


ARTICLE

A Lunar Day Count at Monte Alban and the Chronology of Early and Middle Preclassic Zapotec Hieroglyphic Texts (ca. 496–221 BCE)

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Abstract

This article identifies a lunar day count in Zapotec inscriptions at Monte Alban. The lunar records that are accompanied by dates in the Mesoamerican 52-year cycle make it possible to determine intervals between recorded events. Seven placements of the resulting series of intervals in absolute time are consistent with dates of the lunar crescent's first visibility at Monte Alban between 650 and 50 BCE; just one is also consistent with the seventeenth-century Zapotec calendar. The data show that Zapotec divinatory calendar dates likely began around noon, as in the sixteenth century, and that the return of the year-bearer on the year's 261st day was celebrated in the afternoon by 222 BCE.

Resumen

Este artículo identifica un conteo de días lunares en las inscripciones zapotecas de Monte Albán. Las fechas lunares inscritas, unidas al ciclo mesoamericano de 52 años, permiten calcular los intervalos de días entre eventos registrados. Siete inscripciones legibles fueron utilizadas para calcular intervalos. Estos intervalos fueron comparados con los primeros datos de la creciente lunar visible en Monte Alban (en tiempo absoluto) entre el 650 y el 50 aC. Las siete posibilidades permitieron fechar las inscripciones en tiempo absoluto. Solo una de estas también corresponde al calendario zapoteca del siglo XVII. Adicionalmente, los datos muestran que las fechas del calendario adivinatorio zapoteco probablemente comenzaron alrededor del mediodía, como en el siglo XVI, y que el regreso del portador del año en el día 261 se celebraba por la tarde hacia el 222 aC.

Keywords: Mesoamerican calendrical astronomy; Mesoamerican calendar histories; lunar calendar; Zapotec calendrics

Palabras clave: astronomía calendárica mesoamericana; historia del calendario mesoamericano; calendario lunar; calendarios zapotecas

Zapotec civilization yields the earliest corpus of hieroglyphic texts from Mesoamerica. The definitive modern work on Zapotec writing is by Javier Urcid and his collaborators; his 2001 monograph is a comprehensive analysis. Building on Urcid's foundation, this article demonstrates that “Glyph W”—a calendrical notation in hieroglyphic texts from the Danibaan/Monte Alban Ia (ca. 500–300 BCE) and Pe/Monte Alban Ib (ca. 300–100 BCE) phases at Monte Alban in Oaxaca, Mexico ([Figure 1](#))—specifies how many evenings the moon had been visible since the new moon on the accompanying date, establishes absolute distances among seven fully preserved dates with Glyph W records, and identifies every possible placement of the series of these dates in absolute time.¹ Only one placement is consistent with the seventeenth-century Zapotec calendar.

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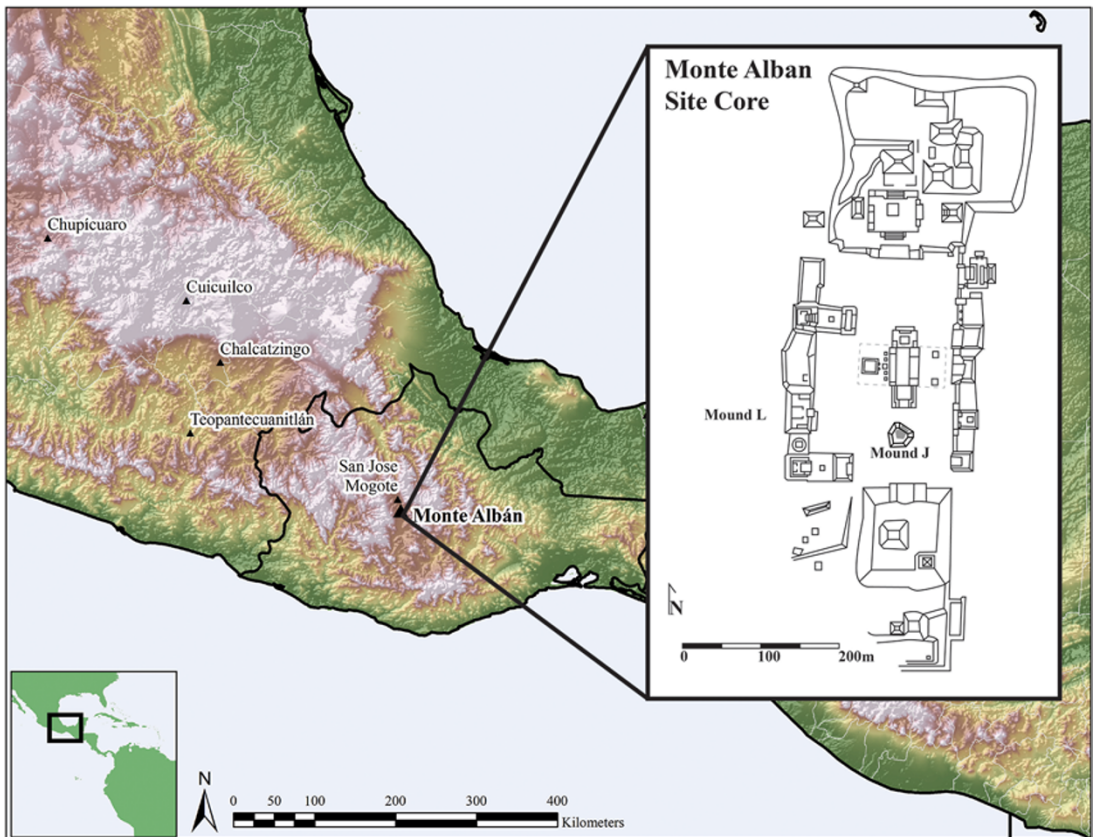


Figure 1. Map of Oaxaca, and Monte Alban site core, based on Urcid (2001:Figure 4.25); position of structures in the southern half of the plaza adjusted based on Levine and colleagues (2021:Figure 10), and earlier construction phases of Mound J are based on Urcid and Joyce (2014:Figure 9.6). (Color online)

Mesoamerican Calendars

Two concurrent calendars were used throughout Mesoamerica before the Spanish invasion: the divinatory calendar and the “vague year.”

Divinatory Calendar

The divinatory calendar, 260 days long, permutes a *trecena* of 13 days, almost everywhere consisting of numerals 1–13, and a *veintena* of 20 days, named mostly by words for plants, animals, or forces of nature. Zapotec individuals were preferentially named for the day of their birth in this calendar.

Colonial Zapotec divinatory calendar names are well attested in colonial documents. Their most copious attestations come from document 822 in the Archivo General de Indias in Seville: a set of 103 calendars confiscated by the Inquisition from daykeepers in northern Zapotec territory and accompanied by community confessions of idolatry; a photographic copy is provided by Oudijk (2021). These divinatory calendar names show that, unlike day names in other Mesoamerican languages, Zapotec day names contained no *trecena* numeral. Instead, a non-numerical classifier, corresponding to a *trecena* position, preceded the *veintena* name; together, the classifier + *veintena* name formed a single phonological word (Justeson 2014:760). For example, the proto-Zapotec “6 Deer(s)” is reconstructible as **k-šoʔkk^wa* (“six”) *k^we+ tzina* (“deer”), whereas the divinatory calendar date “6 Deer” is **kk^wa+ tzina*. The calendrical term contains no numeral word, and instead of the classifier **k^we+*, which is associated mostly with words for spirits, humans, and animals, it is preceded by the classifier **kk^wa+* that marks this “Deer” as day six in a *trecena*. Linguistic forms marked by * are Terrence Kaufman’s proto-Zapotec reconstructions, reported in Justeson and Tavárez (2007:18, 20).



days 1-13 of 260 days		days 1-13 of 260 days	
yagchilla	1	yagguечи	14
yeolla	2	guiollina	15
gueolla	3	guiollao	16
llachii	4	llaxoo	17
yooçee	5	yohlopa	18
cuallana	6	cuallapag	19
billachina	7	billallao	20
llaba	8	chilla	21
yollagniza	9	yoollaha	22
billatella	10	billaha	23
yaallaho	11	llachi	24
binobia	12	yoocee	25
yece	13	yecellana	26

Note: bino- is expected for yoo- in yoocee

Figure 2. Calendario 91, AGI 882 folio 1492r (Oudijk 2021:459). Notes: The numerals 1 to 13 to the right of each column of day names are indexes, not part of the names. Kaufman’s phonemic analysis of the colonial Northern Zapotec spellings of these day names (reported in Justeson and Tavárez 2007:18–20), with the preposed trecena classifier in italics and the veintena name in roman type, are in column 1, yag-chila, yeo-lo-ee, yeo-lo-Ela, la-chii, yoo-çee, kwa-lana, 0-laba, yo-lo-niza, bila-tela, ya-lawo, bino-biaa, and yeze-ee; in column 2, yag-Etzi, yeo-lo-ina, yeo-lo-lao, la-xoo, yo-opa, kwa-Epag, bila-lao, 0-chila, yo-lo-ee, beo-Ela, 0-la-chii, yoo-çee (an error: it should be bino-çee), and yeze-lana.

In Zapotec hieroglyphic writing, however, divinatory calendar dates are represented by veintena signs, followed by the numeral corresponding to the trecena position of the date: no sign corresponding to a classifier appears before the veintena sign. Although classifiers are spelled on some nouns in Zapotec hieroglyphic texts (Justeson and Kaufman 2011), glyphic numerals’ ungrammatical postposed placement effectively served a classifier-like function in writing. Similarly, 54 of the seventeenth-century Zapotec calendars, in Spanish script, index each date by a numeral; in 47 of these, the numeral is uniformly after the date (Figure 2).

Mesoamericanists typically cite veintena dates using indigenous or translated names from a particular Mesoamerican language. They are cited here by the English translation of the Zapotec name, and for broader accessibility, the roman numeral corresponding to their veintena positions is added in brackets. Córdova’s spellings of sixteenth-century Central Zapotec veintena names’ forms and meanings, determined by Terrence Kaufman (Justeson and Tavárez 2007:18), are as follows: *chilla* Cayman[I]; *ii* Wind[II]; *EEl*a Night[III] (elsewhere House); *Echii* Lizard[IV]; *zii* (Zapotec meaning unknown, elsewhere “Snake”[V]); *laana* Stench[VI] (i.e., smelling like fish, meat, or metal [elsewhere Death]); *china* Deer[VII]; *laba* Rabbit[VIII]; *niça* Water[IX]; *tella* Knot[X] (elsewhere Dog); *loo* Monkey[XI]; *piia* Soaproot[XII] (elsewhere Tooth); *ii* Reed[XIII]; *Eche* Jaguar[XIV]; *nnaa* Corn[XV] (elsewhere “Eagle”); *loo* Crow[XVI] (also Buzzard); *xoo* Earthquake[XVII]; *opa* Cold[XVIII]; *aappe* (meaning unknown, elsewhere “Storm” [XIX]); and *lao* Face[XX] (elsewhere, varied).

Vague Year

The pan-Mesoamerican “vague year” (so called because it was exactly 365 days long; hereafter, “year”) consisted of 18 named 20-day units (“months”), followed by a 5-day unit. In colonial calendars, Zapotec

Table 1. Evidence against Previous Hypotheses.

	Glyph W	Model Predictions for Glyph W			Calendrical Data			
		Day of Month (Caso)	Month(s) (Edmonson)	Trecena (Whittaker)	Divinatory Calendar	DC Position	Year Name	Day(s) of Year
M-21/D-142	18	4	<i>1</i>	4	2 XX	40	12 XVII	4
M-21/D-142	14	4	14	4	2 XX	40	12 XVII	264
M-21/D-142	4	17	2 or 15	10	1 XVIII	118	4 II	37 or 297
J-14	5	17	5 or 18	15	11 XIII	193	6 XVII	97 or 357
J-10	8	5 or 18	5 or 18	15	12 XIV	194	6 XVII	98 or 358

Note: Predictions from each hypothesis (day of month, month number, and trecena number are registered in the last three columns). Bolding is added to call attention to correct predictions for Caso, Edmonson, and Wittaker's proposed models, and italics are used for incorrect predictions.

years were named by the divinatory calendar date of their first day, preceded by the word “ruler” (proto-Zapotec **ko+ kke*). In hieroglyphic texts, the year's name is represented by that date, surmounted by a sign depicting a ruler's headgear (Urcid 2001:111–113, Figures 4.5–4.7).

Zapotec hieroglyphic texts specify dates in the divinatory calendar; they do not mention the month within the year nor the day within the month. In well-preserved texts, at least one divinatory calendar date is associated with a named year.

The placement of a specific divinatory calendar date at a specific place in the year recurs only after $73 \times 260 = 52 \times 365 = 18,980$ days (a “calendar round”). The calendar round surely began with the year 1 Earthquake [XVII]: 50 of the 103 calendars surrendered by northern Zapotec communities to the Inquisition (Oudijk 2021) list the names of years, in order, always beginning with that year; 43 calendars list all 52 years of the calendar round, in order (calendars 44 and 64 mention 1 Earthquake [XVII] only).

In Mesoamerica, years were named for their 1st or 260th day; in 1695, the first day of the Zapotec year was 11 Earthquake[XVII] (Justeson and Tavárez 2007:41), so the 260th day was 10 Crow [XVI]. This shows that Zapotec years were named by their first day.

Glyph W

The next most frequent Zapotec calendrical expression is “Glyph W,” so designated by Caso (1928:43, Figure 20; 1947:10). Numerals follow Glyph W, spelled in “bar-and-dot notation,” with rectangles representing fives and “dots” ones.

Previous attempts to interpret Glyph W linked its numeral to features of the divinatory calendar or the year, addressed only a limited set of features or examples, and are demonstrably incorrect. This article shows that Glyph W counts evenings in a lunation, beginning with the first visibility of the lunar crescent, at the time of the recorded event; determines the intervals among seven Glyph W records with knowable placements in both the divinatory calendar and the year; and that they date from 496 to 222 BCE. These inscriptions appear on monoliths (aka “stelae”) from Mound L and orthostats (“tablets”) from Mound J at Monte Alban.

Because Glyph W specifies the day in a lunation, the number of days separating Glyph W records can be determined. Generally, there can be only one solution. During archaeological phases of the monuments' origins, around 600–200 BCE, a date can recur in both the 260- and 365-day calendars, within a two-day range in the lunar cycle, only at $7 \times 52 \times 365$ days (about 350 years; lunar offset, 1.8936 days). If the divinatory calendar date appears twice in its year, it can recur also at $3 \times 52 \times 365 + 260$ days (about 150 years; lunar offset, –1.4996 days). The first span could only occur between monuments of different archaeological phases; the second can occur within or crossing those phases.

Previous Hypotheses for the Function of Glyph W

Three previous hypotheses for the function of Glyph W have been proposed. Table 1 shows that each is inconsistent with five complete, legible dates that are accompanied by a year name.

Day in a 20-Day Month

Caso (1928:95) treated Glyph W as a veintena sign in its appearance on Stela 13 (now designated monolith D-140), with a coefficient 4. With the discoveries of Stela 17 (monolith M-21), on which the numeral 18 follows Glyph W, and of Stela 15 (monolith D-142) with Glyph W followed by 14, Caso (1947:10) abandoned this hypothesis, because only numerals 1–13 follow veintena glyphs. Caso then suggested that Glyph W specified the day in a 20-day month. Later, mistakenly reading the trecena part of a date 13 Monkey[XI] as 18, Caso (1965:938, Figure 14) stated more obliquely that it and another sign “are the glyphs for months,” with Glyph W the glyph for a particular month. However, the non-numerical part of this glyph is now known to be veintena day Monkey[XI] (Urcid 2001:198, Figure 4.99); using variable-angle lighting to bring out its details, Urcid established its numeral as 13.

Caso’s hypothesis may be adjusted so that Glyph W’s coefficient indicates the day within *any* month. Table 1 presents results for this hypothesis. If the divinatory calendar date naming the year was that year’s first day, as in the 1600s, the place(s) in the year of each divinatory calendar date can be determined. For five examples of Glyph W whose divinatory calendar date has a postposed trecena numeral and specified year, and for which Urcid (2012:857, Figure 65.1) definitively established a position, Table 1 (in the column for Edmonson) shows that the hypothesis that Glyph W refers to a specific month can be made to agree with only one or two of five instances.

Count of Trecenas

Whittaker (1980, 1983) proposed that Glyph W’s coefficient specifies in which of 20 13-day sequences the divinatory calendar date fell, based on a single pair of dates that he interpreted as 10 Night[III] W-2 and 11 Night[III] W-5. He identified the veintena sign as Night[III] based on an assumption that it depicts a building, because the name of the third day in the veintena meant “house” in some central Mexican traditions. However, the Zapotec word for this day, spelled <Ela> and <EELA> in colonial documents, reflects proto-Zapotec **ee?la* ‘night’ (Justeson 2014:763), the usual and likely earliest name for day three in Mesoamerican languages. Whittaker’s interpretation was immediately rejected by Mixtec epigraphers, because the symbol he identified as day three is secured in Zapotec iconography as depicting a reed dart (Carlos Aróstegui and Nancy Troike, personal communications 1981–1982; Urcid 2001:222–224, 2012:250–273), and thus day Reed[XIII] (“reed” and “dart” are often the same word in Mesoamerican languages). Urcid and Domínguez (2013:11) show that, at Cacaxtla, a day sign that is virtually identical to the Zapotec sign at issue and depicts a reed (Urcid 2012:Figure 65.1) contrasts with a sign that depicts a building frontally or from the side, securely identifiable with the central Mexican name for day 3 “House.”

In addition, day 12 Jaguar[XIV], the day sign depicting a feline head, is recorded as W-8 on Orthostat J-10. In the eighth trecena, the Jaguar day is 3 Jaguar[XIV] ($7 \times 13 + \underline{3} = 20 \times 4 + \underline{14}$), and Night is 12 Night[III] ($7 \times 13 + \underline{12} = 20 \times 5 + \underline{3}$)—which is 12 House according to Whittaker’s hypothesis. His hypothesis therefore entails that this feline head also represented a day name meaning “house”, the clear 2 Jaguar date falls in trecena 15 ($14 \times 13 + \underline{12} = 20 \times 9 + \underline{14}$).

Whittaker’s hypothesis also requires distinguishing as separate signs what appear to be forms of Glyph W in the text spanning monoliths M-21 and D-142. The variant on D-142 is Glyph W’s usual form; that on M-21 is the left half of Glyph W, rotated counterclockwise, with an unusually large bar-and-dot numeral 18 squeezed below it. Sign rotation for visual reasons and glyphs partly overlaid on neighboring glyphs are common in Mesoamerica’s highly pictorial scripts.

Whittaker’s hypothesis is also inconsistent with the difference of three units in the W cycle for dates on J-13 and J-14, one day apart in the divinatory calendar and both falling in trecena 15. Whittaker (1992:13) addressed this by treating J-14’s W-5 record as the text’s first sign—and not paired with any divinatory calendar date. This is unparalleled in the corpus and conflicts with the standard reading order, toward the glyphs’ faces, in Zapotec writing (also in epi-Olmec and Mayan); on J-14 they face leftward, so reading was surely left to right, beginning from the leftmost column. Furthermore, every other instance of Glyph W in columnar format occurs immediately after a divinatory calendar date; here, it is consistent only with reading W-5 after 11 Reed[XIII], which ends the column immediately to W-5’s left. 5 Soaproot[XII], the last date to the left of the year named 6 Earthquake[XVII], is the name of the

immediately preceding year (and its 1st and 261st day); Whittaker's interpretation would place them out of chronological order.

Urcid (2001:250–273) discusses other details that contradict Whittaker's proposal. The occurrence of different Glyph W coefficients for examples of the same date, 2 Face[XX] (Urcid 2001:269–271, Figure 4.167a), is decisive evidence against it.

Count of Months

The meaning of Edmonson's (1988:273) hypothesis—that Glyph W specified “month in general”—is unclear. It could be interpreted as Caso's day-of-month hypothesis, disproven above. Another possible interpretation—that the divinatory calendar date falls in the year's n th month—must also be rejected. Divinatory calendar dates 12 Jaguar[XIV] on J-10 and 11 Reed[XIII] on J-14 are one day apart, and both fall in a year 6 Earthquake[XVII]. Under a month-count hypothesis, they would fall either in the same month or 13 months apart, and so they would not necessarily be in the same calendar round; however, their W coefficients differ by 3.

Determining the Length of the Glyph W Cycle

Zapotec hieroglyphic texts do not distinguish dates by the calendar round in which they occur. Monoliths D-139/D-140 and M-21/D-142 are from the Danibaan/Monte Alban Ia phase (ca. 500–300 BCE), and the orthostats (“tablets”) are from the following Pe/Monte Alban Ib phase (ca. 300–100 BCE) and later set along Building J (Urcid and Joyce 2014:16). However, each Zapotec text from these eras is associated with a single named ruler; therefore, dates on any text cannot span much more than one calendar round (52 years), and a sequence of dates with Glyph W from a single text provides constraints on the Glyph W cycle's length. Two such texts are fully legible: two dates occur in the text spanning M-21 and D-142, and four occur on J-14 (Figure 3c–d, f).

M-21 and D-142 both record an instance of the day 2 Face[XX] in a year 12 Earthquake[XVII]: this day falls on that year's 4th and 264th days, the first at W-18 and the second at W-14 (see the Appendix for a detailed discussion).

J-14 contains four divinatory calendar dates, each with Glyph W, across at least two successive years. Urcid (2001) definitively established the placements of the last three days' signs in the veintena, so their placements in the divinatory calendar are known.

The standard format for orthostats containing calendrical data is the image of a hill, sometimes with a postposed title; a year-name appears immediately before that image, and a divinatory calendar date and Glyph W appear immediately after it (see Figure 3e–f). The last date on J-14—11 Reed[XIII] W-5—follows the year-name 6 Earthquake[XVII], year 45 of the Zapotec calendar round; therefore, it falls in a year 6 Earthquake[XVII]. 11 Reed[XIII] occurred on days 97 and 357 of that year; we show below that it refers to day 97.

5 Soaproot[XII] is the last date before the year-bearer reference; it named and was the 1st and 261st day of the immediately preceding year and does not occur before day 97 in the year 6 Earthquake[XVII]; one of just 4 dates on J-14 out of 260 possibilities, it surely dates to that year. Assigned to day 261, this and J-14's preceding dates could all fall in that year. Ceremonies were held on day 261, the return of the year-bearer, in several Mesoamerican communities; for example, a 1939 Ixil ceremony began on day 260, “at sunset of the Gregorian day before when the Year Bearer day enters and are continued the next morning [day 261] at sunrise” (Lincoln 1942:112).

Our analysis therefore begins with the premise that 5 Soaproot[XII] W-10 fell on day 261 of year 5 Soaproot[XII] and that the preceding date—11 Reed[XIII] W-2—fell on day 162 of the same year. Under these assumptions, the Glyph W cycle turns out to be a lunar day count.

Glyph W's coefficients drop from 18 to 14 over 260 days on monoliths M-21 and D-142, yielding 264 days as a multiple of the cycle. This is a non-integer multiple because its factors ($264 = 3 \times 8 \times 11$) are all smaller than each monolith's Glyph W coefficient. Similarly, the minimal sequence of J-14's three secure dates places 10 Reed[XIII] on day 162 of year 44 (5 Soaproot[XII]), followed by the return of the year-bearer on day 261 and then by 11 Reed[XIII] on day 97 of the next year (6 Earthquake[XVII]); intervals between these dates are 99 and 201 days. Glyph W's coefficient changes from 2 to 10 over the

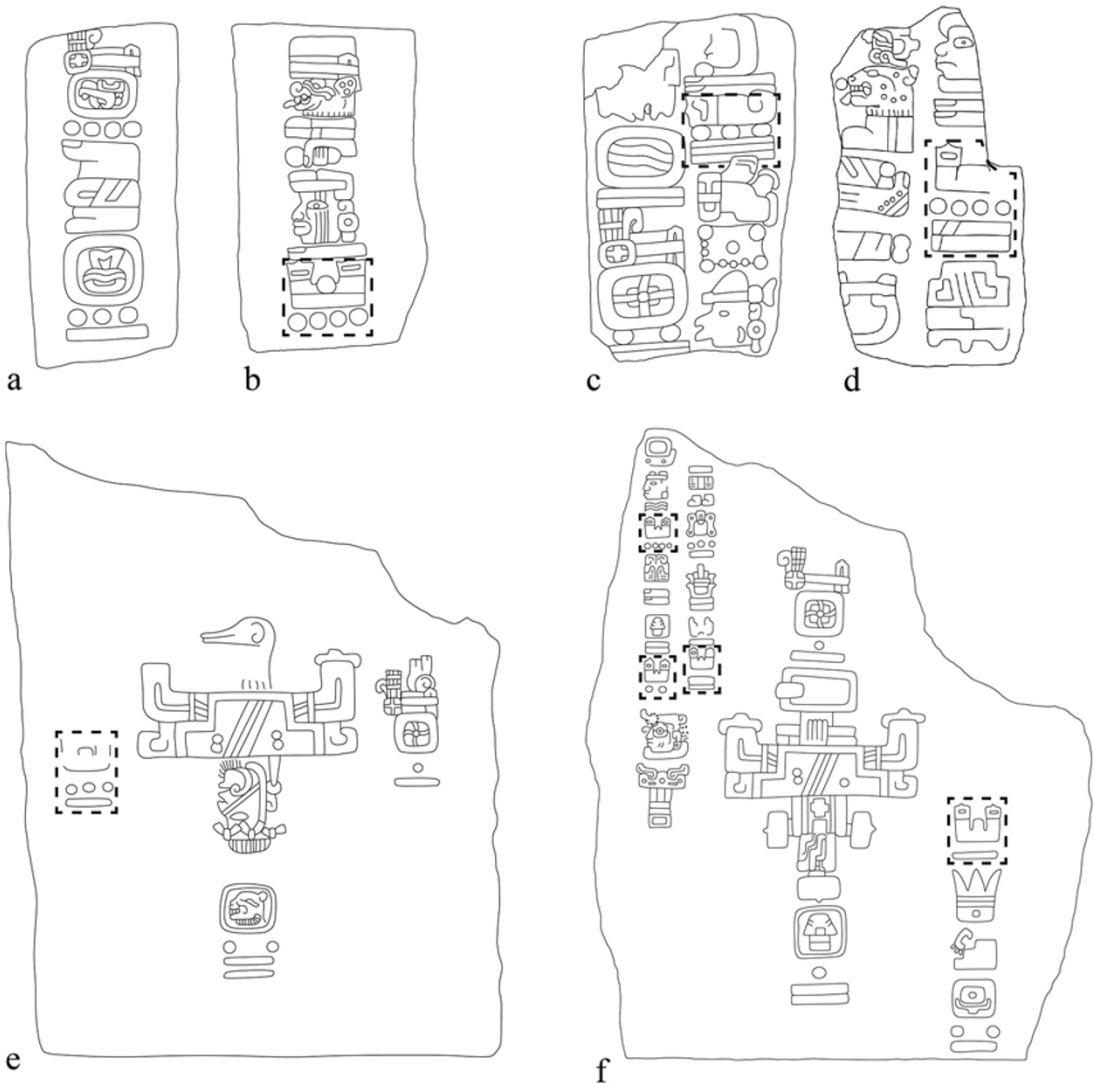


Figure 3. Inscriptions from Monte Alban, usable for calibration of the Glyph W cycle: (a) monolith D-139; (b) monolith D-140; (c) monolith M-21; (d) monolith D-142; (e) orthostat J-10; (f) orthostat J-14 (drawings courtesy of Elbis Domínguez and Javier Urcid).

99-day interval—assuming units of one day—and therefore to 2 after 91 days. Both factors of 91 (7×13) are less than Glyph W's coefficients on the monoliths, again reflecting a non-integer length of Glyph W's cycle.

We evaluated 7,401 candidate lengths, from 18 to 92 days, at intervals of 0.01 days. Each candidate was tested for its fit to intervals among three known dates with W coefficients on J-14, and, independently, to the interval between the two dates on M-21 and D-142. We averaged the estimate for each candidate across the four intervals, three from J-14 and the single interval from M-21 and D-142. Each candidate was ranked for both texts, from the closest fit at rank 1 to the greatest deviation at rank 7,401, relative to the maximum percent deviation for that candidate cycle's length (see Figure 4).

Justeson arrived at the lunar day count hypothesis in 1994, calculating the deviations across these 7,401 candidate lengths for J-14. Table 2 lists all pairs of local minima, one member from each text, for which no other local minimum lies between their values, and with the rank for both texts being in the smallest 5%—the most generous standard criterion for statistical significance. Only five intervals have ranks that meet the 5% threshold, each under 1.76% for both monuments.

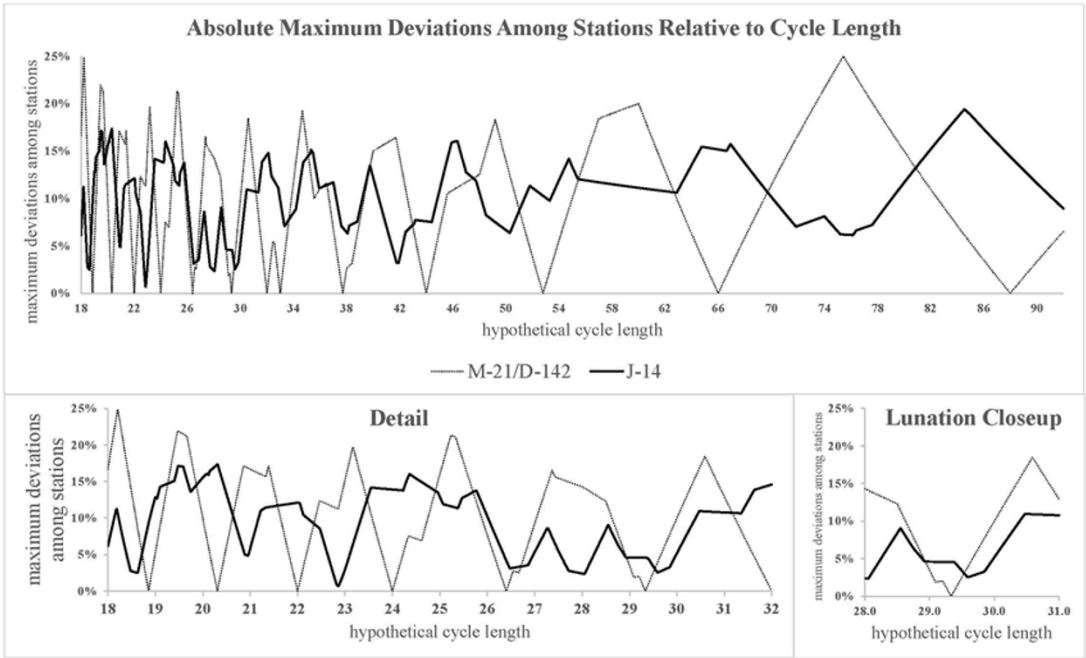


Figure 4. Deviations across 7,401 candidate intervals between 18 and 91 days. Deviations based on J-14 are in bold; those based on the monoliths are dotted.

Table 2. Distributions of Local Minima as Candidates for the Glyph W Cycle’s Length.

Source	Rank: 1 to 7401		Rank’s Weighted Average across Texts		Cycle Length Estimate (in Days)	Local Minima (in Days)	Length Estimates’ Difference	
	Num.	%	Num.	%			In Days	% of Cycle
J-14	36	0.486	36.75	0.497	18.6875	18.63	0.23	1.23
monoliths	39	0.527				18.86		
J-14	1	0.014	2.25	0.030	23.1450	22.86	1.14	4.93
monoliths	6	0.081				24.00		
monoliths	8	0.108	35.75	0.483	26.4600	26.40	0.08	0.30
J-14	119	1.608				26.48		
monoliths	20	0.270	25.75	0.348	29.5250	29.33	0.26	0.88
J-14	43	0.581				29.59		
J-14	130	1.757	97.75	1.321	50.9250	50.30	2.50	4.91
monoliths	1	0.014				52.80		

An independent criterion is how close the two estimates for a candidate are, relative to their average. The interval of about 23.145 days has by far the best average rank, 3.5 of 7,401, but its difference between texts, at 4.93% of that interval, is the worst among the candidates. An interval averaging 29.525 days has the next-best average rank, 31.5 of 7,401; its percentage of between-text discrepancy, 0.88%, is also second-best for closeness of the texts’ intervals. The only interval with closer between-text minima, averaging 26.48 days long, is fourth in average rank (63.5). Multiples of the 29.525-day interval agree closest with the 91- and 264-day intervals, at 3.0821 and 8.9416 estimated units, deviating by 0.0821 and 0.0584 units, respectively; both the arithmetic and geometric means of these deviations are the lowest among the candidates.

Furthermore, the interval of roughly 29.525 days has a meaningful interpretation: its estimates flank the 29.5306-day average length of one lunation. We therefore interpret W-1 as day 1 of the lunation, beginning at the first appearance of the lunar crescent after the new moon.

This result is predicated on 11 Reed[XIII] W-5 being day 97 of the year 6 Earthquake[XVII]. A calibration placing it on day 357 of that year produces far more (115) local minima, and its smallest between-text deviations are larger than those of the 23 local minima under the day 97 calibration, which is a more random distribution.

Only numerals 1–18 are generally recognized in Zapotec writing. However, using raking lighting, Urcid (2001:271) determined that the example of Glyph W on J-13 is followed by four rather than three numerical bars for “20”; they therefore range at least from 2 to 20 on Glyph W.

Inverted Glyph W

Three examples of Glyph W are inverted; none has a coefficient. The only such record that has fully legible year and divinatory calendar dates is 13 Monkey[XI] in a year 8 Wind[II], on J-16. If it dated in or near the same calendar round as J-10 or J-14, it would fall one calendar round plus 4,263 days before J-14's W-2 on day 162 of the year 5 Soaproot[XII]. This span produces an average abnodal shift of 2.43 days, consistent with this inverted W record registering the moon's invisibility. Alternatively, having three of 11 instances of Glyph W inverted is consistent with inverted W marking any placement in the 21st or higher day of lunar visibility: $3.550 \approx 11 - 11 \times (20/29.530586)$.

Placing Glyph W Records in Real Time

Seven calendar round placements of Glyph W records are consistent with their placement in the lunation and with Monte Alban's archaeological chronology.

Absolute Distances among Recorded Dates

A divinatory calendar date has only one or two placements in a calendar round when the year in which it occurs is known. The possible placements for the Glyph W records are as follows:

Monoliths D-139 and D-140 (Figure 3a–b):

1 Cold[XVIII] W-4, in year 4 Wind[II] = day 37 *or* 297 in year 30;

so W-1 fell on day 34 or 294 = 11 Corn[XV]

∴ W-1 fell *either* on day $29 \times 365 + 37$ *or* $29 \times 365 + 297$ in some calendar round.

Monoliths M-21 and D-142 (Figure 3c–d):

2 Face[XX] W-18 and 2 Face[XX] W-14, in year 12 Earthquake[XVII] = days 4 and 264 in year 25;

so W-1 fell on 11 Night[III] in year 11 Soaproot[XII] = day 352 in year 24

and on 2 Deer[VII] in the next year, 12 Earthquake[XVII] = day 251 in year 25

∴ W-1 fell on day $23 \times 365 + 352$ *and* on day $24 \times 365 + 251$, in the same calendar round.

Orthostat J-10 (Figure 3e):

12 Jaguar[XIV] W-8 in year 6 Earthquake[XVII] = day 98 or 358 in year 45;

so W-1 fell on 5 Deer[VII] = day 91 or 351 in year 45

∴ W-1 fell on day $44 \times 365 + 91$ *or* on $44 \times 365 + 351$ in some calendar round.

Orthostat J-14 (Figure 3f):

10 Reed[XIII] W-2 in year 5 Soaproot[XII] = day 162 in year 44;

so W-1 fell on 9 Soaproot[XII], day 161

5 Soaproot[XII] W-10 in year 5 Soaproot[XII] = day 261 in year 44;

so W-1 fell on 9 Night[III], day 252

11 Reed[XIII] W-5 in year 6 Earthquake[XVII] = day 97 in year 45;

so W-1 fell on 7 Water[IX], day 93

∴ W-1 fell on day $43 \times 365 + 161$ *and* on day $43 \times 365 + 261$, *and* on day $44 \times 365 + 93$ in the same calendar round.

Table 3. Spans between Recorded Dates, Separated by Multiples of 29.530586 Days after Adjusting to W 1.

Text	Date	Day of Year (1 to 365)	Year (1 to 52)	Cumulative Span from D-139's Date	Calendar Round at W-1	Intervals between W-1's	Cumulative Span from D-139's W-1	Cumulative Offsets in Lunation
D-139, 140	1 Cold[XVIII] W-4, year: 4 Wind[II]	37	30	10,622	10,619			
M-21	2 Face[XX] W-18, year: 12 Earthquake[XVII]	4	25	46,724	46,707	36,088	36,088	1.623908
D-142	2 Face[XX] W-14, year: 12 Earthquake[XVII]	264	25	46,984	46,971	264	36,352	-0.151366
J-10	12 Jaguar[XIV] W-8, year: 6 Earthquake[XVII]	358	45	92,338	92,331	45,360	81,712	0.868538
J-14	10 Reed[XIII] W-2, year: 5 Soaproot[XII]	162	44	110,757	110,756	18,425	100,137	-1.217126
J-14	5 Soaproot[XII] W-10, year: 5 Soaproot[XII]	261	44	110,856	110,847	91	100,228	1.191116
J-14	11 Reed[XIII] W-5, year: 6 Earthquake[XVII]	97	45	111,057	111,053	206	100,434	0.477014

Note: 1 XVIII W 4 assigned to day 37 of year II 4.

A day 1 Cold[XVIII], recorded on D-139/D-140, has two possible placements in year 30: day 37 and day 297. Counted from day 37, the 2 Face[XX] dates of M-21 and D-142 agree to within one day with the recorded lunar day count; counted from day 297, they would be seven days too late. 1 Cold[XVIII] therefore fell on day 37 in year 30.

On the orthostats, J-14 records 11 Reed[XIII] W-5 in a year 6 Earthquake[XVII]; also in a year 6 Earthquake[XVII], J-10 records 12 Jaguar[XIV] one day later in the divinatory calendar, with W-8. With 11 Reed[XIII] on J-14 secured at day 97, had J-14's events been earlier than J-10's, shifting forward from W-5 to W-8 on 12 Jaguar[XIV] would require $156 \times 365 + 261$ days; with J-10 earlier, W-5 is reached from W-8 after $51 \times 365 + 259$ days. The J-14 text is far longer and more detailed than that of any other orthostat; the terser texts seem to be background historical material, with the elaborate forthcoming text on J-14—recording the repeated ceremonial seating of two named individuals—being the focal monument closest to contemporaneous with its initial erection. For more detail, see the section, “Determining the Real-Time Placements of Zapotec Dates with Glyph W.”

There are 21 interstation intervals among the seven W-1 stations in Table 3. The variation relative to an average lunation ranges from -2.088 days for the 18,425-day interval between stations at 46,707 and 110,756 days, to $+2.408$ days for the 91-day interval between station 110,756. Four and a half days exceed the observational range for first appearances (see the later discussion); two systematic factors account for the excess.

The hour when days in the Zapotec year advanced is unknown. Among twentieth-century Ixils, it advanced at midnight in some Mije communities, whereas the divinatory calendar advanced “when the sun is overhead” (Lipp 1991:62); the Zapotec divinatory calendar also advanced at noon in the sixteenth century (Córdova 1578:212). The divinatory calendar advanced before the year in Classic Lowland Mayan communities as well (Mathews 2001:405–407).

Cases and colleagues (2004) demonstrated that the Classic Mayan lunar day count began with the first appearance of the lunar crescent. Following the moon's disappearance, its crescent is first observable, briefly, just after sunset; at Monte Alban, this occurred on average around 6:44 pm locally (see the later discussion on lunar first appearances).

With the divinatory calendar date changing at noon, its date is the same for a morning event as for the lunar first appearance the evening before; starting at noon after the first appearance, the same day in the lunation advances one day later in the divinatory calendar. Accordingly, if the first day of the lunar day count begins with the first observable lunar crescent, we will mistakenly project lunar dates from divinatory calendar dates of afternoon events one day later than from those of morning or evening events. Because we calibrate to the lunar first appearance, our calculations from afternoon events for what are actually sunset events are one day too late.

Our calibrations confirm that the next-to-last divinatory calendar date on J-14 falls on the year's 261st day, the year-bearer's return, which is likely the event that the text records. Because the divinatory calendar advanced that afternoon, this date guides our interpretation of the model's calibration results to the actual dates of the lunar first appearance.

This factor accounts for just one day of deviation of the Glyph W record from first-appearance data; negative offsets of more than one day require an additional factor. Another systematic reason for a projected W coefficient being too large is daykeepers' delay in observing the crescent. From the plaza at Monte Alban, at the highest elevation in its region, nothing blocked observation of its western horizon; the only systematic basis for delays is atmospheric interference. Such delays would be sporadic.

Between 650 and 50 BCE, data summarized in the next section show that every interval between successive first appearances at Monte Alban was 29 (46.94%) or 30 (53.06%) days long. This would be the full range of daykeepers' observationally reliable experiences, so at most one day of deviation is plausibly attributable to delayed observation. Therefore,

- Candidates with cumulative deviations of -3 or -4 days, from the earliest date to any station, must be rejected.

- Candidates with cumulative deviations of -2 days can be due to delayed observation if and only if the recorded event occurred in the afternoon, the first appearance of the lunar crescent occurred 29 days after its prior first appearance, and the lunar crescent was not observed on that date, an offset of maximally 30 hours.
- Candidates with cumulative deviations of -1 day are acceptable. If the candidate's actual first appearance took place 30 days after the previous one, it must be interpreted as an afternoon event; otherwise, it could have been an afternoon event or delayed observation, but not both.
- Candidates with positive deviations, indicating observation prior to the event, must be rejected.

Resolving Additional Glyph W Records

Given the calibration's results, its W-20 record is consistent only with 5 Cold[XVIII] in year 3 Wind[II] of the calendar round before J-14. Projecting from 10 Reed[XIII] W-2 in year 5 Soaproot[XII], with no offset, its expected W coefficient is 19.009, an offset of -1 day.

The earliest date on J-14 places a unique day sign with trecena position 2 on W-4. If it occurred in the same year as J-14's next two dates, its W-4 record is consistent only with Iguana[IV]. There is iconographic support for this placement: its features agree most closely with the snout and the hard-palate markings on the sculptured 10 Iguana[IV] date of the entrance to Tomb 5 at Cerro de la Campana (Urcid 1992:Figure 4, 2015:Figure 5a).

Determining Appearances of the Moon at Monte Alban, 650–50 BCE

Caldwell and Laney (2001) provide a reliable empirical model characterizing the conditions under which a lunar crescent is first observable on the western horizon. Limits for young crescents' visibility are affected by astronomical and optical properties, such as interference from the setting sun (Caldwell and Laney 2001:16) and the Danjon limit—the smallest elongation angle between the sun and moon at which a lunar crescent can be seen (Fatoohi et al. 1998:Figure 2). The main issues in observing the developing crescent relate to environmental and empirical limitations, such as weather, altitude, latitude, and human physiology (Schaefer 1988:520–522). External conditions aside, the crescent is observable within three days after the new moon.

Caldwell and Laney (2001:17–20) established a systematic pattern for crescent observability after reviewing predictive models for characterizing the timing of the lunar crescent's first appearance by naked-eye observation and the data on which they are based (Caldwell and Laney 1999, 2001). Krauss (2012) applied Caldwell and Laney's characterization of these conditions to a corpus of 209 records of the moon's first appearance at Babylon and found that 206 (98.5%) conform to their model.

We determined that the following equation accurately distinguishes every example that Caldwell and Laney (2001) evaluate as observable under clear viewing conditions and that can be accurately distinguished to within a fraction of a degree from every example they evaluate as not observable:

$$\text{lunar elevation} > 1.67 \times \sin \left((\text{lunar azimuth} - \text{solar azimuth}) \times \frac{\pi}{21} \right) + 3.55$$

Lowry applied this criterion to determine the dates of the 8,052 lunar first appearances at Monte Alban from 650 through 0 BCE, extracting data on solar and lunar positions at 10-minute intervals from 23:30 to 2:00, Greenwich time, using Horizon Systems (Giorgini et al. 2022), the Jet Propulsion Laboratory's online query system. For each day selected by this formula, two records were produced that were 10 minutes apart: one before and one after the sun reached -4° elevation. Each record specifies the difference in lunar and solar azimuths, the lunar elevation above the horizon, and the solar-lunar-observer elongation angle; each pair among these intervals was interpolated to match a solar elevation at -4° . For difficulties detecting a young crescent moon, see Schaefer (1988), Doggett and Schaefer (1994), and Krauss (2012).

Determining the Real-Time Placements of Zapotec Dates with Glyph W

A viable placement of the seven Glyph W dates with dates in the Zapotec divinatory calendar and a 365-day year must be consistent with the constraints on offsets from the calibrated placements of W-1: all

discrepancies in cumulative spans across the seven stations must be nonpositive, and negative discrepancies must be at most two days. Thousands of rejected sequences have positive cumulative deviations, and hundreds have negative deviations of -3 or -4 days; only seven satisfy the constraints (Table 4). All seven are consistent with archaeological chronology: the monoliths' stations fall before 360 BCE, and the orthostats' stations thereafter. However, only one turns out to be consistent with established features of Mesoamerican calendar histories.

The span from the earliest date, on monolith D-142, to the latest, on orthostat J-14, is 175 years and five months. This interval approximates the range of dates between the construction phases of buildings in the Danibaan/Monte Alban Ia and Pe/Monte Alban Ib phases.

Mound J's first incarnation is associated with the very beginning of the Pe/Monte Alban Ib archaeological phase, about 300 BCE (Elson 2012:16). The orthostats along the bottom level of Mound J—including J-14, J-10, and J-13—were found in situ but not in the primary context (Urcid and Joyce 2014:151) associated with the third building phase of this often-refurbished building (Urcid 2011:183, Figure 14, 184, Figures 15 and 17).

The two monoliths bearing Glyph W records from Building L-sub were produced “by circa 400 BCE” (Urcid and Joyce 2014:151) and reliably between 450 and 350 BCE. Our analysis places them in 397 BCE (see Table 4), a result predicated on the traditional view that together they form a single text. Because Urcid (2011:183–184, Figures 14 and 15) treats them as separate texts, the Appendix provides detailed evidence for the traditional interpretation.

Urcid and Joyce (2014:151) attribute the inscribed Mound J orthostats to a demolished building of the Pe/Monte Alban Ib phase (300–100 BCE); given the ± 50 -year reliability of these limits, the latest absolute date from these texts—11 XIII[Reed] in year 6 XVII[Earthquake]—must fall no later than 50 BCE. All seven candidate placements for the earliest of the orthostats' dates on J-10 fall between 356 and 243 BCE.

Urcid and Joyce (2014:151) conclude that the five-sided Mound J may also date to this phase, but that the orthostats facing it came from an older four-sided building that was demolished for Mound J's construction. We suggest, however, that J-14, the latest and most elaborate text, was designed for a five-sided building. J-14's text differs from those of all other orthostats, which have a single date if any and, at most, a minimal text; in contrast J-14 has a long four-sentence text, with each sentence referring to a dated event. Justeson and Kaufman (2011) read the sentence concerning the return of the year-bearer, 5 Soaproot[XII], as stating that two named individuals “were repeatedly—five times—in a seated position” (some descendant of proto-Zapotec **ka:ʔyuʔ v'i+sok^wa*, **ka:ʔyuʔ* meaning “five,” *v'i+* being an aspect marker for repeated/“habitual” actions, and **sok^wa* the verb “[to be] seated”). The passage suggests that ceremonies relating to the five-sided building or its venue were already underway or that the text and building were designed for staging such a ceremony.

An independent criterion for evaluating the candidates is their relationship to Zapotec calendrical practices documented after the Spanish invasion of Mesoamerica. The correlation of the colonial Zapotec calendar round with the Gregorian calendar agrees precisely with that of the colonial Aztec system at Tlatelolco in AD 1508 (Justeson and Tavárez 2007:37–38, 66; see also 41, 42, 46, 48). Building on work by Jiménez Moreno (1961) and Kirchhoff (1950, 1955), Calnek (2007) demonstrated that the Aztec calendar was changed in that year at the Aztec capital in Tenochtitlan, with dates in both the divinatory calendar and the vague year shifted later by 20 days from a system that until then had been synchronous with that at nearby Tlatelolco. Jiménez Moreno had shown that 10 other central Mexican communities had systems with fewer or more such adjustments to the calendar round. One interpretation—accepted, for example, by Edmonson (1988)—is that such adjustments were undertaken to maintain agricultural ceremonies, observed in a particular 20-day month, with their seasonal associations.

Calnek (2007) showed that, at the end of some calendar rounds, the last 20 divinatory calendar days were repeated, while the months advanced as usual. Although he did not endorse it as explaining the practice, an effect of such adjustments is to offset the departure of the 365-day cycle from the solar year of 365.24219 days: because 52 solar years amount to $52 \times 365.24219 = 18,992.5939$ days, after one calendar round the place of a given calendar round date falls just over $12\frac{1}{2}$ days earlier in the seasonal cycle.

Table 4. Calibrated Candidates with Complete Glyph W Records.

		Mon. 12_13 1 XII	Mon 17 2 XX	Mon. 15 2 XX	Tablet 10 12 XIV	Tablet 14 10 XIII	Tablet 14 5 XII	Tablet 14 11 XIII	Offsets in CR from
		W 4	W 18	W 14	W 8	W 2	W 10	W 5	5 XII Year 5 XII
		year 4 II	year 12 XVII	prior lunation year 12 XVII	year 6 XVII	prior lunation year 5 XII	year 5 XII	prior lunation year 6 XVII	prior lunation in 1650
Candidate 1	first appearance: intended W 1	1509555.5139 08 Dec 580 BCE	1545641.5347 26 Sep 481 BCE	29 17 Jun 480 BCE	1545906.5556 24 Aug 356 BCE	29 05 Feb 305 BCE	1609692.5347 05 May 305 BCE	29 28 Nov 305 BCE	11984.46
	time of day, and/or delayed observation		offset -2d: afternoon & delay	offset -1d: afternoon or delay	offset -2d: afternoon & delay		offset -2d: afternoon & delay	offset -1d afternoon or delay	
	inscribed date	11 Dec 580 BCE	15 Oct 481 BCE	30 Jun 480 BCE	31 Aug 356 BCE	06 Feb 305 BCE	14 May 305 BCE	02 Dec 305 BCE	
		1509558.5139	1545660.5347	1545919.5556	1591272.5486	1609693.5347	1609790.5417	1609992.5139	
Candidate 2	first appearance: intended W 1	1511179.5486 20 May 575 BCE	1547266.5417 08 Mar 476 BCE	30 27 Nov 476 BCE	1547530.5139 04 Feb 351 BCE	1592890.5347 18 Jul 301 BCE	1611316.5556 15 Oct 301 BCE	29 10 May 300	10358.48
	time of day, and/or delayed observation		offset -1d afternoon or delay	offset -1d afternoon or delay		offset -2d: afternoon & delay			
	inscribed date	23 May 575 BCE	26 Mar 476 BCE	11 Dec 476 BCE	11 Feb 351 BCE	19 Jul 301 BCE	26 Oct 301 BCE	14 May 300 BCE	
		1511182.5486	1547284.5417	1547544.5139	1592897.5347	1611317.5556	1611416.5208	1611617.5486	
Candidate 3	first appearance: intended W 1	1530551.5486 03 Jun 522 BCE	1566638.5417 22 Mar 423 BCE	30 12 Dec 423 BCE	1566903.5139 18 Feb 298 BCE	1612262.5347 31 Jul 248 BCE	1630688.5556 28 Oct 248 BCE	29 24 May 247 BCE	9966.49
	time of day, and/or delayed observation		offset -1d afternoon or delay	offset -1d afternoon or delay		offset -2d: afternoon & delay			
	inscribed date	06 Jun 522 BCE	08 Apr 423 BCE	25 Dec 423 BCE	26 Feb 298 BCE	01 Aug 232 BCE	08 Nov 248 BCE	28 May 247 BCE	
		1530554.5486	1566656.5417	1566916.5139	1612270.5347	1630689.5556	1630788.5139	1630989.5486	

(Continued)

Table 4. Calibrated Candidates with Complete Glyph W Records. (Continued.)

		Mon. 12_13 1 XII	Mon 17 2 XX		Mon. 15 2 XX	Tablet 10 12 XIV		Tablet 14 10 XIII	Tablet 14 5 XII		Tablet 14 11 XIII	Offsets in CR from	
		W 4	W 18		W 14	W 8		W 2	W 10		W 5	5 XII Year 5 XII	
		year 4 II	year 12 XVII	prior lunation	year 12 XVII	year 6 XVII	prior lunation	year 5 XII	year 5 XII	prior lunation	year 6 XVII	prior lunation	in 1650
Candidate 4	first appearance:	1530935.5556	1567021.5417	29	1567287.5208	1612646.5417		1631072.5486	1631161.5139	29	1631368.5556	29	9582.49
	intended W 1	22 Jun 521 BCE	09 Apr 422 BCE		31 Dec 422 BCE	09 Mar 297 BCE		19 Aug 247 BCE	16 Nov 249 BCE		11 Jun 246 BCE		
	time of day, and/or delayed observation		offset -2d: afternoon & delay		offset -1d afternoon or delay		offset -2d: afternoon & delay		offset -1d afternoon or delay				
	inscribed date	25 Jun 521 BCE	28 Apr 422 BCE		13 Jan 421 BCE	17 Mar 297 BCE		20 Aug 247 BCE	27 Nov 247 BCE		16 Jun 246 BCE		
		1530938.5556	1567040.5417		1567300.5208	1612654.5417		1631073.5486	1631172.5139		1631373.5556		
Candidate 5	first appearance:	1540001.5417	1576087.5347	29	1576352.5208	1621712.5208		1640138.5556	1640227.5417	29	1640435.5417	516.46	
	intended W 1	17 Apr 496 BCE	03 Jun 397 BCE		26 Oct 397 BCE	02 Jan 272 BCE		15 Jun 222 BCE	11 Nov 195 BCE		08 Apr 221 BCE		
	time of day, and/or delayed observation		offset -1d afternoon or delay		offset -1d afternoon or delay	offset -1d afternoon or delay		offset -2d: afternoon & delay					
	inscribed date	20 Apr 496 BCE	21 Jun 397 BCE		09 Nov 397 BCE	10 Jan 272 BCE		16 Jun 222 BCE	23 Sep 222 BCE		12 Apr 221 BCE		
		1540004.5417	1576105.5347		1576366.5208	1621720.5208		1640139.5556	1640238.5417		1640439.5417		

(Continued)

Table 4. Calibrated Candidates with Complete Glyph W Records. (*Continued.*)

		Mon. 12_13 1 XII	Mon 17 2 XX	Mon. 15 2 XX	Tablet 10 12 XIV	Tablet 14 10 XIII	Tablet 14 5 XII	Tablet 14 11 XIII	Offsets in CR from				
		W 4	W 18	W 14	W 8	W 2	W 10	W 5	5 XII Year 5 XII				
		year 4 II	year 12 XVII	prior lunation	year 12 XVII	year 6 XVII	prior lunation	year 5 XII	year 5 XII	prior lunation	year 6 XVII	prior lunation	in 1650
Candidate 6	first appearance: intended W 1	1550307.5556 05 Jul 468 BCE	1586394.5417 24 Apr 369 BCE	30	1586659.5278 14 Jan 368 BCE	1632018.5417 22 Mar 244 BCE	1650444.5417 02 Sep 194 BCE	1650533.5139 30 Nov 194 BCE	29	1650740.5556 25 Jun 193 BCE	29	9190.49	
	time of day, and/or delayed observation		<i>offset -1d afternoon or delay</i>		<i>offset -1d afternoon or delay</i>		<i>offset -2d: afternoon & delay</i>	<i>offset -1d afternoon or delay</i>					
	inscribed date	08 Jul 468 BCE	12 May 369 BCE		27 Jan 368 BCE	30 Mar 244 BCE	03 Sep 194 BCE	11 Dec 194 BCE	30 Jun 193 BCE				
		1550310.5556	1586412.5417		1586672.5278	1632026.5417	1650445.5417	1650544.5139	1650745.5556				
Candidate 7	first appearance: intended W 1	1550691.5556 24 Jul 467 BCE	1586777.5486 11 May 368 BCE	29	1587043.5347 01 Feb 367 BCE	1632401.5417 09 Apr 243 BCE	1650828.5347 21 Sep 193 BCE	1650917.5139 19 Dec 193 BCE	29	1651124.5556 13 Jul 192 BCE	29	8806.49	
	time of day, and/or delayed observation		<i>offset -2d: afternoon & delay</i>		<i>offset -2d: afternoon & delay</i>		<i>offset -2d: afternoon & delay</i>	<i>offset -1d afternoon or delay</i>					
	inscribed date	27 Jul 467 BCE	30 May 368 BCE		14 Feb 367 BCE	18 Apr 243 BCE	22 Sep 193 BCE	30 Dec 193 BCE	18 Jul 192 BCE				
		1550694.5556	1586796.5486		1587056.5347	1632410.5417	1650829.5347	1650928.5139	1651129.5556				

Note: Calibrations of spans between recorded intervals among dates of the first visibility of lunar crescents at Monte Alban. Bolding in this table was added to emphasize dates, while italics are used for comments or notations on observational issues (time of day or delayed observation).

After two calendar rounds, it falls nearly $25^{3/16}$ days earlier; the 20-day addition would reduce the offset to $5^{3/16}$ days.

Only one of the seven candidate chronologies in [Table 4](#) is offset by such adjustments from the colonial Zapotec placement of the first day of a calendar round. A year 11 Earthquake began on February 23, 1695 (Justeson and Tavárez 2007:25–26); the first day of its calendar round would have fallen on March 4, 1659. For the candidate set spanning 496 to 221 BCE, the offset from the prior calendar round base to the 1659 base is 516.46 days. Accumulated corrections totaling 520 days entail 26 adjustments. Thirty-seven calendar rounds separate the calendar round base preceding the latest Glyph W record from the 1659 Zapotec calendar round base.

Optimally, five of eight calendar rounds should be 19,000 days long, just 0.751 days short of $8 \times 18,992.59388$ days; to maintain a correlation with the seasons, 26 calendar rounds of 19,000 days would be optimal after 41 or 42 calendar rounds. Forty-two calendar rounds reach the 1659 base from the 528 BCE base date of the calendar round in which the earliest of the attested Monte Alban lunar day counts occurs. Although a 19,000-day calendar round might be expected among the three completed calendar rounds of our calibration, no such model yields any viable candidate series. The 26 adjustments of the successful calibration must have occurred during the 36 calendar rounds between 212 BCE and CE 1659, which are three adjustments more than optimal.

Based on Jiménez Moreno's data, 26 adjustments across 36 calendar rounds fall within the range of variation for this practice over this span. He showed that the first day of calendar rounds in 10 Central Mexican communities ranged minimally 180 days apart, reflecting a difference of at least nine adjustments from their common source—most likely near the loosening of Teotihuacan's control of central Mexico around AD 550, 18 or 19 calendar rounds before 1508 (optimally 11 or 12 adjustments). The attested range of variation is therefore at least ± 4 of 18 or 19 calendar rounds; the two or three of 37 for the 496–221 BCE candidate of [Table 4](#) fall well within this range: this independent evidence supports this placement of the Monte Alban records.

The next closest offset among candidates, 8,807 days, would entail an impossible 440 20-day adjustments in 36 calendar rounds. This secures the candidate series from 496 to 221 BCE as the era of the Glyph W records, spanning four calendar rounds: the first beginning on October 1, 528 BCE on 1 Earthquake, and the last ending on January 3, 213 BCE.

Conclusion

Monte Alban's texts document the antiquity of lunar day counts in Mesoamerica 857 years before they were previously known to scholarship. The closest parallel to the Zapotec lunar day count is one surviving in hundreds of Mayan hieroglyphic texts. Guthe (1921) recognized lunar day counts—day counts within a lunation embedded in a cycle of six or occasionally five lunar months—in the “Lunar Series” recorded on stone monuments of the Mayan Classic period. Ignacio Cases recognized the earliest example, dated AD August 1, 361, on Naachtun Stela 23, produced by a Teotihuacan-associated military takeover of Mayan centers (Nondédéo et al. 2019:62).

The only plausibly earlier Mayan lunar record appears on a looted stela in the John Hauberg collection. A consensus agrees with Schele and colleagues' (1990) interpretation of its recorded date as falling in AD 197. Justeson would place it in AD 98 CE, yet either placement supports a conclusion that it was the Teotihuacanoid invasion that introduced Mayan lunar day counts into Mayan lunar dates.

Appendix: M-21 and D-142 as a Single Text

The most thorough, detailed, and definitive research on Zapotec hieroglyphic writing was conducted by Javier Urcid. Nonetheless, we follow Caso in treating monoliths M-21 and D-142 (aka Stela 17 and 15, respectively), which are regularly published together, as forming a single connected text, whereas Urcid interprets them as presenting distinct narratives.

This issue is relevant to cycle-length calibration. Intervals among Glyph W dates are key to determining the length of the cycle; texts with multiple dates are required to determine intervals. In our analysis, two texts with multiple dates provided independent calibrations of the cycle; comparing their results,

the lunation emerges, unambiguously, as its length. This appendix presents internal evidence that the two monoliths form a single text.

Circumstantial Evidence

Five divinatory calendar records survive from the Danibaan/Monte Alban Ia phase: 10 Water[IX] and 2 Face[XX] on M-21, 8 Water[IX] on D-139, 1 Cold[XVIII] on D-140, and 2 Face[XX] on D-142. The 10 Water[IX] and 8 Water[IX] records are not accompanied by Glyph W. Justeson and Kaufman analyze these as the names of individuals. For example, 10 Water[IX] is the second sign in its column, following a single sign depicting a downward-facing human head and preceding a year name. With no verb prefix, it must be an equational sentence: “10 IX is [downward-facing-head].” This construction is unknown among dates with Glyph W. However, indigenous Mesoamericans, including Zapotecs, were conventionally named for the divinatory calendar date of their birth. With this 10 Water[IX] referring to a person, the downward-facing head glyph would state a property of that person—plausibly, being a sacrificial victim. The other two divinatory calendar records on these monoliths are clearly dates, immediately preceding Glyph W. If D-142 were not a continuation of M-21, its divinatory calendar + Glyph W record would be the only instance during the era of Glyph W notations that is not anchored in its text by a year name.

The recurrence of the same divinatory calendar date is not plausibly a coincidence; the probability that two or more of five unrelated divinatory calendar dates would recur by chance is

$$1 - (260/260) \times (259/260) \times (258/260) \times (257/260) \times (256/260) = 3.795\%.$$

Because the two 2 Face[XX] events occurred on days 18 and 14 in the lunation, they must have taken place on different dates. Falling on the same day of the divinatory calendar, in a single text with no other dates, they would have had related significance as occasions of related ritually scheduled events.

Glyph W’s coefficients are consistent with this interpretation. The day 2 Face[XX] occurs twice in year 12 Earthquake[XVII]. Its placements at W-18 and W-14 are viable as placements in their lunations during that year, on days 4 and 264: if the earlier event occurred in the afternoon and the second in the evening or morning, 34.32% (2,760/8,043) of nine-lunation intervals in the Horizon data are consistent with this interval.

Direct Evidence

If the two monoliths did not constitute a single text, M-21 would be the only monument with a Glyph W record that is not anchored in a specified year, and the chance that Glyph W would happen to be at a position within ± 1 day of the lunar shift after 260 days would be roughly $2/27 \approx 7.4\%$. Coincidence is therefore implausible. Together, M-21 and D-142 constitute an almost literal copy of the text on Danzante 55; neither part appears in any other text (Figure 5).

The three-sign sequence that begins the text on the torso of the danzante (##4–6 on Figure 5) are the last three signs on M-21. It contains no sign recognized by Justeson and Kaufman as spelling an aspect-marking proclitic, which is required on verb stems; if the text on M-21 does not continue on another monument, this passage must be an equational sentence on both the monolith and the danzante. This shared sign sequence occurs in no other text; Urcid (2011:Figure 15) highlights this textual agreement.

On the danzante, two more signs (##7–8 in Figure 5) follow the three-sign sequence shared with M-21; the second is identifiable, by comparison with Mayan glyphs, as a logogram for being in a seated position (Justeson 1986:449; Justeson and Mathews 1990:97), which is associated with a person’s status as ruler. This logogram must spell the local descendant of the proto-Zapotec verb root **sok^wa* “to be seated” (i.e., “to be in a seated position”). Verb words in Zapotec begin with an aspect marker, indicating whether the action of the verb is completed, habitual, or potential: here, “was seated,” “was repeatedly seated,” or “could be seated.” This is consistent with the beginning of a sentence: in Zapotec languages, in the basic and by far most common word order, the verb precedes the subject (noun phrase or pronoun), which precedes an object if present. Because Urcid (2011:216) interprets the angle of the figure’s legs on this and other danzantes as depicting a squatting position, it is consistent to treat the hieroglyphic

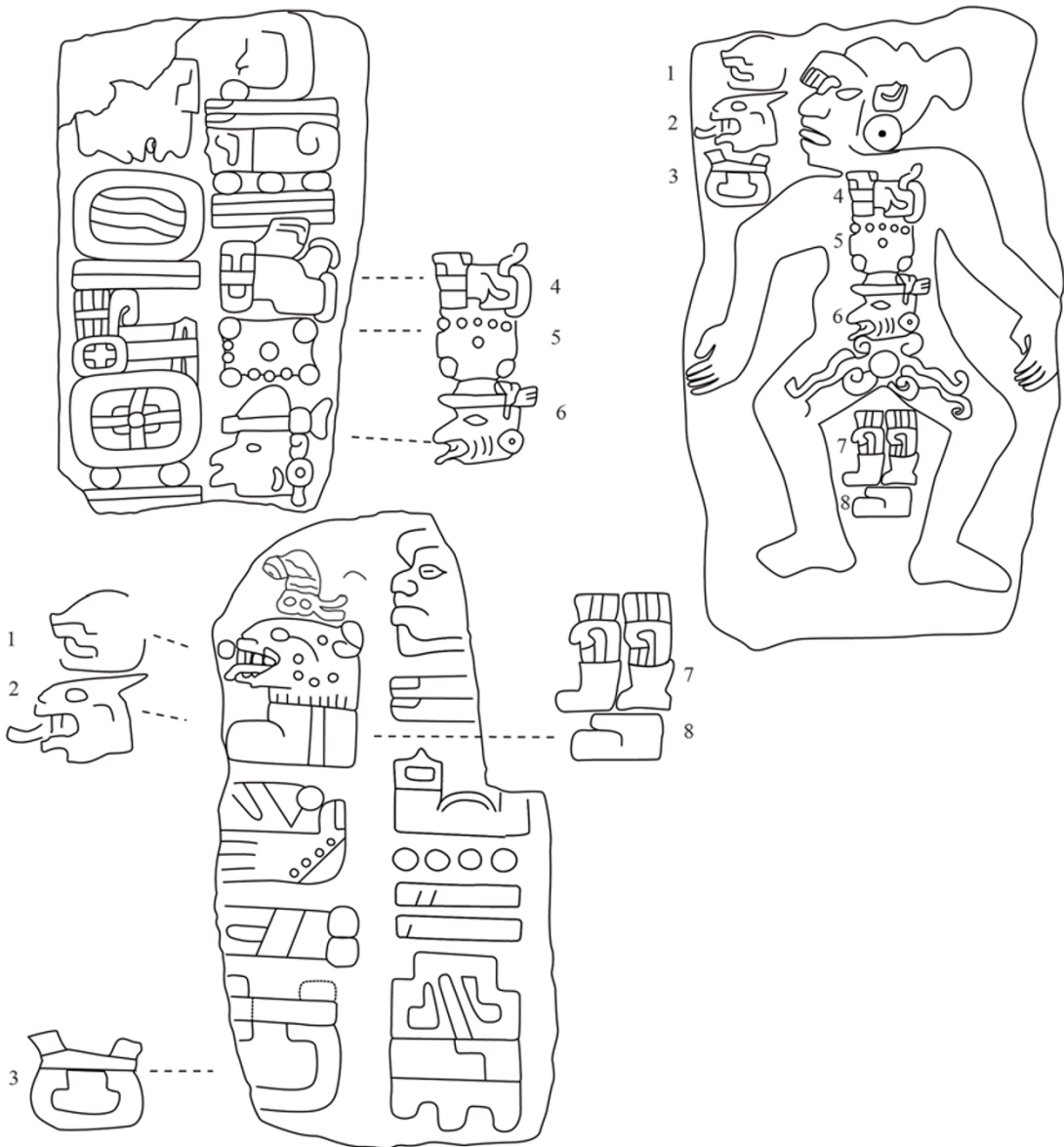


Figure 5. Correspondences between danzante 55 and monoliths D-142 and M-21 (drawings adapted from Urcid [2001] and courtesy of Elbis Domínguez and Javier Urcid).

sentence as describing the accompanying image. This analysis supports the interpretation of the three-sign sequence (##4–6) preceding this verb as a complete sentence on the danzante, and therefore in the identical passage ending M-21.

On the danzante, a column of three glyphs (##1–3 in Figure 5) begins in front of the figure’s face: first, the head of an animal; next, the head of another animal with spotted fur, a fringed neckline, and tongue protruding; and, finally, a “bag” or “bundle” sign. Urcid (2001:417–24, 2011:185–86) notes that the bag sign frequently ends phrases associated with prominent individuals, as in this case. Justeson and Mathews (1990:109) had noted the co-occurrence of the Zapotec bag sign with that for being seated, relating it to the association of bundles in Mayan art and texts with rulers’ accessions. It also occurs within the year-name headgear logogram for “ruler” in spelling “Lord 10 Earthquake[XVII]” on Monolith 7V-6 (Urcid 2001:Figure 4.28).

Zapotec texts, like later epi-Olmec and Mayan texts, were read toward glyphs' faces, so the signs to the figure's left were read before those on its torso. Because Zapotec word order is normally verb-initial, they likely spell an equational sentence, "So-and-so is lord," or a caption labeling this person. The text along the torso therefore ends with the "be seated" logogram. Verb-final position is unusual in Zapotec but is grammatical in those Zapotec languages in which a third-person subject can be referenced with a "zero" (i.e., no) pronoun (Terrence Kaufman, personal communication 1999), with the preceding material being a separate sentence or an adverbial expression. The sign labeled 4 in [Figure 5](#) is consistent with a person's headgear (Urcid 2001:Figures 4.47 and 4.48), so signs 4–6 seem to spell a noun phrase or an equational sentence. If it is a noun phrase, it could spell an equational sentence with the name/caption to the figure's left: "so-and-so, lord, is ruler X Y"

D-142 begins with a sign depicting a penis + scrotum ([Figure 6](#)), also found on orthostat J-26; this is followed by the spotted animal sign, with protruding tongue and fringed neckline, as on the *danzante*. Based on its similarity to the *danzante* caption, Justeson (1986:450, [Figure 7](#)) mistakenly interpreted the monolith's three-sign sequence as exemplifying an ungrammatical subject-verb word order. Terrence Kaufman (personal communication 1992) rejected this analysis, given the absence of any sign for an aspect marker, which is required before verbs. Lacking a prefix, a verb logogram must be interpreted as a participle. Most participles are derived from a verb by preposing **na*+, for which a syllabogram should precede the verb logogram; however, the participle of **sok*^h*a* "to be seated" is one of the few consisting of the verb alone. Kaufman's analysis agrees with Zapotec word order and is paralleled by another example of the same participle construction on *danzante* M-4 (Justeson and Kaufman 2011). The D-142 passage therefore conveys that the person named in the *danzante* caption is "seated, verb(s/ed) as lord."

Together, M-21 and D-142 present substantially the same message as D-55, and M-21 presents about the same situation as D-55. A version of D-55's name/caption appears on M-21; the clause(s) on D-55's figure occurs on D-142. Because neither passage shared with D-55 by these monoliths appears anywhere else in the corpus, the straightforward conclusion is that they express related events involving the ruler named on D-55. In our view, these identical elements demand an interpretation of M-21 and D-142 as constituting a single narrative, to be read in that order. Urcid (2011) does not address the glyphs shared by D-55 and D-142.

The monoliths show that the divinatory calendar date of the first situation described on D-55, and recorded on M-21, preceded that associated with the occasion on which Jaguar is said to be a seated lord. Similarly, the sequence of the passages on the *danzante* suggests that the seating of the ruler came after the initial situation described in its text. The differing Glyph W placements on M-21 and D-142 show that they occurred some multiple of 260 days apart. If they occurred in the same year, the first situation, whose character is currently unknown, followed the arrival of the year-bearer by just three days; the ceremonial seating of the ruler was timed like the return of the year-bearer, again, just three days later.

Finally, the basis for Urcid's (2011:Figure 15) interpretation of D-142 and D-55 as separate texts was his model for the original placements of these monuments, now displaced, on Building L: a hypothetical boustrophedon presentation, rightward on M-21 in the top third of the building; leftward on D-142 in the middle; and rightward again on the text spanning D-139, D-140, and D-141. This model cannot be correct: the reading order of D-142 violates the universal reading order in Zapotec, Mayan, and epi-Olmec texts, which is always toward the faces of day signs, and of the vast majority of other signs depicting human or animal faces.

Solving Glyph W without the Monoliths

As an alternative to the calibration results of [Table 2](#), a numerical model based solely on the J-14 text yields three potential estimates for the cycle's length. Among them, the lunation can be favored because it alone has a clear motivation, interpretation, and basis for implementation by Zapotec calendar specialists. It is also supported by the resulting correlation of J-14's dates with the seventeenth-century placement of the Zapotec 52-year cycle.

Three intervals that are recoverable from J-14 are 91, 206, and 297 (= 91 + 206) days. The largest known Glyph W coefficient is 20, so the 91-day interval is between 1 and 4.5 (= 91/20)

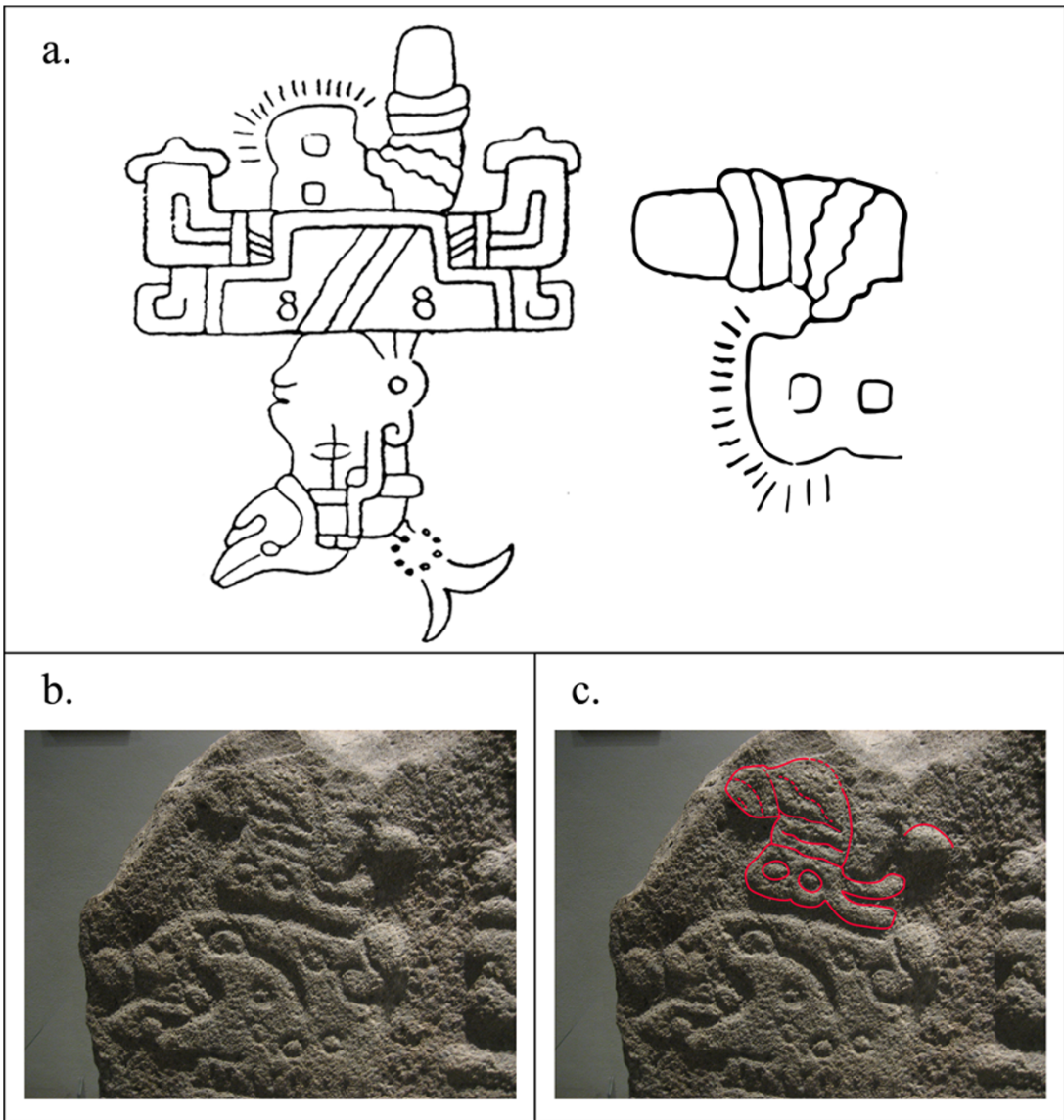


Figure 6. Penis glyph comparison from monolith D-142 and orthostat J-26: (a) orthostat J-26 with penis glyph rotated; (b) photo of glyphs in question on monolith D-142; (c) penis glyph highlighted in red. (Color online)

cycles; 206 is between 2 ($\approx 206/91$) and 10 ($\approx 206/20$) cycles, and 297 is the sum of the previous two. Five sets of estimates emerge from these comparisons (intermediate estimate is bolded and underlined):

- (1) 18.20 (91/5), **18.56** (297/16), 18.73 (206/11)
- (2) 22.75 (91/4), **22.85** (297/13), 22.89 (206/9)
- (3) 30.33 (91/3), **29.70** (297/10), 29.43 (206/7)

and, with more varied estimates,

- (4) 45.50 (91/2), **42.43** (297/7), 41.20 (206/5)
- (5) 91 (91/1), **93** (297/3), 103 (206/2)

Among these alternatives, the 29.53-day lunation stands out as a meaningful interpretation.

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Competing Interests. The authors declare none.

Note

1. Dates in this article are given in the CE/BCE chronology, the standard in astronomy, in which the year before year 1 CE is 0 BCE, rather than the journal's BCE/AD standard, in which the year before 1 AD is 1 BCE.

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