveni, 1977, Fig. 17 and pp. 57-59), but their dates reveal that the Maya became interested in recording the cycle only when the 819-day station (i.e. usually when the MDN divided by 819 gave a remainder of 816) took place or had recently taken place near, and often about a fortnight after, a lunar eclipse. Such dates might suggest a link with the formal Venus stations, for 819 = 584 + 235. However, the Maya would then know that 3,276 days later there was a possibility of a solar eclipse.

Eclipse glyphs

Two non-Dresden dates have been added to Table 1 because they are associated with eclipse glyphs on the monuments.

There are thus 'two or three unusual glyphs which seem to refer to disappearance of moon or perhaps to conjunction' (i.e. New Moon) wrote Thompson (1950, p. 240), in discussing irregular forms of Glyph D (cf. Kelley, 1976, Fig. 7, Numbers 2 to 8). If we follow his clue but apply the new correlation we find that 5 out of the 6 cases are indeed only 12/17 days away from eclipses.

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		Maya date	*+ 615 824 =*	*Lunar eclipses*
1	Copan I	9.12.3.14.0	761 July 26	(Solar August 5)
4	Quirigua F	9.16.10.0.0	847 July 19	847 July 2
3	Quirigua D	0.16.15.0.0	852 May 28	857 June 11
2,5	Quirigua E and Piedras Negras	9.17.0.0.0	857 June 23	None
6	Quirigua Alt 0	9.17.14.16.18	872 Feb. 16	872 Feb. 28

Illustrations of 2, 4, and 6 are given by Thompson (1950, Fig. 36, Nos. 29-33; Fig. 37, Nos. 63-66 and Nos. 26-31 and see his p. 269).

The Copan I date (Text No. 1) is a New Moon date interpreted as 'dead moon in the house of storms'. In this case there was no visible eclipse, but the date was appropriate for a prediction of one, as a solar eclipse was to occur (in the Western Pacific) in 761 on August 5. We have no further examples of this glyph but the 'House of Storms' might be merely a constellation. There was likewise no eclipse in the case of No. 3, where the second glyph is described by Thompson as 'possibly, although not probably, a sign for darkness'.

After the above was written, Professor Kelley pointed out to me that the glyphs associated with one of the dates 9.17.0.0.0 corresponded with the glyphs at the first base of the Dresden eclipse table 9.16.4.10.8 (personal communication May 21st, 1977, now in Kelley, 1977, pp. 405-409) and Kelley independently concluded that the glyphs indicated an eclipse. Some glyphs cited by him as evidence are reproduced as his Fig. 1.

In the new chronology both dates are new moons preceding important visible lunar eclipses almost at node passage — the 857 lunar eclipse of June 11 was indeed sandwiched between two overall partial solar eclipses dated 9.17.0.0.0 and 9.17.0.1.9 (June 25) which dates correspond respectively to the Dresden bases 9.16.4.10.8 and 9.16.4.11.18 (the latter is likewise an overall partial, and the former date corresponds to a 'near miss').

The Piedras Negras Stela (F2 in Kelley's, Fig. 1, p. 406) thus has the glyphs for black as its main sign and could perhaps refer to the Lunar Eclipse, a fortnight later. The strongest eclipse evidence discussed by Kelley relates to Quirigua Stela E; this includes the same glyph for black in A 206 and certain links with the eclipse indications associated with the 32nd eclipse in the Dresden Codex Eclipse Table.

The Hieroglyphic Stairway at Naranjo has, on block five, a date with the half darkened sun glyph, and Kelley (in ed. Aveni, 1977,

p. 69) discussed a possible connection with a Tortuguero date. The two dates convert to 729 April 9 and 735 Nov. 30. Solar eclipses took place in 729 May 2 and 735 Dec. 19 but they were both *West* Pacific eclipses. The lunar eclipse of 729 April 18 was visible but small and we have not added it to our table. A further Tortuguero 'astronomical' date discussed by Kelley becomes 797 Aug. 13 and that precedes, by the usual fortnight, the important solar eclipse of 797 Aug. 28. However, there is no clear eclipse glyph and again we have not included that date in Table 1.

The date 9.16.12.5.17 associated with the so-called Astronomical Congress at Copan has been critically discussed by Carlson (in ed. Aveni, 1977) who points out that it may be merely the inaugural date of a ruler. This ruler's glyph is interpreted as New-Sun-at-Horizon, and, curiously, there had been a nearly total horizon solar eclipse at sunrise on 847 December 11. Such a date was 2,097 days (cf. Lounsbury, p. 792) after the 12 Lamat day of the eclipse table and thus fitted, with less than 1 day error, the 12th place in the expansion of that table. The date of the inauguration of New-Sun-at-Horizon was fixed 2 days before a node-passage *lunar* eclipse of 4 November 849, an eclipse no doubt correctly predicted for the 16th place (Day 2776) in the Akbal table; the impending lunar eclipse was perhaps considered an appropriate sign from heaven for a ruler with such a name.

The final inscription used in our table (A.D. 876) contains glyphs considered to represent a solar eclipse, and they possibly contain a reference (Schove, 1977/8, p. 104 and 1978b, p. 628) to a near transit of Mercury if the 'St. Andrew's Cross' or 'Crossed-bands' can be so interpreted (Professor Kelley points out that this 'Cross' may represent conjunctions of all kinds). There was a solar eclipse at this date visible in S. America. The Maya would have found the visibility of solar eclipses much more difficult to predict than the dates: nevertheless, they seem to have used cycles (as in the Venus table) that led them towards Western Hemisphere eclipses both of the sun and moon.

Animal skull glyphs, noted by Kelley (in ed. Aveni, 1977) as probably astronomical, convert from 9.14.0.0.0 and 8.15.16.0.5 to 798 April and 439 July and may possibly refer to a recent 'death of the Sun'. Certainly there had been significant solar eclipses in both 798 (Feb. 20) and 439 (May 28) but we need to find more examples before we can accept this interpretation.

Table 1

DRESDEN CODEX DATES NEAR ECLIPSES
(615 824 correlation)

Page & Colour a	*Date* b		*Equivalent (615 824)* c	*JDN* d	*Eclipses (Solar)* e	*(JDN) (Lunar)* f	*Difference* g	
63b	8.16.3.12.3	13 Akbal	447 Jan 23	1884 347	'326		— 21 (S)	Important visible
31b								Eclipse cycle and glyphs of Earth and Moon
70b	8.16.19.0.12	4 Eb	462 Mar 14	1889 876	'879	'864	+ 3 (S)	E. Hemisphere only. Near Node Passage
			(380 years before A.D. 842)				— 12 (L)	Total (28°W 7°N). Eclipse glyphs p. 69 & 71.
45b	8.17.11.1.10	13 Oc	474 Jan 28	1894 214	'219	'205	— 9 (L)	Total (118°W 21°N)
					'190		— 24 (S)	
			(A total solar eclipse on 24 Dec. 74)				+ 5 (S)	Solar eclipses partial only
24b	9.9.9.16.0	1 Ahau	709 Jun 13	1980 184	'154	'168	— 16 (L)	Total (84°W 22°N)
			(Venus base)				— 30 (S)	
58b	9.12.10.16.9	13 Muluk	769 Aug 6	2002 153	'183	'169	+ 16 (L)	Small 32°W 11°N)
			(1st NewMoon base of earlier Eclipse Table)				+ 30 (S)	Eclipse glyphs
51b	9.16.4.10.8	12 Lamat	842 Mar 15	2028 672	'702	'687	+ 15 (L)	Eclipse table. Near Node Passage
			(1st New Moon base)				0 (S)	Solar eclipse invisible
							+ 30 (S)	
52r	9.16.4.11.3	1 Akbal	842 Mar 30	2028 687	'702	'687	0 (L)	Total (54°W 5°S)
			(Full Moon base)					Eclipse glyphs pp. 52, 53
							— 15 (S)	Solar eclipses invisible
							+ 15 (S)	

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52b	9.16.4.11.8	3 Etznab	842	Apr	14	2028 702	’702	’687	0 (S)	Partial, invisible
			(2nd New Moon base)						— 15 (L)	The principal Eclipse
									— 30 (S)	Partial, invisible
69r	9.17.15.6.14	9 Ix	872	Jul	21	2039 758	’776	’790	+ 18 (S)	
62b	10.4.6.15.14	3 Ix	1002	Mar	1	2087 098	’084	’098	+ 0 (L)	Total (14°E 5°N) Visible
									— 14 (S)	Partial only
62b	10.6.1.1.5	3 Chicchan	1035	Nov	14	2099 409	’397	’413	+ 4 (L)	Small (78°W 21°N)
			(A visible and conspicuous solar eclipse)						— 12 (S)	Eclipse glyphs pp. 61, 63
61b	10.7.4.3.5	3 Chicchan	1058	Aug	25	2107 729	’726		— 3 (S)	Visible in S. Pacific only
						(cf. Lounsbury 1978 p. 823)				Rebirth of Moon glyph. Eclipse glyphs
70b	10.11.4.0.14	9 Ix	1137	May	11	2136 478	’488		+ 10 (S)	Visible
						(Probable epoch of extant Codex)				Eclipse glyphs pp. 69, 71
51r	10.19.6.1.8	12 Lamat	1297	Jan	25	2194 812	’899		+ 87 (S)	New Moon but no eclipse
						(Calculated forward from A.D. 842)				
IMPLICIT VENUS DATES:										
24b	Venus 3 Xul base		683	Oct	28	1970 824		’807	— 17 (L)	Lunar 169°W (Kelley 1977 pp. 59-62)
24b	Venus 13 Ix base		742	Mar	12	1992 144		’128	— 16 (L)	Lunar 116°W (Kelley 1977)
24b	(9.12.16.6.0)		774	Dec	9	2004 104	’073	’088	— 16 (L)	Near total
									— 31 (S)	
NON-DRESDEN DATES WITH ECLIPSE GLYPHS										
—	9.17.0.0.0	13 Ahau	857	May	27	2034 224	224	239	0 (S)	Eclipse glyphs. Partial
							253		+ 15 (S)	(Kelley 1977, p. 63)
									+ 29 (S)	
—	9.17.19.13.16		876	Nov	19	2041 340	’340		0 (S)	Eclipse of Sun. Glyphs

No reference has been found to the important solar eclipse of 884 June 26 or 9.18.7.8.12 in the new correlation. However, its anniversary could possibly be commemorated in 'astronomical' glyphs on Stela 12 at Naranjo 9.18.8.8.12 (five days after a West Indian solar eclipse), and 'eclipse overtones' may be implied in a Palenque date of the 819-day count, 9.18.7.10.13 (884 August 6) noted by Kelley (1977, p. 66) in connection with the (later) accession of a ruler.

Lunar eclipse visibility

The lunar eclipses mentioned in this paper were nearly all large and visible in Mesoamerica. This provides support for the 615 824 correlation. Mid-eclipse was mostly before midnight and this encourages us to believe that the Maya watched many of the eclipses (e. g. 462, 709, 769, 842, 872, 883, 1035). The 1002 eclipse was visible immediately after sunset: those of 846 and 857 were not visible until after midnight but at this period (and possibly in A.D. 474) the moon would no doubt have been watched all night.

In Table I (cf. col. g) the eclipses fell (A.D. 474 excluded) into three nearly equal groups, either very near the eclipse date (−3/+4) or a fortnight away (−17/−12 or +10/+18) on either side. Such dates fit the threefold pattern of the eclipse table.

Eclipse table evolution

The prototype of the Eclipse Table appears to have been flexible, changing as the eclipse patterns changed. The three bases of the Dresden Codex version then seem to have become so sacrosanct that, I suggest, to keep the eclipses in step with the eclipse table it became necessary to change the calendar. These three stages are illustrated in Fig. 1 and the first two are explained by Lounsbury who describes the two types of change. First there is the small change (Lounsbury, p. 796) in the precise position of the node so that the 12 Lamat (Day 168) table had been preceded by a 13 Muluc (Day 169) table and the 7 Lamat (Day 228) by an 8 Muluc (Day 229). These changes have been ignored in our figure.

There is, however, a more fundamental change by which, through the recession of the node, the tables gradually became obsolete from the right. Thus Lounsbury shows that the 1 Akbal base was near

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the node at the time of the first three bases (9th century in our dating) but that the 12 Lamat base was near the node some three centuries later (Lounsbury, *op. cit.,* p. 802). If we go back three centuries we should expect the 3 Etznab table to have been near the node and 3 centuries further back we come to a period when this would have fitted the New Moons *preceding* Lunar Eclipses. The 7 Lamat table, given equal importance in Columns B-H, would have been the third or second New Moon base at that time. However, if we adopt this hypothesis we must push the first prototype of the Eclipse Table well before the fifth century A.D.: no solar eclipse at Tikal had occurred on a 7 Lamat day since 20 B.C.

Going forwards from A.D. 842 we find that the last 3 Etznab solar eclipse was in A.D. 900 and the last 12 Lamat solar eclipse was in A.D. 1228.

Some confused folk-memories of these changes may have been passed down to the Toltecs and later to the Aztecs. Alva Ixtlilxochitl thus stated that 166 years after an astrologer's gathering there was an eclipse of the sun that came near the beginning of the native year, a year he gave as 1 House and which other later writers gave as 10 House and 7 Rabbit. He said that in the same period there was also an eclipse of the moon.

Mrs. Cline, personal communication based on the unpublished work of Dr. Cline

These short count names are years but if they were originally Mayan days they become 1 Akbal, 10 Akbal and 7 Lamat. The middle date appears to be a misquotation of the first source but the other days are evidently derived from the Eclipse Table.

About 1200 the subtleties of eclipse forecasting had presumably been forgotten and the astrologers had to explain why lunar eclipses occurred not near a 1 Akbal day (183) but near a 12 Akbal day (103). The simplest answer was to decree that the calendar was wrong and that there was an error of 2 days in the day numbers. (In the case of Lamat the change may appear at first to be 11).

The Dresden tables may have been more important than the Calendar; either the Eclipse Table or the Calendar had to be changed, and we argue that it was easier to change the Calendar than the Codex.

In order to preserve also the connection with the Long Count a loss of 80 days was not enough; some multiple of 260 days had

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also to be deducted from the Long Count dates. The precise multiple would be fixed as soon as a calendar correction for the second part of the short count had been fixed. However, the total Long Count had to fit not only the Eclipse Table but also the Moon Count and the Venus table. The difference had therefore to be:

a) An eclipse cycle.
b) A multiple of the lunar month.
c) A multiple of the Venus year.

The astronomers, we may suppose, solved this problem by changing both the month and day. In this way they had in effect omitted about 31,540 days. That the Maya knew of an eclipse cycle of 31,539 days is confirmed by a letter from Kelley stating he had found eclipse glyphs on an unpublished pot associated with a cycle of that very length (Personal communication 21 May, 1977, received after I had submitted my 1977 article).

This change would appeal to the Maya, always fond of multiples of 91, as 31,541 days were 2 x 13 x 7 x the length of an eclipse cycle of 173.302 days.

The ordinary people by that time had presumably ceased to use Long Count dates, and the magnitude of this calendar change might not have been appreciated. On the date we know as 1297 Jan. 25 they might have been told that due to an error of the 'previous government' the day 12 Lamat was incorrect and that it should have been 10 Lamat. This would then have brought further eclipses back into the 12 Lamat/1 Akbal region and the usefulness of the Eclipse Table would have been restored and prolonged for several centuries more. Using the Modified Thompson correlation, or other correlations that fit the intertribal Calendar Round, the first visible 12 Lamat solar eclipse would have been the important one of A.D. 1365 Aug. 17; others followed (± 2 days) in 1372, 1384, 1398, 1405, 1416, 1431, 1438, 1470, 1496, 1510, 1543 July 31. Even by 1365, however, the node was already earlier than the 1 Akbal day in the G-M-T correlation, and 1 Akbal lunar eclipses had occurred much earlier.

Since the above paper was accepted Lounsbury (1982) has shown that Venus dates at Bonampak and elsewhere are consistent with the Thompson correlation and Schove (1983b) has pointed out that they fit the 615 824 correlation slightly better still. X-rays and other methods for dating annual rings in the Maya area (ed. Bormann and Berlyn, 1981) open up the possibility of a drendrochronological check on the solution.

This is not the whole story, for in addition to the 80-day change, there was a small additional change of 1 day — the difference between the Classic and the Colonial correlations being 31,541. However, whether or not we accept such a speculative explanation, we have in this paper demonstrated that the G-M-T gives a fairly good and the new correlation a very good fit with the Lunar Cycle, the Venus Table and the Eclipse Table in the Dresden Codex.

Conclusions

We have thus shown that:

a) If we suppose that the Node-Passage day was very near the date 9.16.4.11.3 1 Akbal (our 842 March 30) i.e. we accept Kelley's 7th not his 6th criterion,

b) we then find that about 12 of the Dresden dates fit (within the 18 day eclipse limits) eclipse dates listed in the standard catalogue.

c) If we further adopt the 615 824 rather than the 584 283 correlation,

d) we then find that the eclipses fall into three sets and the lunar ones are largely those visible in Mesoamerica. The years or months of *visible* solar eclipses, with outstanding exceptions in A.D. 447, 474, 1035 and 1137, do not normally figure in our table so that solar eclipse dates were known to the Maya by calculation.

e) We have also suggested how the attempt to preserve the usefulness of the Dresden Codex may have led to a calendar change corresponding effectively to a change in the correlation constant of 31,451 days. Such a change would have preserved the usefulness of the Dresden version of the Eclipse Table and would have continued to fit approximately the requirements of the Venus Table and the Lunar Count.

Acknowledgment

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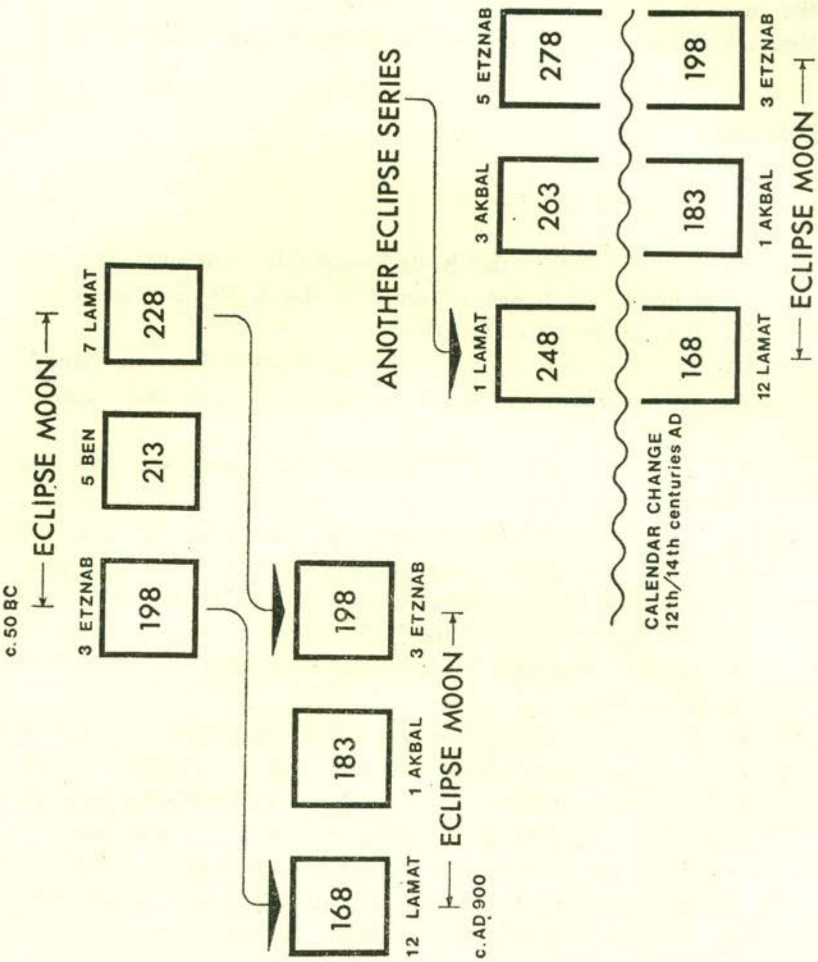

Figure 1.

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