THE ROLE OF SOLAR OBSERVATIONS IN DEVELOPING THE PRECLASSIC MAYA CALENDAR

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Intervals of 260 days are recorded by architectural orientations at a number of Maya sites, a pattern that may have developed early at sites such as Nakbe. The 260-day calendar, emphasizing sets of 13 and 20 days, dates back to the Middle Preclassic, when early E-Groups in the Maya area were used for solar observations. These observations were probably linked with a maize cycle spanning 260 days. By the end of the Late Preclassic, however, most E-Groups were abandoned or modified for a different function, serving as a stage for rituals performed by rulers at a time when the Long Count calendar was being developed. The changing role of E-Groups relates to the rise of royal rituals associated with the detailed historical records documented in Maya Long Count inscriptions.

En varios sitios en el área maya se registran, a partir de las orientaciones arquitectónicas, intervalos de 260 días. Este patrón pudo haberse desarrollado de forma temprana en sitios como Nakbe, Petén, Guatemala. El calendario de 260 días, que enfatiza los conjuntos de 13 y 20 días, data del preclásico medio, cuando se utilizaron los primeros grupos conmemorativos en el área maya para realizar observaciones solares. Estas observaciones probablemente estuvieron vinculadas con un ciclo del maíz que dura 260 días. Sin embargo, a finales del preclásico tardío, la mayoría de los grupos conmemorativos fueron abandonados o modificados para servir una función diferente. Estos grupos fueron utilizados como escenarios para rituales llevados a cabo por la realeza en el periodo durante el cual se desarrolló el calendario de cuenta larga. El nuevo papel de los grupos conmemorativos se relaciona con el aumento de los rituales reales. Estos mismos son asociados con los detallados registros históricos documentados en inscripciones mayas que usan fechas de cuenta larga.

During the Middle Preclassic (1000/900–400 B.C.), specialized architectural complexes were constructed to track the changing seasonal positions of the sun along the horizon. The oldest known complex, ca. 1000 B.C., is found in the Maya area (Inomata et al. 2013:467). These are called E-Groups, based on an architectural assemblage first recognized in Group E at Uaxactun. They represent the earliest civic architecture and predate documented evidence of calendar records in Mesoamerica, suggesting that solar observations in these groups may have helped develop the calendar.

Middle Preclassic E-Groups had a pyramid on the west side facing a flat range structure to the east that served as an artificial horizon. These early range structures may have had wooden posts or stone markers to measure the movement of the sun along the horizon (Rice 2007:87, 147, 155). Archaeological evidence for markers is lacking, but these could have been impermanent, such as crossed sticks or small rocks on the surface of the structure. The orientations in Middle and Late Preclassic E-Groups emphasize the solstices, and Anthony Aveni and colleagues (2003:163) conclude that the earliest orientation calendar, well before written records, was based on solstice alignments.

E-Group structures clearly served some astronomical purpose in the evolution of the Mesoamerican calendar (Aveni et al. 2003:174). As Aveni (2002:211) notes, early Lowland Maya E-Groups concentrate in the "magic latitude," where the year can be segmented into multiples of 20 days that separate the solstices, equinoxes, and solar zeniths. These 20-day sets are an essential component of both the Mesoamerican year and the 260-day ritual calendar. With 13

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sets of 20 days, the ritual calendar apparently developed in tandem with a calendar dividing the 365-day year into 18 "months" of 20 days each and an added five-day period.

E-Groups: Changing Function Over Time

Prudence Rice (2007:147) points out that proto-E-Groups are evident in Middle Preclassic mound-plus-platform arrangements in Chiapas and in Tabasco at the Olmec site of La Venta (Str. D1 and D8). She suggests these sites had multiple markers along the platform to determine the solstices, equinoxes, and the zenith sun, when the marker would act as a gnomon and cast no shadow at noon (Aimers and Rice 2006:80, 92; Rice 2007:87). Even though the orientations differ markedly, La Venta may be the progenitor of the early E-Group at Chiapa de Corzo (Clark and Hansen 2001:4; Sullivan 2015:456), or possibly vice versa because there is evidence of shared ideas that may have come from Chiapas to La Venta in the Middle Preclassic (Milbrath 1979:44–45). The La Venta mounds are aligned 8° west-of-north, in keeping with the main orientation of the urban core, which translates into 8° north-of-east (90° minus 8°) for the east-facing pyramid (Rice 2007:81–83, Figure 5.3). The E-Group at Chiapa de Corzo also follows the primary orientation of the site (28° east-of-north), translating into 28° south-of-east for the pyramid, according to Timothy Sullivan (2015:460, Figure 4), but Aveni and Horst Hartung (2000:58, 60, Table 1) measured alignments closer to 25°, which have been confirmed by Ivan Šprajc and Francisco Sánchez Nava (2015:57, Table 3.1).

Despite widely different orientations at Middle Preclassic sites, Takeshi Inomata (2017) points out that recent studies by Michael Blake (2013) suggest the possibility that early E-Groups in Chiapas and at La Venta represent a compromise between celestial orientations and topographic landmarks, such as mountains and volcanoes. Blake found that the central axis of these E-Groups was oriented toward the winter or summer solstice sunrise, and, depending on which solstice was centered on the mound, the equinox sunrise aligned approximately with the northern or southern end of the eastern mound. Inomata concludes that these solar alignments served as generalized representations of cosmological symbolism, rather than as devices for precise solar observations. Greater precision in the solar orientations is evident in early E-Groups from the Maya Lowlands, perhaps because there were fewer topographic features on the horizon to serve as alternate sight lines.

With such an expansive horizon in the lowlands, stellar alignments should also be considered. Grant Aylesworth (2004) notes that many Maya E-Groups are aligned with the zodiacal band, a band about 18° wide centered on the ecliptic, the apparent "path" of the sun through the sky. The approximate equinox orientation of some early E-Groups is noteworthy because this alignment also marked the horizon position of Orion (ca. 1000–400 B.C.; Aveni et al. 2003:173). Orion's Belt is also considered to be significant in early orientations in the Valley of Oaxaca that display alignments similar to those at La Venta (Peeler and Winter 1992/1993; but see Šprajc and Sánchez 2015:44–52). Around 500 B.C., Orion's Belt disappeared from the sky from April 23 to June 12 (Aveni 2001:Table 10). Its annual disappearance coincided with the first maize planting, and it reemerged when the maize was sprouting (Milbrath 1999:248). A metaphorical connection between Orion's Belt and maize may have developed in Preclassic times because the first bright star in the belt became visible on the eastern horizon at dawn in early June, when the young maize sprouted. By September, when the maize matured, the three stars of Orion's Belt aligned vertically above the horizon around midnight, like a mature maize plant rising up tall and tasseled.

The recently discovered E-Group at Ceibal, Guatemala, first constructed around 1000 B.C., seems to confirm earlier suggestions that E-Groups originated in the Maya Lowlands (Clark and Hansen 2001:23; Rice 2007:203; Stanton and Freidel 2003:9, 11). This early E-Group (ca. 1000–800 B.C.) had a platform to the west and a range structure to the east, which was buried around 800 B.C. when they built a new version of the elongated platform farther to the east (Inomata et al. 2013:467–468).

Maya E-Groups were widely distributed in the Middle Preclassic, and are found at sites such as Caracol, Cenote, Cival, Nakbe, Takalik Abaj,

Table 1. Earliest Long Count Dates in Maya Region and Bordering Areas.

Earliest Long Count dates	Long Count	Tzolkin	Julian/Gregorian equivalent in 584,283 correlation	Notes on Correlation factor
Chiapa de Corzo Stela 2	[7.16.]3.2.13?	6 Ben yearbearer (Reed)	Dec. 8, 36 B.C. Julian Dec. 6, 36 B.C. Gregorian	For 584,265 Epi-Olmec correlation subtract 18 days = November 19, 36 B.C. Julian
Tres Zapotes Stela C	7.16.6.16.18	6 Etz'nab (Knife)	Sept. 3, 32 B.C. Julian Sept. 1, 32 B.C. Gregorian	For 584,265 Epi-Olmec correlation subtract 18 days = August 16, 32 B.C. Julian
El Baul Stela 1	7.19.[15.7.12]?	12 Eb	March 4, 37 A.D. Julian March 2, 37 A.D. Gregorian	A Maya style date, using 584,283 correlation
Takalik Abaj Stela 5 (left)	8.4.5.17.11	[7 Chuen]	June 4, 126 Julian June 3, 126 Gregorian	A Maya style date, calculated with 584,283 correlation.
	Alternate reading: 8.4.5.[0].17	Alternate reading: 11 Earthquake	In alternate reading: July 5, 125 Julian July 4, 125 Gregorian	Alternate reading based on presumed lack of a Uinal zero notation
Takalik Abaj Stela 5 (right)	8.2.2.10.5 or 8.3.2.10.5	[7 Chicchan] or [5 Chicchan]	August 23, 83 Julian August 21, 83 Gregorian or May 10, 103 Julian May 9, 103 Gregorian	A Maya style date, calculated with 584,283 correlation. First two dates based on damaged Katun notation
	Alternate reading: 8.3.2.[0].10	Alternate reading: 5 Coyote	Alternate reading: October 27, 102 Julian October 26, 102 Gregorian	Third date an alternate reading based on presumed lack of a Uinal zero notation
La Mojarra Stela 1	8.5.3.3.5	13 Chicchan (Snake)	May 20, 143 Julian May 19, 143 Gregorian	For 584,265 Epi-Olmec correlation subtract 18 days = May 2, 143 Julian
Tikal Stela 29	8.12.14.8.15	[13 Men]	July 6, 292 Julian and Gregorian	A Maya style date, using 584,283 correlation

and Tikal (Aveni et al. 2003:Table 1; Chase and Chase 1995; Chase et al. 2017; Clark and Hansen 2001:9, 16; Doyle 2012; Estrada-Belli 2011:52, 68–69, 74; Hansen 1998:66, 2013; Laporte and Fialko 1990, 1995). Arlen and Diane Chase (2017) point out that E-Groups represent the first form of public architecture in the Lowland Maya area. James Doyle (2012:369, 374) emphasizes that Middle Preclassic E-Groups with their broad plazas may be the earliest large-scale settings for political and community gatherings in the Maya Lowlands. People from distant areas could have gathered in accompanying plazas, where the interchange of ideas likely developed at a time when many Middle Preclassic Maya sites shared Mamon-sphere ceramics (Doyle 2012:372–374).

The Late Preclassic E-Group at El Mirador aligns to the position of the sun on the summer and winter solstices, and the Central Acropolis is aligned to sunrise on February 12 and October 30, designating a 260-day interval seen in orientations elsewhere at El Mirador. This is one of the most common alignment patterns in the Maya Lowlands (Aveni et al. 2003; González-García and Šprajc 2016:196; Šprajc et al. 2009:87–90, Table 1; Sánchez and Šprajc 2015). The solstice alignments of the El Mirador E-Group repeat at Uaxactun, but many of the E-Groups Aveni profiled show a variety of orientations. Kathryn Reese Taylor (2017) notes two patterns for E-Groups in the Karstic Uplands, home to sites such as Calakmul, El Mirador, Naachtun, Nakbe, and Yaxnohcah. One orientation group apparently tracks the Haab with alignments to dates that fall in sets of 20 days on either side of the summer solstice or zenith passage. Another less common patterning seems to commemorate the 260-day agrarian year with alignments to dates in February and October, as seen in the Middle Preclassic E-Group at Nakbe (Aveni et al. 2003:Table 1).

The Middle Preclassic E-Group at Cival is typical of these constructions, characterized by bedrock knolls forming the western and eastern structures, with the western side modified into a low platform with stairs (only partially excavated) and the eastern side modified into an elongated platform (Figure 1; Estrada-Belli 2006:63; 2011:74, 78–79, 82–83, Figure 4.1; 2016). Near the eastern range structure, a jade cache with a post marked the centerline of the platform and an axial line of 92° azimuth between the eastern and western structures. Francisco Estrada-Belli (2011) concludes that the 92° alignment may have been used to mark solar positions synchronized with the agricultural season divided into four parts at the equinoxes and solar zeniths.

True equinox orientations with a 90° azimuth (March 20/21 and September 22/23) are uncommon. More often orientations mark the quarter days (March 23 and September 21), falling halfway between the solstices (Šprajc 2015; Šprajc and Sánchez Nava 2012, 2013). It was probably easier to divide the number of days between the two solstices than to determine the exact date of the equinox. At the solstices, the sun seems to "pause" before it moves away from its northern and southern extremes on the horizon, making the solstices easier to observe than the equinoxes.

When formal constructions began to be added to the E-Group's range structure, the first phase was usually a single elevated building at the center, as at Tikal, Nakbe, Wakna, and El Mirador (Hansen 1998:66). The early E-Group at Tikal in the Mundo Perdido complex (5C-54-5) began around 700–600 B.C. with a low platform to the west bearing radial stairs and an elongated range structure to the east. The central building added subsequently is aligned to sunrise on February 24 and October 18, suggesting a link with the agrarian year (discussed below), according to Šprajc et al. (2013:1069, Table 1; but see Aveni et al. 2003:174, Table 1 for somewhat different dates). During the Late Preclassic two more buildings were added to mark the solstices (Aveni et al. 2003:174, Table 1; Laporte and Fialko 1990:Figures 3.9, 3.11, 1995).

In addition to changes in the configuration of E-Groups over time, their evolution shows changes in function. A long process of transformation for the Group E of Uaxactun is evident. Initially, during the Late Preclassic, the E-Group was a working observatory with a pyramid (E-7sub-1) facing an elongated platform to the east that marked both equinoxes and the solstice extremes. Later remodeling made the alignment astronomically nonfunctional. As Stanislaw Iwaniszewski (2002:510–511) points out, after the three temples were added to the range structure, ca. A.D. 240–550, the direct sight line of the sun on the solstices and equinoxes was obstructed. By then, the power center at Uaxactun had shifted from Group E to Group A, which became the focal point for royal rituals (Aveni 2003:161–162).

The decline of E-Groups as a focus of Maya architecture is notable between 300 B.C. and A.D. 150, when the Triadic Architectural Style associated with the rise of divine kingship became dominant (Estrada-Belli 2011:49, 56, 68, 76–77, 144; Hansen 1998, 2013:157–160). This change seems related to the origin of Maya state-level society during a period when the Long Count was in the process of formation.

Near the end of the Preclassic, many E-Groups were either abandoned or modified for other purposes. The E-Group at Cival was last modified around A.D. 100 and thereafter was left to decay (Estrada-Belli 2011:64–65). Other E-Groups at sites like Tikal and Calakmul were transformed into stages for royal rituals in the Early Classic (Dowd 2015). Many E-Groups were maintained for use in public gatherings during the Early Classic (Doyle 2012:363). These "modified" E-Groups dating from the Late Preclassic to Early Classic were apparently also used for rituals commemorating longer periods of time, especially the Katun cycle, a period approximating 20 years (Aimers and Rice 2006:87, 90–92; Estrada-Belli 2011:79–80).

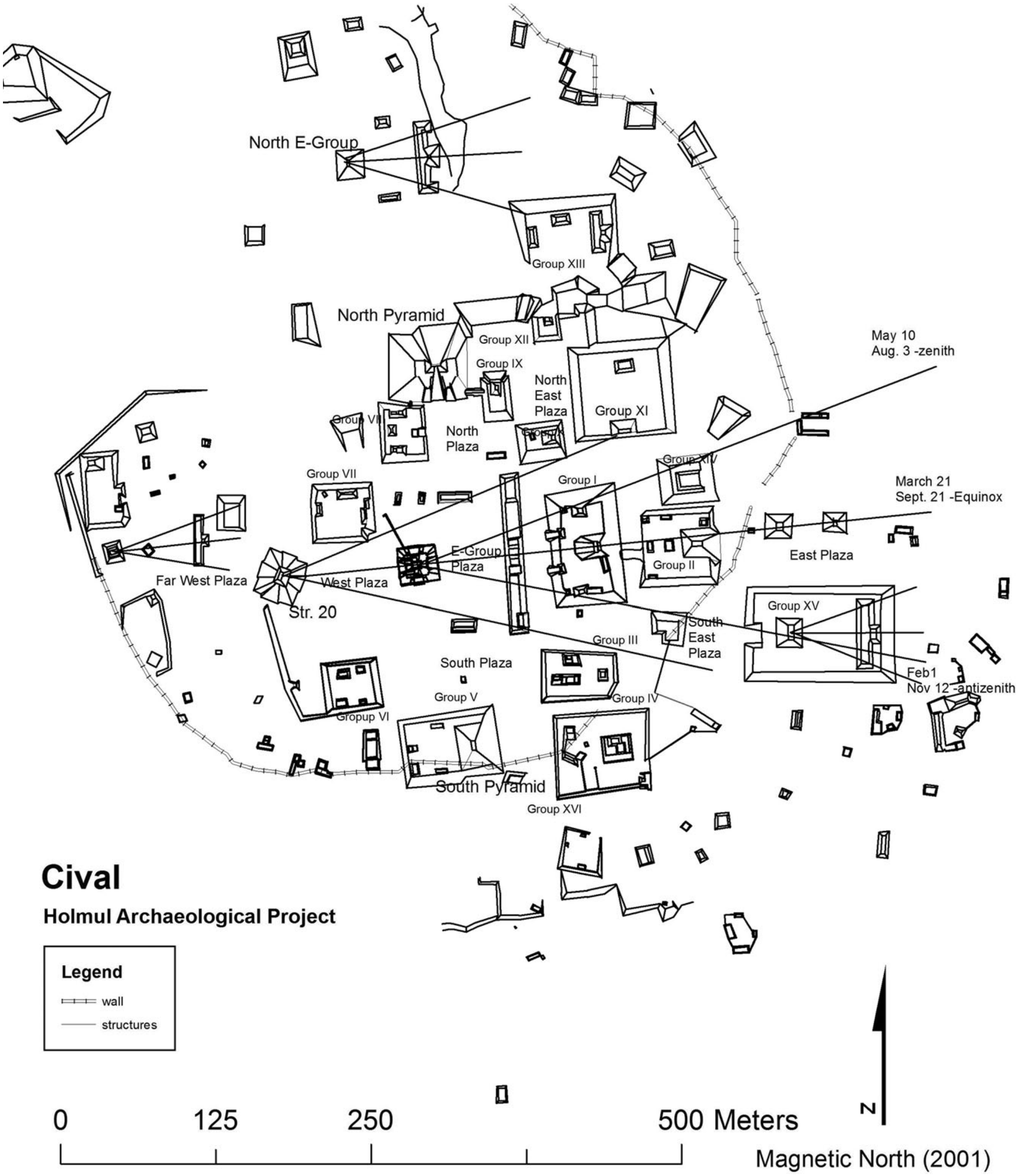

Figure 1. Cival E-Groups (after Estrada-Belli 2017).

By the end of the Preclassic (A.D. 250/300), E-Groups were used as stages for solar rituals, and they developed into customized complexes for royal rituals during the Classic period (Aveni et al. 2003:174; Dowd 2015; Aimers and Rice 2006:79, 82, 86–87). According to Aveni and colleagues (2003:162–163, 174–175, Figure 4), some later E-Groups aligned to mark 20-day intervals that lead up to the solar zenith, anticipating the planting season. This reflects a greater emphasis on the solar zenith that could have begun with a calendar reform stimulated by Teotihuacan influence in the Early Classic.

Earliest Calendar Records in Mesoamerica

Both the 365-day solar calendar and the 260-day ritual calendar include sets of 20 days that may be derived from a count of fingers and toes (Stuart 2011:153; Rice 2007:44). Linguistic data suggest that Tzolkin day names were probably used as early as 600 B.C. in the Maya area (Justeson 1989:79). Eric Thompson (1972:21–23) argued for a Highland Maya origin for the 20 day names, but most scholars now concur that the 260-day calendar probably originated in the Olmec area. David Stuart (2011:36–37) notes that although Olmec dates in the ritual calendar are not preserved, the widespread distribution of the 260-day calendar suggests it was developed by the Olmec "mother culture."

Few if any records of calendar dates survive at Olmec sites, but the ritual calendar may appear there around 900–700 B.C. (Justeson 1989:79; Rice 2007:45). Olmec symbols representing pseudo-glyphs are apparent on the Cascajal block, a monument found near San Lorenzo, but no dates are evident (Rodríguez Martínez et al. 2006). La Venta Stela 13 ("the Ambassador") has glyph-like symbols, including possibly the number one, but no specific day signs can be identified (Lacadena 2009). The range of dates proposed for Stela 13 (600–400 B.C.) places it contemporary with early Oaxacan inscriptions (Milbrath 1979:41, Table 2).

By 600–400 B.C., a count of 260 days was recorded with 20 different named days in the Valley of Oaxaca (Marcus 1992:41). The first unequivocal evidence of the combined use of the 365-day calendar with the 260-day calendar appears in Calendar Round dates at the Zapotec site of Monte Alban. On Monte Alban Stela 12, the yearbearer 4 Wind paired with the day 8 Water forms a Calendar Round read as 594 B.C. (Edmonson 1988:20–21). Inscriptions on Stelae 12 and 13 also show the earliest evidence of yearbearers, if we discount the dubious Olmec example cited by Munro Edmonson (1988:21). These early Zapotec dates are "Type II" yearbearers, comparable to yearbearers in the K'iche' Maya system and those used by the Early Classic Maya (Ik, Manik, Eb, and Caban; Edmonson 1988:8–9; Tedlock 1992:89–92). Month glyphs were originally identified on Monte Alban Stelae 12 and 13, based on a notation (Glyph W) that appears in inscriptions with numbers larger than 13 (Marcus 1992:38–41; Prem 1971:119), but other scholars have concluded that Glyph W remains undeciphered, even though a calendrical function seems likely (Urcid 2001:273; Whittaker 1992:18).

Stuart (2011:38) points out that Maya hieroglyphic writing with calendrics is as old as 300 B.C. Mural texts at San Bartolo dating around 300–200 B.C. are only partially readable, and an early version of Ahau is used as a title rather than a day sign (Saturno et al. 2006:1282). Stuart (2005a:4–6, Figure 3) identifies a 3 Ik yearbearer date at San Bartolo, estimated to fall somewhere between 131 and 27 B.C., representing the seating of Pop (0 Pop), the first Maya month. The actual month glyph is not recorded at San Bartolo, but an understanding of the Haab cycle (18 x 20 + 5) is implicit in Stuart's interpretation. San Bartolo may also record an early Katun-ending date (255 B.C.), if Mario Giron-Ábregon (2013:9–10) is correct in proposing that a stone block in the mural complex records the Katun 5 Ahau (7.5.0.0.0).

John Justeson and colleagues (1985:76, n. 32) suggested that the Maya Long Count calendar was invented during Katun 7.6.0.0.0 (255–235 B.C.), beginning on the day 1 Imix and ending on 11 Ahau, which was the first Katun created according to the Chilam Balam of Chumayel. They also noted that 4 Ahau 8 Cumku may have become important as a starting point of the Maya Long Count because this Calendar Round date was a Tun ending in 7.2.7.0.0 around 300 B.C.

Early texts from the Maya area and neighboring zones apparently lack month glyphs, but they do record the 260-day calendar, and the yearbearer identified at San Bartolo indicates that the Haab was known by the Late Preclassic. Victoria Bricker (1982:102–103) suggests that the Haab first developed ca. 550 B.C. when the Maya names for rainy season months appear to be correlated with the proper season and 0 Pop occurred on the winter solstice. More speculatively, Rice (2007:47, 57, 62–63) argues that the Haab is perhaps as old as 2060 B.C., when 0 Pop also coordinated with the winter solstice (as in 550 B.C.), and she suggests that the 52-year Calendar Round combining the 260-day calendar with the 365-day year developed as early as 1650 B.C. It remains uncertain when and where the Haab and Tzolkin developed.

Geographic Origin Point of the Haab and Tzolkin

The idea of identifying a specific site as the origin point of the Haab seems to be based on faulty premises. Vincent Malström (1991) incorrectly used the Postclassic date (1 Pop) for the beginning of the year in Preclassic times and then later revised his argument to begin the year on the summer solstice (Malström 1997:64), contrary to the more likely proposition that the year originally began on the winter solstice.

A stronger case for the geographical origin point of the Tzolkin has been made based on links to a locale where the dates for the two solar zeniths mark a 260-day interval. This idea, originally proposed by Zelia Nuttall (1904:497–498), was recently given a measure of support by Stuart (2011:153). Malström (1997:50–53, Figures 9–10) proposed that the Tzolkin originated at Izapa (14°8’N), bordering the Maya area, because this site has two solar zeniths spaced at 260-day intervals, with the second one falling on August 13. He argued that the Tzolkin originated in 1359 B.C. at Izapa, when 1 Imix, the starting point of the Maya Tzolkin, coincided with the local solar zenith on August 13. He also links the August 13 date to 4 Ahau 8 Cumku, the "calendar creation date," because it falls on 13.0.0.0.0 in the Long Count calendar, making the beginning of the Baktun cycle on August 13, 3114 B.C. (Gregorian). The lack of Long Count records from Izapa makes this theory problematic and there appears to be only one surviving Tzolkin date (6 Death on Miscellaneous Monument 60; Justeson 1988; Rice 2007:116). Malström used the 584,285 correlation, but in the 584,283 correlation (discussed below), 4 Ahau 8 Cumku falls on August 11, which compromises his argument. Bordering the Lowland Maya area at 14°20’ N, El Baul and Takalik Abaj (formerly Abaj Takalik) both have a zenith date on August 15 and very early Maya calendar inscriptions (Table 1; Edmonson 1988:120). The zenith passage dates, however, do not show a 260/105 day split. In general, the geographic explanation for the origin of the Tzolkin at any specific latitude remains weak. On the other hand, the 260-day calendar does reflect an interval related to the Mesoamerican maize cycle in the Maya area.

Solar Observations and Subdivisions of the Calendar

The 260-day Tzolkin may have developed from a natural subdivision of the solar year relating to agriculture. The 105-day interval from April to August has been described as the growing season (Peterson 1962:186–187), but the Maya agricultural season actually spans 260 days, a period referred to as the agrarian year (Rice 2007:35–36; see also Milbrath 1999:15, 59). Objections have been raised that the theory explaining the origin of the 260-day calendar in terms of agricultural cycles does not account for variations in the length of the growing season that depend on altitude (Earle and Snow 1985:212). Nonetheless, the 260-day agricultural cycle is preserved today in both the lowlands and highlands. A span of 260 days represents a subdivision of the maize cycle into 13 sets of 20 days, surviving today in the maize cycle of the Tzeltal (Stross 1994:29–31), and the 260-day agricultural cycle is also recorded among other Maya groups (Guiteras-Holmes 1961:33; Milbrath 1999:15, 59–62; Tedlock 1992). Furthermore, as noted above, orientations in the Maya area that establish a fixed 260-day period between February and October help demonstrate a focus on the agrarian year, and alignments marking 20-day intervals before and after the solar zenith reflect an interest in subdividing the 260-day agricultural period. Subdivisions of the agrarian year are also evident in clusters of architectural orientations in the Maya Lowlands corresponding to a four-part division of the maize cultivation cycle, with preparation of the plots in February, planting in April-May, first fruits in August, and the harvest in October-November (González-García and Šprajc 2016:199–200).

There are variations in practices depending on altitude, but generally the pattern of rainfall determines when the main crop is planted. Although there may be multiple plantings, there is considerable uniformity in the lowlands, with the main crop planted at the onset of the rainy season, around the first solar zenith (Milbrath 1999:13). In Yucatán, some farmers risk an early planting (*tikin muk*) during April, in hopes of early rainfall, but the main crop (*xnuk nal*) is planted in May through June to coincide with the rainy season, which runs through October. There is a repeat of planting in June through August to take care of any shortcomings in the crop caused by dry weather or pests (Terán and Rasmussen 1994:127, 205–207). The pattern along the coast of Belize seems to be the same, with rainfall beginning in May, but there is enough rain for a second crop to be planted in the alluvial soils beginning in November, and this extra crop is harvested during the dry period that spans from January through April (Iwaniszewski 2002:506). In some other Maya areas it is also possible to plant a second crop during the dry season, but generally the second crop is planted around July in the midst of the rainy season, as is the practice in Yucatán and among the Ch'orti', whose territory spans from eastern Guatemala to Honduras (Estrada-Belli 2011:79; Girard 1962; Milbrath 1999:13–14, Plate 1).

According to Raphael Girard, the Ch'orti' begin their 365-day year and a fixed 260-day agricultural calendar on New Year's day (February 8), but because their calendar year is said to start with the first visible crescent moon, there seems to be some flexibility for the beginning date (Girard 1962:3–15, 55, 76, 328–342). Girard (1962:340, n. 21) noted that the Ch'orti' agricultural calendar is like that recorded in Yucatán by Diego de Landa, with a beginning date of 1 Imix falling in February (Tozzer 1941:151–152). Critics of Girard's work have questioned how the Ch'orti' could relate 1 Imix to the beginning of their agricultural count on February 8, not only because the Tzolkin does not have a fixed relationship to the solar year, but also because other ethnographers have not found evidence of the survival of the Tzolkin among the Ch'orti' (Starr 1951:263, 265). Even though the Ch'orti' do not use day signs in the Tzolkin, Girard's data suggest they maintained a count of 260 days using 52-day sets and multiples of 20 days.

The Ch'orti' 260-day agricultural count starts during the dry season with preparation of fields for 80 days, a period subdivided at the March equinox into two 40-day periods. The 80-day period ends on the first solar zenith on May 1, coinciding with the onset of the rainy season, when the planting begins. Then a count of 52 days leads up to the summer solstice (June 21 or 22), followed by another 52-day period that includes the Día de Santiago (July 25), which marks a brief halt in rains associated with *canícula* (a brief midsummer drought). The second 52-day set ends on the second solar zenith on August 12/13 (Girard 1962:250–253, 257–258, table facing 328). The remainder of the fixed agricultural count is used to plant a second crop shortly after the ears of the first crop are doubled over, which keeps the birds from eating the kernels and rainfall from rotting of the maize cobs. The second crop, planted in July, is cultivated during a period that includes the fall equinox, a time of maximum rainfall, but doubling the ears of this second crop is not necessary because by the time the maize matures, the rain has ceased (Girard 1962:265–268). Harvesting begins in October, and Girard notes that on October 25 the fixed 260-day agricultural count ends with a midnight ceremony. The residual period of 105 days in the year is considered to be a period of rest that completes the year, ending with a five-day period (February 3–7) directly before the New Year.

In the mountains of Guatemala, the K'iche' year-end events seem to take place just before a time of heightened agricultural activity, as they do among the Ch'orti' (Tedlock 1992:35, 189–190). Taking advantage of the mist and fog that retard evaporation, mountain maize is planted beginning in March and harvested in December, with the agricultural cycle spanning 260 days. March is also the month of the New Year when the new Mam or yearbearer is installed—a Tzolkin date that names the year. The relationship between the 260-day count and the agricultural season echoes the pattern seen among the Ch'orti', living hundreds of miles away, and the fact that the yearbearer falls near the beginning of the 260-day agricultural count is useful in designating a span of 260 days.

The yearbearer cycle has implications for the early calendar because it indicates a division of the year into two sections of 260 and 105 days. The same division of the year into 260- and 105-day periods is evident in a number of orientations documented in the Maya area and beyond (Aimers and Rice 2006:88; Aveni 2001:228–229; Šprajc 2000:409). Many alignments facing to the east in the Maya Lowlands seem to mark intervals of 260 and 105 days, with subsets of 13 and 20 days, or alternatively, intervals of 240 and 125 days (González-García and Šprajc 2016:196–197, Table 9; Šprajc and Sánchez Nava 2012:984).

Šprajc (2000) notes that orientations at Teotihuacan also suggest a 260-day cycle beginning in February, with alignments to a prominent peak on the eastern horizon marking the dates February 11 and October 29 (see also Iwaniszewski 2005). These dates reflect measurements taken from the summit of the Pyramid of the Sun, and those taken from the base differ by only a day (Šprajc 2001:226–229, Tables 5.38, 5.39). Alignment at the base facing east mark the rising sun on February 10 and October 30, and the setting sun to the west on April 30 and August 13. Šprajc concludes that these four dates divide the agricultural season in quarters, beginning with preparations for planting in early February, then planting with the onset of the rains (late April or early May), followed in mid-August by the first ears of maize, and then the beginning of the main harvest in late October. The Teotihuacan alignments involve a mountainous horizon, but Šprajc and colleagues (2009:88–90, Table 2) note that in the Maya area, with a flat horizon, the same group of dates corresponds to a 14° orientation like that found in Preclassic El Mirador and Yaxnohcah, sites characterized by alignments marking the dates February 12 and October 30. Like the Teotihuacan alignments, these dates define a 260-day period that Šprajc describes as an observational calendar related to agriculture, like that surviving today among the Maya.

The Puuc-Maya site orientations seem to be distributed into two groups: the 25° group translating into a winter solstice sunrise alignment and a 14° group more closely related to Teotihuacan (Aveni 2002; Aveni et al. 2003). The 14° east-of-north group marks alignments that are at 20-day intervals from the solar zenith, and Aveni and Hartung (1986:18–19, Table 3) also note that the 14° alignment would coincide with dates in February and October, important dates in the agricultural calendar spanning 260 days. They propose a hypothetical solar orientation calendar centered on the zenith passage dates at different latitudes in the Maya area, with alignments focusing on the horizon position of the sun on the zenith passage date, or intervals of 20 or 40 days before and after the zenith date that mark sets of 20 days useful in recording subdivisions of the agricultural cycle. A similar 14° orientation is found at Late Preclassic T'isil in Quintana Roo, where the main *sacbé* is aligned to sunrise in mid-February and late October (Vadala 2009), recalling the El Mirador alignments, and T'isil also has a winter solstice alignment (25° orientation) like the E-Group at El Mirador.

An agrarian year of 260 days beginning in February and ending in October may have been widespread early on in the Lowland Maya area. Aveni (2012) suggests that the fixed count of 260 days predates the solar-based cycle of 365 days, and this count was used for the period of subsistence activities. This fixed agricultural cycle of 260 days was probably measured using day names that developed from a count of 20 used to subdivide the solar year. By the Middle Preclassic, tracking the solar positions using E-Groups helped to formulate more detailed subdivisions of the agricultural cycle in relation to the solar year. By the Late Preclassic multiple calendar cycles developed, and the solar and agricultural cycles were subsumed in the complex workings of the Maya Long Count calendar of the Classic period. Throughout the Preclassic and Classic, the Tzolkin was probably used to calculate the fixed agricultural cycle, so that any date in the Tzolkin could begin the agrarian year, and the agricultural cycle would end when that date repeated again 260 days later.

Early Long Count Inscriptions

The earliest Maya inscriptions record the Tzolkin and possibly also the yearbearer cycle. The 365-day Haab may have originally coordinated with the seasonal cycles, but as the Preclassic drew to a close it became subordinate to the Long Count, which provided a more precise record of time. In the Long Count, the base unit is the day itself, but the primary intervals are multiples of 20 days. The Long Count calendar combined many cycles, including the Baktun (20 x 20 x 360 days), the Katun (20 x 360 days), the Tun (18 x 20 days), and the Uinal (20 days).

An important consideration in any discussion of the early calendar is the correlation factor, a coefficient added to the Long Count date to obtain the equivalent date in the European calendar. The 584,285 correlation, originally proposed by Eric Thompson in 1972 and revived by Floyd Lounsbury (1982, 1983), is generally referred to as the GMT correlation. Although Gerardo Aldana (2011, 2015:12–17) has questioned the GMT correlation and disputes supporting evidence from the Tikal lintels, Douglas Kennett and colleagues (2013:4) conclude that the Tikal lintels were probably carved by removing the exterior wood (the more recent wood), so the radiocarbon dates assessed with Bayesian modelling help confirm the GMT correlation. Of course, this evidence cannot be used to distinguish between variants of the GMT that adjust dates by only a few days or weeks.

For the general discussion of E-Groups in relation to the developing calendar, it is not essential to know the exact correlation factor, but it does become important when tying astronomical events with specific dates on monuments. In an analysis of a possible solar eclipse record on Poco Uinic Stela 3, a 584,286 correlation (584,285 + 1 day) has been proposed (Martin and Skidmore 2012), but there are several other possible explanations for this date (Daniel Graña-Behrens, personal communication 2012). Astronomy also figures prominently in the correlation proposed by Justeson (2010; see also Kaufman and Justeson 2001) for the Isthmus region, an area where the earliest complete Long Count inscription is found at Tres Zapotes (Table 1). He suggests that an Epi-Olmec correlation factor displaced the months by 20 days (584,285 - 20 days = 584,265), which makes the Long Count dates on La Mojarra Stela 1 align with specific astronomical events, including a solar eclipse and a Venus elongation. Aveni (2001:167, Figure 65) supports this interpretation of the astronomical events, but it should be noted that Venus elongations probably were not significant in the Maya records (Bricker and Bricker 2011:39), and the solar eclipse glyph is unlike ones seen in later texts.

Using the Epi-Olmec correlation factor of 584,265, Tres Zapotes Stela C is interpreted as a record of a lunar eclipse followed by an almost total eclipse (Justeson et al. 1985:75, n. 31; Pool 2007:252, 307, n.1). La Mojarra Stela 1, a monument from Veracruz, has a Long Count in A.D. 143, recorded as 8.5.3.3.5 13 Snake (Table 1; Kaufman and Justeson 2001:2.34–2.35). The month patron is incorporated in the ISIG (Initial Series Introductory Glyph) with a Tun sign directly below it, and the Tzolkin date appears at the end of the column. This Long Count inscription (A1-9) and a second one (M8-16) have been linked to Venus events separated by the interval of 13.6.2 (4,802 days), and the first interval (H3–I4) links two eclipse events, whereas the second (I5–J5) leads to a solstice date, using the 584,265 correlation factor (Kaufman and Justeson 2001:2.37–2.38, 2.71). Problems with the astronomical events cited on the monument have already have been noted, and until more of the script is understood, caution is required (Houston and Coe 2003). Scholars such as Prudence Rice (2007) and Martha Macri and Laura Stark (1993) use the 584,283 correlation (GMT − 2 days) for the La Mojarra texts, the same correlation used here in Table 1, but the case remains open on the correlation in the Isthmus region, which may be displaced by 18 to 20 days.

Thompson's (1960) long-standing correlation (584,283) used here is vigorously championed by Harvey and Victoria Bricker (2011:90–99) and Munro Edmonson (1988), and is also supported by Barbara Tedlock (1992), based on the Tzolkin cycle surviving among the K'iche'. The precise correlation factor used is not essential to the broader discussion of the relationship of E-Groups to the development of the calendar, but to provide specific dates in Table 1 it was necessary to select a specific correlation factor, with the caveat that some dates have alternate readings or different correlation factors.

Whether the Long Count first developed in the Maya area and diffused to Mixe-Zoque sites in the Isthmus area or vice versa remains uncertain (Justeson et al. 1985:42). Cycle 7 (Baktun 7) monuments are often linked with the Mixe-Zoque language area and calendar innovations may have passed from there to the Lowland Maya. Stela C at Tres Zapotes is the earliest example of a Long Count inscription with a complete column of five numbers (Table 1). An early example of the yearbearer (6 Ben) is recorded in the Long Count on Chiapa de Corzo Stela 2 (Coe 1976), sometimes dated to 36 B.C. (7.16.3.2.13), but owing to its fragmentary

Figure 2. Takalik Abaj Stela 5; left 1980, right 2012 (photos by Susan Milbrath). (color online)

condition the Baktun and Katun inscriptions have to be reconstructed (Table 1). Furthermore, some scholars place this monument more than two centuries later (8.7.3.2.13 or A.D. 182; Riese 1988:68, Table 1).

The most ancient Maya Long Count dates seem to come from Takalik Abaj and El Baul on the Pacific Slope, bordering the Lowland Maya area. Takalik Abaj Stela 2 has been described as a Cycle 7 monument (Coe 1957:605), with an estimated date between 7.6.0.0.0 and 7.16.0.0.0, falling between 235 and 18 B.C. (Graham et al. 1978:89–91). Nonetheless, high definition digital imaging indicates that the original inscription was actually Cycle 8, and two of the three dots in the Baktun inscription have flaked off (Doering and Collins 2011). The calendar inscription on El Baul Stela 1 is first century, but its exact date remains tentative. Given the Tzolkin inscription of 12 Eb, Michael Coe (1957:603) reconstructs the date as A.D. 37 (7.19.15.7.12; Table 1). Both monuments are sometimes considered to be Izapan in style (Guernsey 2006:46–47, Figures 3.3b, 3.4), but they may be a variant of the early Maya style. An even earlier date has been proposed for Takalik Abaj Monument 11, a boulder carved with a column of glyphs and an inscription possibly dating to Cycle 6 (Middle Preclassic), based on a Tzolkin date (11 Ik) that may have an Initial Series glyph attached, but the only legible number is 11 (Graham and Porter 1989). This site also has a Middle Preclassic E-Group that was probably used to peg solar dates before the calendar was more fully developed in Cycle 7. An interest in tracking solar events at this site is also evident in a boulder with relief-carved footprints that are aligned to the winter solstice sunrise (Altar 46; Hatch 2010; Milbrath 2017:Figure 1).

Cycle 8 Long Count dates are more clearly documented at Takalik Abaj, but interpreting these dates is not without controversy, because the texts lack period glyphs and are partially effaced. Stela 5 records dates in two side-by-side glyphic columns (Figure 2; Table 1), which John Graham and his colleagues (1978:92) read as 8.4.5.17.11 and 8.2.2.10.5, but they note the Katun inscription is not clear in the right-hand column and the date could be 8.3.2.10.5 (Table 1). On the other hand, Justeson (2010:48–49, 2012:834) argues that the notation of zero was not yet known, so the zero for the 20-day Uinal (month) was omitted, making the last number in each column a reference to the Tzolkin date and rendering the date as 8.4.5.[0].17 11 Earthquake and 8.3.2.[0].10 5 Coyote. Regardless of whether this alternate reading is accepted, these two early Cycle 8 inscriptions follow Maya Long Count patterns, like Stela 1 from El Baul, placing the beginning of the Baktun cycle on 4 Ahau 8 Cumku.

The Hauberg Stela, an early monument presumably from the lowland Maya area, has an expanded Long Count inscription with a lunar calendar with a nine-day cycle, variously dated to A.D. 197 or A.D. 199 (Bricker and Bricker 2011:720–723, Figure 12-2; Justeson 1989:79), but it may be much later. Based on its style, Stuart (2005b:163) dates the monument no earlier than 8.15.0.0.0 (A.D. 337). Given this uncertainty, I have expanded my discussion of this monument to a more lengthy treatment in another publication (Milbrath 2017).

One of the markers of the Early Classic period (A.D. 250/300–600) in the Maya Lowlands is the use of the fully developed Long Count calendar with period glyphs. Tikal Stela 29 remains the earliest known stela with an ISIG Long Count documented from a Maya site in the lowlands. Stela 29 lacks the lower part of the inscription, which would have had the Haab and Tzolkin recorded at the bottom. The Long Count date is reconstructed as 8.12.14.8.15, equivalent to July 6, A.D. 292 in both the Julian and Gregorian calendars (Jones and Satterthwaite 1982:Figure 29). The ISIG month patron is Zip, and the ISIG has the Tun sign, but it lacks the T25 (*ka*) element that became common later (Coe 1976:11). It may have been erected in the Mundo Perdido E-Group during the Manik 1 ceramic phase (A.D. 250–300), when the complex had a radial pyramid and three structures on the range to the east (Laporte 1987; Laporte and Fialko 1990:46, Figure 3.13).

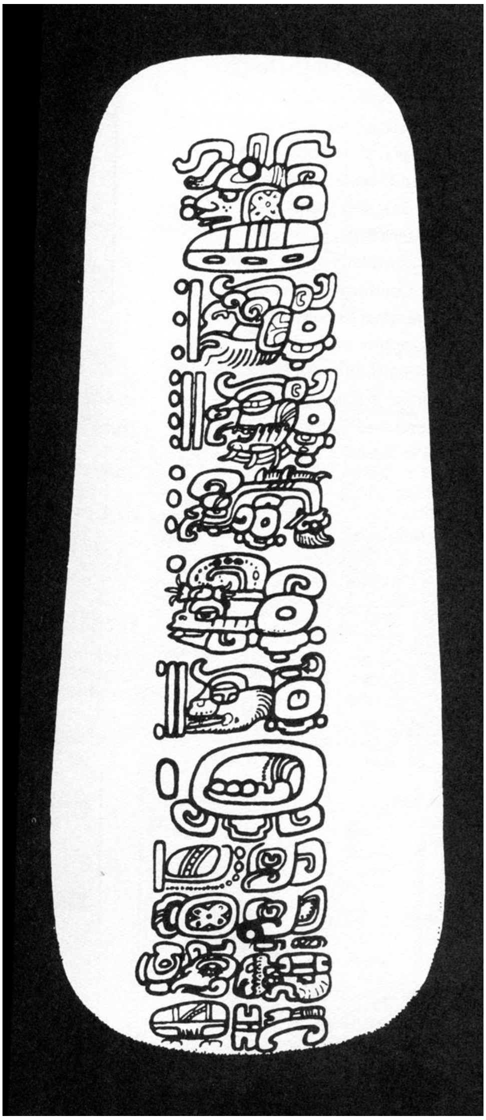

Figure 3. Leiden Plaque (modified after Milbrath 1999:Plate 2).

The Leiden Plaque, dating to September 14, A.D. 320 Julian (September 15, A.D. 320 Gregorian), is an early Maya example of a standardized Long Count with the Haab month recorded at the base of the inscription and the corresponding month patron in the ISIG (Figure 3; after Milbrath 1999:Plate 2). The month patron represents Yaxkin in the ISIG, which is followed by the Long Count inscription: 8.14.3.1.12 1 Eb 0 Yaxkin. A seating symbol refers to zero paired here with Yaxkin to be read as 0 Yaxkin. In addition to the Haab date, it also bears an early reference to the G5 in the cycle of nine glyphs in the Lunar Series (Thompson 1960:Figure 34, no. 25). The image probably shows the accession of a ruler. The plaque may be from the tomb beneath Mundo Perdido Structure 5D-86-6 (Laporte 1987). As in the case of Stela 29, this links an early inscription to Tikal's E-Group.

By the time these inscriptions were carved, E-Groups like the one at Tikal had lost any function in terms of solar observations, having been converted into a stage for royal rituals. Some Classic inscriptions record solar events, especially the solstices (Milbrath 1999:64–65; Šprajc and Sánchez Nava 2013:334), but they seem to be subordinate to more complex astronomical cycles and records of historical events in the lives of rulers. Although Classic period architecture continued to be characterized by astronomical alignments, the most common orientations are to dates in February and October, months coinciding with the initial phases of the agricultural cycle and the beginning of the harvest (Sánchez and Šprajc 2015:Tables 7–10).

The Role of E-Groups in Formulating the Early Calendar

The fixed 260-day count surviving today in the Maya agricultural cycle is apparently quite ancient and may have originated as a subdivision of the 365-day year, first tracked by marking the solstices in the earliest E-Groups. Tzolkin records appear earlier than the Haab in the Maya area, but 20-day sets in the Maya Haab most probably developed in tandem with the 20 day signs of the Tzolkin, and the Tzolkin itself may have evolved from observing the maize cycle in relation to solar positions noted in early E-Groups.

The maize cycle probably inspired Mesoamerican calendar priests to develop a 260-day calendar that coordinated with the agricultural cycle. The 260/105 split of the year is codified in the yearbearer cycle. The yearbearer appears in the Maya area at San Bartolo as early as 131 B.C., and even earlier in Oaxaca (600–400 B.C.). The early development of the pattern subdividing the year into a 260-day agricultural period and 105-day residual, non-agricultural season, may have been widespread.

The early calendar record from San Bartolo uses a yearbearer cycle that signals a division of 260 days in the solar year in the Southern Lowland Maya area. The two annual occurrences of the yearbearer would mark a 260/105 split in the 365-day year. It seems likely that the 260-day period originally was visualized as a subdivision of the 365-day year. Measuring these intervals in the solar year initially involved E-Group architectural orientations keyed to the seasonal cycle, dating back to 1000 B.C. in the Maya area, well before calendar records were recorded on monumental art. Observations of the solar cycle were initially important in early E-Groups, but as the precision of the calendar developed the apparent interest in tracking the solstices declined.

Early Epi-Olmec records often use the month patron system developed in the Late Preclassic to indicate positions in the 365-day cycle before the Haab dates were incorporated in the Long Count inscriptions. These texts lack true Haab notations, and the same is true of early Cycle 8 dates from the Pacific Slope. These texts also lack the month patron, which seems to make its earliest appearance in the Isthmus region. Nonetheless, early calendar records from the Pacific slope of Guatemala could be considered formative to the Maya Long Count.

Because the Long Count was not useful in recording the tropical year, solar observations continued to be important (Šprajc 1995:598). Alignments marking intervals of 260 days that were useful in tracking the agrarian year are evident in both the Preclassic and Classic (González-García and Šprajc 2016). There is evidence that the 260-day agrarian year was timed by the Tzolkin during the Postclassic (Milbrath 1999:60–62), and it clearly survives in modern times among the K'iche'. With minor adjustments to correlate with lunar phases, this 260-day agrarian count is fixed within the year, and can be calculated using the Tzolkin, because whatever day begins the agrarian year will also end the cycle.

Early records from the Maya area show the yearbearers, a cycle useful in subdividing the year into sets of 260 and 105 days. The agrarian year developed earlier than the yearbearer cycle, but this calendar cycle no doubt helped to record the two segments of the year. Architectural alignments helped codify the continued importance of the 260-day agricultural cycle and lend support to its long-standing link with the ritual calendar.

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References Cited

Aimers, James J., and Prudence M. Rice
2006 Astronomy, Ritual, and the Interpretation of Maya "E-Group" Architectural Assemblages. *Ancient Mesoamerica* 17(1):79–96.
Aldana, Gerardo
2011 The Maya Calendar Correlation Problems. In *Calendars and Years*, Vol. II, edited by John M. Steele, pp. 127–178. Oxbow Books, Oxford.
2015 ^{14}C and Maya Long Count Dates: Using Bayesian Modelling to Develop Robust Site Chronologies. *Archaeometry*, http://dx.doi.org/10.1111/arcm.12200, accessed March 13, 2016.
Aveni, Anthony F.
2001 *Skywatchers of Ancient Mexico*. University of Texas Press, Austin.
2002 *Empires of Time: Calendars, Clocks and Cultures*. Basic Books, New York.
2003 Archaeoastronomy in the Ancient Americas. *Journal of Archaeological Research* 11(2):149–191.
2012 Calendars and Archaeoastronomy. In *Oxford Handbook of Mesoamerican Archaeology*, edited by Debra L. Nichols and Christopher H. Pool, pp. 787–794. Oxford University Press, New York.
Aveni, Anthony F., Anne S. Dowd, and Benjamin Vining
2003 Maya Calendar Reform? Evidence from Orientations of Specialized Architectural Assemblages. *Latin American Antiquity* 14:159–178.
Aveni, Anthony F., and Horst Hartung
1986 Maya City Planning and the Calendar. In *Transactions of the American Philosophical Society* 76(1):1–87. Philadelphia.
2000 Water, Mountain, Sky: The Evolution of Site Orientations in Southeastern Mesoamerica. In *Precious Greenstone, Precious Feather/In Chalchihitl in quetzalli: Essays on Ancient Mexico in Honor of Doris Heyden*, edited by Eloise Quiñones Keber, pp. 31–55. Labyrinthos, Lancaster City, California.
Aylesworth, Grant R.
2004 Astronomical Interpretations of Ancient Maya E-Group Architectural Complexes. *Archaeoastronomy: Journal of Astronomy in Culture* 18:34–66.
Blake, Michael
2013 Solar Orientations and Formative Period Site Layouts in SE Mesoamerica: Sunrise and Sunset Alignments during the Equinoxes and Solstices. Paper presented at the Annual Meeting of the Society for American Archaeology, Honolulu.
Bricker, Harvey M., and Victoria R. Bricker
2011 *Astronomy in the Maya Codices*. American Philosophical Society, Philadelphia, Pennsylvania.
Bricker, Victoria
1982 The Origin of the Maya Solar Calendar. *Current Anthropology* 23(1):101–103.
Chase, Arlen F., and Diane Z. Chase
1995 External Impetus, Internal Synthesis, and Standardization: E-Group Assemblages and the Crystallization of Classic Maya Society in the Southern Lowlands. In *The Emergence of Lowland Maya Civilization*, edited by Nikolai Grube, pp. 87–102. Verlag Anton Surwein, Markt Schwaben, Germany.
2017 E Groups and the Rise of Complexity in the Southeastern Maya Lowlands. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.
Chase, Arlen F., Anne S. Dowd, and David Freidel
2017 The Distribution and Significance of E Groups: A Historical Background and Introduction. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.
Clark, John E., and Richard D. Hansen
2001 The Architecture of Early Kingship: Comparative Perspectives on the Origins of the Maya Royal Court. In *Royal Courts of the Ancient Maya*, Vol. 2, edited by Takeshi Inomata and Stephen D. Houston, pp. 1–45. Westview Press, Boulder, Colorado.
Coe, Michael D.
1957 Cycle 7 Monuments in Middle America: A Reconsideration. *American Anthropologist* 49(4):597–611.
1976 Early Steps in the Evolution of Maya Writing. In *Origins of Religious Art and Iconography in Preclassic Mesoamerica*, edited by Henry B. Nicholson, pp. 107–122. UCLA Latin American Center Publications, Los Angeles, California.
Doering, Travis F., and Lori D. Collins
2011 *The Takalik Abaj Monumental Stone Sculpture Project: High Definition Digital Documentation and Analysis*. Electronic document, https://www.academia.edu/4026691, accessed September 9, 2016.
Dowd, Anne S.
2015 Maya Architectural Hierophanies. In *Cosmology, Calendars, and Horizon-based Astronomy in Ancient Mesoamerica*, edited by Anne S. Dowd and Susan Milbrath, pp. 37–75. University Press of Colorado, Boulder.
Doyle, James
2012 Regroup on "E-Groups": Monumentality and Early Centers in the Middle Preclassic Maya Lowlands. *Latin American Antiquity* 23:355–380.
Earle, Duncan Maclean, and Dean R. Snow
1985 The Origin of the 260-Day Calendar: The Gestation Hypothesis Reconsidered in Light of Its Use among the Quiche-Maya. In *Fifth Palenque Round Table, 1983*, edited by Merle Greene Robertson and Virginia

M. Fields, pp. 241–244. Pre-Columbian Art Research Institute, San Francisco, California.

Edmonson, Munro S.
1988 *The Book of the Year: Middle American Calendrical Systems*. University of Utah Press, Salt Lake City.

Estrada-Belli, Francisco
2006 Lightning Sky, Rain, and the Maize God: The Ideology of Preclassic Maya Rulers at Cival, Peten. *Ancient Mesoamerica* 17:57–78.
2011 *The First Maya Civilization: Ritual and Power Before the Classic Period*. Routledge, New York.
2017 The History, Function, and Meaning of Preclassic E-Groups in the Cival Region. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.

Girard, Raphael
1962 *Los mayas eternos*. Libro Mex Editores, Mexico City.

Giron-Ábrego, Mario
2013 A Late Preclassic Distance Number. *PARI Journal* 13(4):8–12.

González-García, A. César, and Ivan Šprajc
2016 Astronomical Significance of Architectural Orientations in the Maya Lowlands: A Statistical Approach. *Journal of Archaeological Science: Reports* 9: 191–202.

Graham, John A., Robert F. Heizer, and Edward M. Shook
1978 Abaj Takalik 1976: Exploratory Investigations. In *Studies in Ancient Mesoamerica, III*, edited by John A. Graham, pp. 85–110. Contributions of the University of California Archaeological Research Facility 36, Berkeley.

Graham, John A., and James Porter
1989 A Cycle 6 Initial Series? A Maya Boulder Inscription from the First Millennium B.C. from Abaj Takalik. *Mexicon* XI(3):46–49.

Guernsey, Julia
2006 *Ritual and Power in Stone: The Performance of Rulership in Mesoamerican Izapan Style Art*. University of Texas Press, Austin.

Guiteras-Holmes, Calixta
1961 *Perils of the Soul: The World View of a Tzotzil Indian*. Free Press of Glencoe, New York.

Hansen, Richard D.
1998 Continuity and Disjunction: The Pre-Classic Antecedents of Classic Maya Architecture. In *Function and Meaning in Classic Maya Architecture: A Symposium at Dumbarton Oaks, 7th and 8th October 1994*, edited by Stephen D. Houston, pp. 49–122. Dumbarton Oaks, Washington, D.C.
2013 Kingship in the Cradle of Maya Civilization. In *Fanning the Sacred Flame: Mesoamerican Studies in Honor of H.B Nicholson*, edited by Matthew Boxt and Brian D. Dillon, pp.139–172. University Press of Colorado, Boulder.

Hatch, Marion Popenoe de
2010 Las cerámicas frente al arte escultórico y su información respecto del cambio social. *XXIII Simposio de Investigaciones Arqueológicas en Guatemala. 2009*, edited by Bárbara Arroyo, Adriana Linares Palma, Lorena Paiz Aragón, and Ana Lucía Arroyave. pp. 995–1007. Museo Nacional de Arqueología y Etnología, Guatemala City.

Houston, Stephen D., and Michael D. Coe
2003 Has Isthmian Writing Been Deciphered? *Mexicon* XXV(6):151–161.

Inomata, Takeshi
2017 Lowland Maya Adoption of E Groups and the Invention of Tradition. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.

Inomata, Takeshi, Daniela Triadan, Kazuo Aoyama, Victor Castillo, and Hitoshi Yonenobu
2013 Early Ceremonial Constructions at Ceibal, Guatemala, and the Origins of Lowland Maya Civilization. *Science* 340(1126):467–471.

Iwaniszewski, Stanislaw
2002 Los conceptos del tiempo en el discurso ideológico en el Protoclásico Maya: Cerros y Uaxactún. *Tercer Congreso Internacional de Mayistas: Memoria* (9 al 15 de Julio de 1995), pp. 503–516. Universidad Autónoma de México, Mexico, D.F.
2005 Leer el tiempo: El fenómeno de la sincronicidad en la práctica mántica Teotihuacana. *Perspectivas del la Investigación Arqueólogica: IV Coloquio de la Maestría en Arqueología*, edited by Walburga Wiesheu and Patricia Fournier, pp. 93–108. Concultura and Instituto Nacional de Antropológia e Historia, Mexico, D.F.

Jones, Christopher, and Linton Satterthwaite
1982 The Monuments and Inscriptions of Tikal: The Carved Monuments. *Tikal Report No. 33, Part A*. University Museum, University of Pennsylvania, Philadelphia.

Justeson, John S.
1988 The Non-Maya Calendars of Southern Veracruz-Tabasco and the Antiquity of the Civil and Agricultural Years. *Journal of Mayan Linguistics* 6:1–22.
1989 The Ancient Maya Ethnoastronomy: An Overview of Hieroglyphic Sources. In *World Archaeoastronomy: Selected Papers from the Second Oxford International Conference on Archaeoastronomy*, edited by Anthony F. Aveni, pp. 76–129. Cambridge University Press, Cambridge.
2010 Numerical Cognition and the Development of "Zero" in Mesoamerica. In *The Archaeology of Measurement: Comprehending Heaven, Earth and Time in Ancient Societies*, edited by Iain Morely and Colin Renfrew, pp. 43–53. Cambridge University Press, Cambridge.
2012 Early Mesoamerican Writing Systems. *Oxford Handbook of Mesoamerican Archaeology*, edited by Deborah L. Nichols and Christopher A. Pool, pp. 830–844. Oxford University Press, New York.

Justeson, John S., William M. Norman, Lyle Campbell, and Terrence Kaufman
1985 *The Foreign Impact on Lowland Mayan Language and Script*. Middle American Research Institute Publication 53. Tulane University, New Orleans, Louisiana.

Kaufman, Terrence and John Justeson
2001 *Epi-Olmec Hieroglyphic Writing and Texts*. Mesoamerican Languages Documentation Project. Electronic document, http://www.albany.edu/anthro/maldp.EOTEXTS.pdf, accessed December 12, 2014.

Kennett, Douglas J., Irka Hajdas, Brendan J. Culleton, Soumaya Belmecheri, Simon Martin, Hector Neff, Jaime Awe, Heather V. Graham, Katherine H. Freeman, Lee Newsom, David L. Lentz, Flavio S. Anselmetti, Mark Robinson, Norbert Marwan, John Southon, David A. Hodell, and Gerald H. Haug

2013 Correlating the Ancient Maya and Modern European Calendars with High-Precision AMS ^{14}C Dating. *Nature Scientific Reports* 3:1597–1601.

Lacadena, Alfonso

2009 Escritura y lengua en Takálik Ab'aj: Problemas y propuestas. *XXIII Simposio de Investigaciones Arqueológicas en Guatemala*, pp. 1027–1044. Museo Nacional de Arqueología y Etnología, Guatemala City.

Laporte, Juan Pedro

1987 El Grupo 6C-XVI, Tikal Petén: Un Centro Habitacional del Clásico Temprano. In *Memorias del Primer Coloquio Internacional de Mayistas* (August 1985), pp. 221–244. Universidad Nacional Autónoma de Mexico, Mexico, D.F.

Laporte, Juan Pedro, and Vilma Fialko C.

1990 New Perspectives on Old Problems: Dynastic References for the Early Classic Tikal. In *Vision and Revision in Maya Studies*, edited by Flora S. Clancy and Peter D. Harrison, pp. 33–66. University of New Mexico Press, Albuquerque.

1995 Un reencuentro con Mundo Perdido, Tikal, Guatemala. *Ancient Mesoamerica* 6:41–94.

Lounsbury, Floyd G.

1982 Astronomical Knowledge and Its Uses at Bonampak. In *Archaeoastronomy in the New World*, edited by Anthony F. Aveni, pp. 143–168. Cambridge University Press, Cambridge.

1983 The Base of the Venus Tables of the Dresden Codex, and Its Significance for the Calendar-Correlation Problem. In *Calendars in Mesoamerica and Peru: Native American Computations of Time*, edited by Anthony F. Aveni and Gordon Brotherston, pp. 1–26. BAR International Series 174. British Archaeological Reports, Oxford.

Macri, Martha J., and Laura M. Stark

1993 *A Sign Catalog of the La Mojarra Script*. Precolumbian Art Research Institute Monograph 5. San Francisco, California.

Malström, Vincent

1991 Edzna: Earliest Astronomical Center of the Maya. In *Arqueoastronomía y etnoastronomía en Mesoamérica*, edited by Johanna Broda, Stanislaw Iwaniszewski, and Lucrecia Maupomé, pp. 37–47. Universidad Nacional Autónoma de México, Mexico, D.F.

1997 *Cycles of the Sun, Mysteries of the Moon*. University of Texas Press, Austin.

Marcus, Joyce

1992 *Mesoamerican Writing Systems: Propaganda, Myth, and History in Four Ancient Civilizations*. Princeton University Press, Princeton, New Jersey.

Martin, Simon, and Joel Skidmore

2012 Exploring the 584286 Correlation between the Maya and European Calendars. *PARI Journal* 13(2):3–16.

Milbrath, Susan

1979 *A Study of Olmec Sculptural Chronology*. Studies in Pre-Columbian Art and Archaeology 23. Dumbarton Oaks, Washington, D.C.

1999 *Star Gods of the Maya: Astronomy in Art, Folklore, and Calendars*. University of Texas Press, Austin.

2017 The Legacy of Preclassic Calendars and Solar Observations in Mesoamerica. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.

Nuttall, Zelia

1904 The Periodical Adjustments of the Ancient Mexican Calendar. *American Anthropologist* N.S. 6:486–500.

Peeler, Damon E., and Marcus C. Winter

1992/1993 Mesoamerican Site Orientations and Their Relationship to the 260-day Ritual Period. *Notas Mesoamericanas* 14:37–61.

Peterson, Frederick

1962 *Ancient Mexico: An Introduction to the Pre-Hispanic Cultures*. Capricorn Books, New York.

Pool, Christopher A.

2007 *Olmec Archaeology and Early Mesoamerica*. Cambridge University Press, Cambridge.

Prem, Hanns J.

1971 Calendrics and Writing in Mesoamerica. In *Observations on the Emergence of Civilization in Mesoamerica*, edited by Robert F. Heizer and John A. Graham, pp. 112–132. Contributions of the University of California Archaeological Research Facility, no. 11. University of California, Berkeley.

Reese Taylor, Kathryn

2017 Founding Landscapes in the Central Karstic Uplands. In *Maya E Groups: Calendars, Astronomy, and Urbanism in the Early Lowlands*, edited by David. A. Freidel, Arlen F. Chase, Anne S. Dowd, and Jerry Murdock. University Press of Florida, Gainesville, in press.

Rice, Prudence M.

2007 *Maya Calendar Origins: Monuments, Mythohistory, and the Materialization of Time*. University of Texas Press, Austin.

Riese, Berthold

1988 *The Southeast Classic Maya Zone*, edited by Elizabeth Hill Boone and Cordon R. Willey. Dumbarton Oaks, Washington, D.C.

Rodríguez Martínez, Maria del Carmen, Ponciano Ortíz Ceballos, Michael D. Coe, Richard A. Diehl, Stephen D. Houston, Karl A. Taube, and Afredo Delagado Calderón

2006 Oldest Writing in the New World. *Science* 313:1610–1614.

Sánchez Nava, Pedro, and Ivan Šprajc

2015 *Orientaciones astronómicas en la arquitectura maya de las tierras bajas*. Instituto Nacional de Antropología e Historia, México, D.F.

Saturno, William A., David Stuart, and Boris Beltrán

2006 Early Maya Writing at San Bartolo, Guatemala. *Science* 311:1281–1283.

Šprajc, Ivan

1995 El Satunsat de Oxkintok y la estructura 1-sub Dzibilichaltún: unos apuntes arqueoastronómicos. *Memorias del Segundo Congreso Internacional de Mayistas*, pp. 585–600. Universidad Nacional Autónoma de México, Mexico, D.F.

2000 Astronomical Alignments at Teotihuacan, Mexico. *Latin American Antiquity* 11:403–415.

2001 *Orientaciones astronómicas en la arquitectura prehispánica del centro de México*. Instituto Nacional de Antropológia e Historia, Mexico, D.F.

2015 Pyramids Marking Time: Tony Aveni's Contribution to the Study of Astronomical Alignments in Mesoamerican Architecture. In *Cosmology, Calendars, and Horizon-based Astronomy in Ancient Mesoamerica*, edited by Anne S. Dowd and Susan Milbrath, pp. 19–36. University Press of Colorado, Boulder.

Šprajc, Ivan, Carlos Morales-Aguilar, and Richard D. Hansen
2009 Early Maya Astronomy and Urban Planning at El Mirador, Peten, Guatemala. *Anthropological Notebooks* 15(3):79–101.

Šprajc, Ivan, Heinz-Dieter Richter, and Pedro Francisco Sánchez Nava
2013 El tiempo registrado en el espacio urbano: Alianamientos astronómicos en la arquitectura de Tikal, Petén, Guatemala. *XXVI Simposio de Investigaciones Arqueológicas en Guatemala, 2012*, edited by Bárbara Arroyo and Luis Méndez Salinas, pp. 1065–1078. Museo Nacional de Arqueología y Etnología, Guatemala City.

Šprajc, Ivan, and Pedro Francisco Sánchez Nava
2012 Orientaciones astronómicas en la arquitectura maya de las tierras bajas: Nuevos datos e interpretaciones. In *XXV Simposio de Investigaciones Arqueológicas en Guatemala*, Vol. 2, edited by Bárbara Arroyo, Lorena Paiz, and Héctor Mejía, pp. 977–996. Museo Nacional de Arqueología y Etnología, Guatemala City.
2013 Equinoxes in Mesoamerican Architectural Alignments: Prehispanic Reality or Modern Myth? *Anthropological Notebooks* 19 (supplement):319–337.
2015 *Orientaciones astronómicas en la arquitectura de Mesoamérica: Oaxaca y el Golfo de México*. Electronic document, http://iaps.zrc-sazu.si/sites/default/files/pkc08_sprajc.pdf, accessed March 18, 2016.

Stanton, Travis W., and David A. Freidel
2003 Ideological Lock-In and the Dynamics of Formative Religions in Mesoamerica. *Mayab* 16:5–14.

Starr, Betty
1951 The Chorti and the Problem of the Survival of Maya Culture. *American Anthropologist* 53(3):355–369.

Stross, Brian
1994 Maize and Fish: The Iconography of Power in the Late Formative. *RES* 25:9–35.

Stuart, David
2005a New Year Records in Classic Maya Inscriptions. *The PARI Journal* 5(2):1–6.
2005b *The Inscriptions from Temple XIX at Palenque*. Pre-Columbian Art Research Institute, San Francisco.
2011 *The Order of the Days: The Maya World and the Truth about 2012*. Harmony Books, New York.

Sullivan, Timothy D.
2015 Shifting Strategies of Political Authority in the Middle Through Terminal Formative Polity of Chiapa de Corzo, Chiapas, Mexico. *Latin American Antiquity* 26(4):452–472.

Tedlock, Barbara
1992 *Time and the Highland Maya*. University of New Mexico Press, Albuquerque.

Terán, Silvia, and Christian H. Rasmussen
1994 *La milpa de los Mayas: La agricultura de los Mayas prehispánicos y actuales en el Noreste de Yucatán*. Danida, Merida, Yucatán.

Thompson, J. Eric S.
1960 *Maya Hieroglyphic Writing: An Introduction*. 3rd ed. University of Oklahoma Press, Norman.
1972 *Maya Hieroglyphs without Tears*. British Museum, London.

Tozzer, Alfred M.
1941 *Landa's "Relación de las Cosas de Yucatán": A Translation*. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Vol. 18. Peabody Museum, Cambridge, Massachusetts.

Urcid Serrano, Javier
2001 *Zapotec Hieroglyphic Writing*. Studies in Pre-Columbian Art and Archaeology 34. Dumbarton Oaks, Washington, D.C.

Vadala, Jeffrey
2009 Three Dimensional Analysis and Recreation of Preclassic T'isil. Master's thesis, Anthropology Department, California State University, Los Angeles.

Whittaker, Gordon
1992 The Zapotec Writing System. In *Supplement to the Handbook of Middle American Indians*, Vol. 5, edited by Victoria R. Bricker with assistance of Patricia A. Andrews, pp. 5–19. University of Texas Press, Austin.

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