

ASTRONOMICAL ALIGNMENTS AT TEOTIHUACAN, MEXICO

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It is known that the grid pattern characterizing the city layout of Teotihuacan incorporates two slightly different groups of alignments, skewed approximately 15.5° and 16.5° clockwise from cardinal directions. I argue that these alignments were dictated by deliberate and astronomically functional orientations of the Pyramid of the Sun and the Ciudadela. The two structures recorded sunrises and sunsets on two different sets of dates, allowing the use of an observational calendar composed of intervals that included multiples of 20 days and a 260-day period. The evidence presented suggests also that the location of the Sun Pyramid was not determined by the cave that is now underneath the structure and is probably human-made, but rather by a combination of astronomical and topographic criteria: the place allowed the temple built there to be oriented both to sunrises and sunsets on significant dates and, in the perpendicular direction, to Cerro Gordo to the north; furthermore, sunrises on the so-called quarter-days of the year could be observed from the same spot over a prominent mountain on the eastern horizon. The dates corresponding to the Teotihuacan alignments are attested also at other central Mexican archaeological sites and must have been employed, primarily, for scheduling agricultural and associated ritual activities in the yearly cycle.

Como es sabido, la cuadrícula que domina la traza urbana de Teotihuacan manifiesta dos grupos de alineamientos ligeramente diferentes, desviados aproximadamente 15.5° y 16.5° de los rumbos cardinales en el sentido de las manecillas de reloj. Según se argumenta, estos alineamientos fueron dictados por las orientaciones intencionales y astronómicamente funcionales de la Pirámide del Sol y la Ciudadela. Las dos estructuras, registrando las salidas y puestas del Sol en dos series diferentes de fechas, posibilitaron el uso de un calendario observacional compuesto por intervalos que incluían múltiplos de 20 días y un periodo de 260 días. Los datos presentados sugieren, además, que la ubicación de la Pirámide del Sol no fue determinada por la cueva que actualmente se encuentra bajo la estructura y que es probablemente artificial, sino por una combinación de criterios astronómicos y topográficos: el templo construido en ese lugar pudo ser orientado tanto hacia las salidas y puestas del Sol en las fechas significativas como, en la dirección perpendicular, hacia el Cerro Gordo al norte; además, del mismo punto pudieron ser observadas las salidas del Sol en los llamados días de cuarto del año sobre un monte prominente en el horizonte este. Las fechas que corresponden a los alineamientos teotihuacanos y que están atestiguadas también en otros sitios arqueológicos del centro de México deben haber sido empleadas, en primer lugar, para programar los trabajos agrícolas y actividades rituales asociadas en el ciclo anual.

Systematic archaeoastronomical research carried out during the last few decades has revealed that architectural orientations in Mesoamerica exhibit a clearly nonrandom distribution and that civic and ceremonial buildings were frequently oriented on the basis of astronomical considerations, particularly to the Sun's positions on the horizon on certain dates of the tropical year (Aveni 1991; Aveni and Gibbs 1976; Aveni and Hartung 1986; Šprajc 1997; Tichy 1991). According to various hypotheses forwarded thus far, the dates recorded by the orientations can be interpreted in terms of their relevance in the agricultural cycle and in computations related to the calendrical system; it has been suggested, for example, that these dates are

separated by calendrically significant intervals (Aveni 1997; Aveni and Hartung 1986; Tichy 1991). Some authors have reconstructed possible horizon calendars for particular sites, on the assumption that prominent peaks of the local horizon served as natural markers of sunrises and sunsets on relevant dates (e.g., Aveni et al. 1988; Broda 1993; Galindo 1994; Iwaniszewski 1994; Morante 1993, 1996; Ponce de León 1982; Tichy 1991).

Since both the accumulated fieldwork experiences and the feedback information generated by interpretational attempts revealed that the available alignment data were neither sufficient nor accurate enough for testing such specific hypotheses, I undertook precise measurements of alignments at 37 Pre-

classic, Classic, and Postclassic archaeological sites in central Mexico, taking into account a variety of facts and circumstances whose relevance had not been recognized before. Not only the orientations of civic-ceremonial structures but also the alignments to prominent peaks on the local horizon, placed within the angle of annual movement of the Sun, have been measured. The analyses of the alignment data show that the dates of sunrises and sunsets, both along the architectural orientations and above the prominent hills on the local horizon, exhibit consistent patterns: the intervals separating the dates recorded at a particular site tend to be multiples of 13 and 20 days and are, therefore, significant in terms of the Mesoamerican calendrical system; furthermore, the most recurrent dates apparently marked crucial moments of a ritual agricultural cycle. The regularities detected strongly suggest that the places for the construction of important religious structures were carefully selected, so that certain mountain peaks on the local horizon could have been used as natural markers of sunrises and sunsets on significant dates, and that both the architectural orientations and the prominent local horizon features allowed the use of *observational calendars* that, in view of the lack of permanent concordance of the calendrical and tropical years, were necessary for predicting important seasonal changes and for an efficient scheduling of the corresponding agricultural activities. The detailed argument and the supporting evidence, as well as methodological principles underlying the collection and analysis of the alignment data, have been exhaustively presented elsewhere (Šprajc 1999).

Teotihuacan, one of the archaeological sites included in the quoted study, exemplifies the observational function of the alignments employed in prehispanic central Mexico from the Preclassic on.

Teotihuacan Orientations

Teotihuacan is one of the best-known examples, perhaps the prototype, of the group of orientations that are widely distributed in Mesoamerica and which, ranging from about 15° to 18° clockwise from the cardinal directions, have come to be known as the 17° family of orientations (Aveni 1991:269; Aveni and Gibbs 1976:510). As revealed by the Teotihuacan Mapping Project, the same general orientation of the grid pattern, adopted everywhere in the city since the Tzacualli phase (A.D. 1–150), is actually

composed of two slightly different orientation groups, incorporated into different parts of the urban layout (Dow 1967:326; Millon 1973:17, 37–38, 52; Millon et al. 1973).¹ According to Dow (1967:326–327), the Pyramid of the Sun, the Street of the Dead, and most of the buildings in the central area of the city exhibit a clockwise deviation of about 15°25' with respect to the cardinal directions, while the Ciudadela and two major avenues running east and west of it are skewed approximately 16°30' south of east; in several building complexes the north-south walls align with azimuths around 15°30' and the east-west lines run about 16°30' south of east, whereas in other cases it is difficult to say which of the two major orientations was being followed. Since the two orientation groups were, as argued below, dictated by the orientations of the Sun Pyramid and the Ciudadela, Table 1 presents data on the orientations of these two structures only.²

The Sun Pyramid's slanted faces (*taludes*)—even those having remnants of stucco—exhibit quite irregular lines and divergent azimuths, so that the intended orientation of the structure cannot be determined with precision. Millon (1973:53) observes “it is oriented 15°25' east of north in its north-south dimension and approximately the same orientation south of east in its east-west dimension,” but he adds that some of the readings “taken on the south side of the pyramid where original construction is exposed [. . .] approached 16° south of east, [. . .] suggesting that the angle produced by the intersection of the west and south sides of the pyramid is slightly more than 90°.” These remarks agree with the results of Morante's (1996:95) measurements adopted here: while the north-south axis of the pyramid is parallel to the Street of the Dead (see Millon 1973:53), whose azimuth is 15°28',³ the east-west axis is skewed about 15°45' south of east (Table 1).

It is noteworthy that the Pyramid of the Sun is oriented to the summit of Cerro Gordo to the north (Hartung 1977:270, 1979:90; Hartung and Aveni 1991:23), as one can observe particularly along the west *taludes*, some of which preserve parts of original stucco (Figure 1). The assertion of some authors that it is the Street of the Dead that points to Cerro Gordo was corrected already by Tobriner's (1972:104–105) observation that the avenue “is oriented instead toward an area just to the left of the main peak.” Considering that a number of prehispanic temples in central Mexico have been found to

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Table 1. East-west orientation of the Pyramid of the Sun and the Ciudadela at Teotihuacan. The first/second row of data corresponding to each of the two buildings includes the mean azimuth (A) to the east/west and the corresponding horizon altitude (h), astronomical declination (δ), and sunrise/sunset dates. Estimated margins of error, based on divergent azimuths of the lines measured at both structures, are also given. The alignment data for the Pyramid of the Sun are valid for an observer on top of it, while those for the Ciudadela are true for an observer upon the Temple of Quetzalcoatl.

structure	A	h	δ	dates
Pyramid of the Sun	105°45' ± 1°	2°01' ± 5'	-14°11' ± 1°	Feb 10, Oct 30 ± 3 ^d
	285°45' ± 1°	0°22' ± 10'	14°48' ± 1°	Apr 30, Aug 13 ± 3 ^d
Ciudadela	106°26' ± 15'	2°11' ± 2'	-14°45' ± 15'	Feb 9, Nov 1 ± 1 ^d
	286°26' ± 15'	0°34' ± 2'	15°31' ± 15'	May 2, Aug 11 ± 1 ^d

be aligned to prominent mountain tops in their neighborhood (Šprajc 1999), the orientation of the Sun Pyramid to Cerro Gordo is hardly accidental, but is rather an example of a relatively common practice that must have been related to the outstanding role of the mountains in the Mesoamerican worldview (see Broda 1991, 1993); the aquatic symbolism of Cerro Gordo, specifically, exemplifies the underlying concepts (Tobriner 1972).

The alignment data for the Ciudadela given in Table 1 are based on my readings taken along the



Figure 1. Pyramid of the Sun at Teotihuacan, Mexico; view to the north along a western talud edge aligned to Cerro Gordo.

faces of the Temple of Quetzalcoatl, its abutted platform (*Adosada*), and the so-called Great Platform that surrounds the inner plaza.⁴ The north-south walls of the compound are parallel to the Street of the Dead.

Significance of the Teotihuacan Orientations

The numerous hypotheses that have been forwarded so far on the origin and significance of the Teotihuacan alignments cannot be examined here, but have been exhaustively discussed elsewhere (Šprajc 1999).

The distribution pattern of azimuths corresponding to Mesoamerican architectural orientations clearly shows that the latter are largely astronomical, referring to phenomena observable on the horizon (see Aveni 1991:266–267, Figures 74a and b; Aveni and Hartung 1986:7–14, 56, Figure 2; Šprajc 1997, 1999). For the Teotihuacan orientations, specifically, an origin other than astronomical is difficult to conceive: evidently not influenced by natural topography (Dow 1967:326), they belong to the 17° family of orientations, which is probably the most widespread alignment group in Mesoamerica.

The possibility that the orientation of *each individual architectural complex* was established *directly on the basis of astronomical observations* must be discarded: since the horizon altitudes vary, depending on the exact point of observation, the same azimuths do not correspond in different parts of the city to the same astronomical phenomena (declinations) on the horizon. It is highly unlikely that *particular* architectural compounds were deliberately oriented to *different* astronomical phenomena, because in that case:

- (1) the general uniformity of the urban grid orientation would hardly exist;
- (2) we would expect to find consistent orientations of successive stages of a single compound.

In this context let us recall that Dow (1967:331–332), comparing orientations of successive construction phases of the Zacuala complex, detected considerable but not systematic variations,⁵ and thus concluded that astronomical references were not employed to orient each individual structure, though they may have originally dictated the general orientation of the city layout, to which particular buildings conformed. He also found that north-south alignments on the Plaza of the Moon were practically identical to those measured at the Ciudadela, indicating that a northern star was not used along the Street of the Dead to orient individual structures, because in that case the azimuths at the extreme north of the avenue would be, due to a considerably greater horizon altitude (Cerro Gordo), consistently greater than at its southern extreme (Dow 1967:330–331). It is thus evident that diverse architectural complexes composing the city layout *followed* the orientation of certain important buildings, and that only the orientations of the latter were astronomically functional and precise.

The deviations of approximately 15.5° from the cardinal directions are embodied in the Street of the Dead, the Pyramids of the Sun and the Moon and, possibly, West Avenue, but they prevail in the central area of the city (Dow 1967:327; Millon 1973:52, 56–57; Morante 1996:99). The Street of the Dead, even if it is the most prominent part of urban layout exhibiting this orientation, can hardly be considered as its origin: since the north-south course of the avenue cannot be convincingly accounted for by stellar references (Dow 1967:330–331), it was more likely but an element of urban layout designed in conformity with the orientation pattern established on other grounds. It is the Pyramid of the Sun that must have imposed the alignments skewed about 15.5° from cardinal directions, considering that this structure

- (1) was, in all probability, deliberately oriented to the summit of Cerro Gordo, situated at an azimuth of about 15.5° (Figure 1);
- (2) is located on one flank of the Street of the Dead and in the part of the city where the skews around 15.5° from cardinal directions prevail (see Dow 1967:327);
- (3) was the largest temple of the city;
- (4) was built in the Tzacualli phase, when the overall grid pattern was introduced (the substructure, apparently possessing the same orientation, may date even to the Patlachique phase [Millon et al. 1965; Morante 1996:92–93]).

Since the orientation of the Street of the Dead is determinable with much greater precision than the orientations of other structures conforming to it, its azimuth can be considered as relevant and representative of this orientation group. We can suppose, therefore, that this was the orientation incorporated into the original layout of the Pyramid of the Sun, defining not only its north-south but also its east-west axis. Even if the azimuth given in Table 1 (105°45') and based on the readings along the faces exposed nowadays is not precisely perpendicular to the Street of the Dead, the facts summarized below support the idea that the originally intended east-west orientation azimuth of the Pyramid of the Sun was, indeed, 105°28'.

Assuming that observations were made before the pyramid was built at the center of its future base, i.e., on the natural ground level, the alignment of 105°28'/285°28' recorded, in the first century A.D., the sunrises on February 11 and October 29 and sunsets on April 30 and August 13 (Table 2; Figure 2).⁶ The interval from February 11 to October 29, as well as from August 13 to April 30, is exactly 260 days; while it is obvious that the phenomena separated by this interval occurred on the same dates of the 260-day calendrical cycle, we can also recall that the base of what seems to be the first of two Sun Pyramid's construction stages measures, according to the analysis of Sugiyama (1993:112, 120), 260 Teotihuacan length units of 83 cm each. Probably both pairs of dates were important, considering that declinations within no more than a few minutes off *the two* values given in Table 2 correspond to several accurately measurable alignments found at other central Mexican archaeological sites from different periods (Šprajc 1999).⁷ It is worth adding that, within Teotihuacan, the orientation of 105°28'/285°28' could be functional in both directions, recording the four dates mentioned above, precisely on the spot where the Pyramid of the Sun was built: due to the proximity and irregular outline (variable altitudes) of the western horizon, there are few places in the area at which *the two pairs of dates could have been registered on both horizons with a single alignment*.

Consequently, the orientation of 105°28'/285°28' appears to be significant, particularly if we assume that observations were made at the center of the Sun Pyramid's base. On the top of the structure, the most logical place for observations after the pyramid was built, the same alignment would have recorded sun-

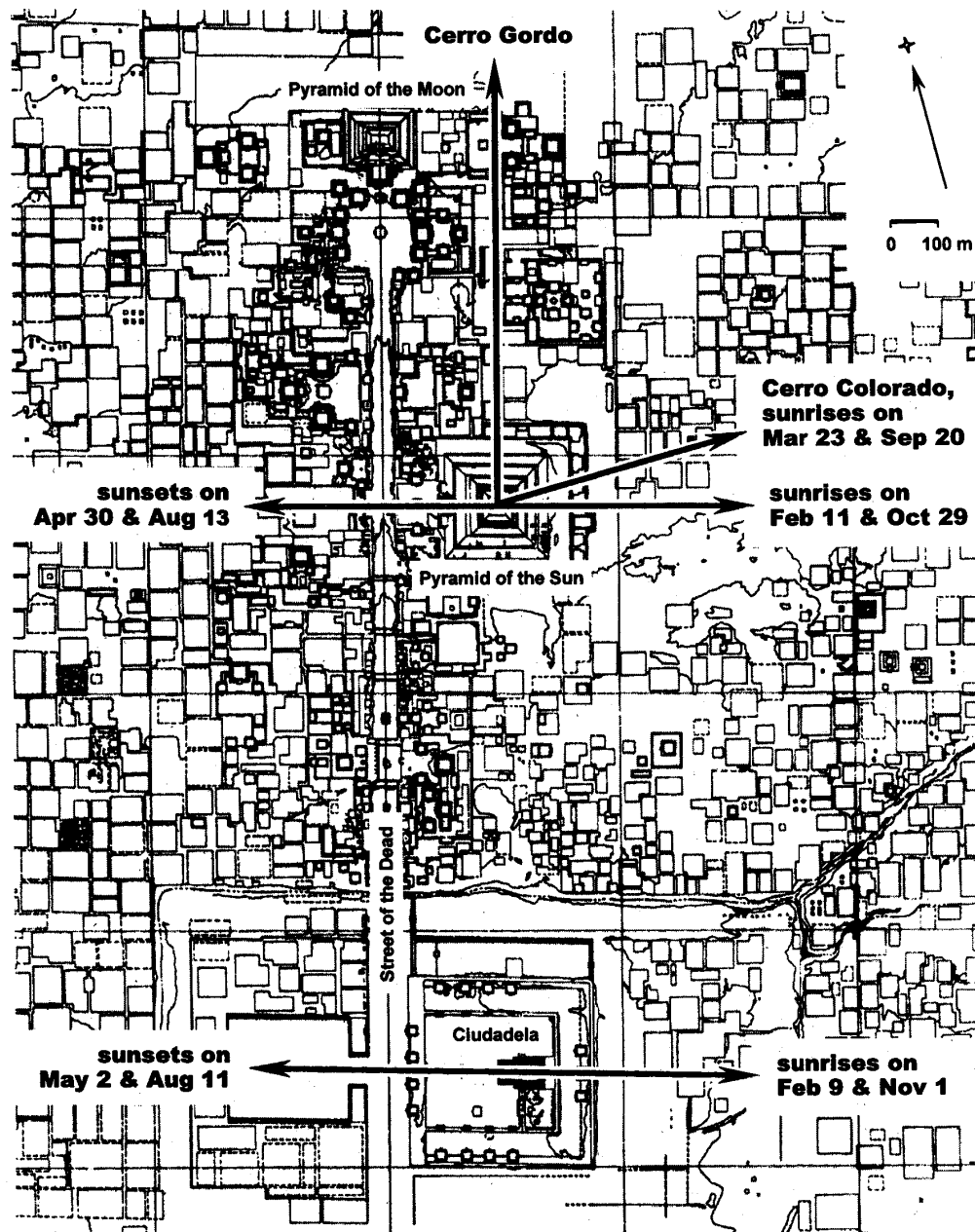


Figure 2. Map of the central area of Teotihuacan (after Millon et al. 1973), with relevant alignments. The sunrise and sunset dates corresponding to the orientation of the Pyramid of the Sun are valid for the azimuth of 105°28'/285°28' and for an observer on the ground level; the alignment of 105°45'/285°45', determined by measurements, recorded the same sunset (but different sunrise) dates, observing on top of the pyramid (see the text and Tables 1, 2 and 3).

Table 2. Azimuths (A), horizon altitudes (h), declinations (δ), and sunrise and sunset dates corresponding to the alignment perpendicular to the Street of the Dead, for an observer at the center of the base of the Pyramid of the Sun.

A	h	δ	dates
105°28'	2°11'	-13°51'	Feb 11, Oct 29
285°28'	1°05'	14°49'	Apr 30, Aug 13

risers on the same dates as on the ground level (February 11 and October 29), but the sunset dates would have shifted—due to the change in the western horizon altitude—to April 29 and August 14 (see Tables 2 and 3).⁸ In other words, on the significant dates April 30 and August 13 the Sun, if observed from the top of the Sun Pyramid, was not setting at 285°28' (15°28' north of west) but rather about 15' to 25' northwards. Surprisingly, we can recall that, according to the measurements, the pyramid's east-west axis, in fact, does not seem to be skewed 15°28' south of east (or, for that matter, north of west) but rather a trifle more (Millon 1973:53). Even though the orientation about 15°45' south of east determined by Morante (1996:95) and given in Table 1 is, due to the present state of the building, not particularly reliable, it may not be a coincidence that the sunsets along this alignment (azimuth 285°45') would have been observed from the top of the pyramid on the same dates as from the center of the structure's base in the direction of 285°28' (see Tables 1 and 2). A possible scenario suggested by these circumstances is the following:

The builders, originally orienting the Pyramid of the Sun (and the surrounding urban grid) 15°28' south of east, did not anticipate that, by elevating the alignment, the corresponding sunset dates would no longer be the same as at the ground level. Upon realizing the fact, they decided to correct the orientation, so that it would keep recording the intended dates on the western horizon: presumably the upper temple was realigned first, but later the new orientation was transferred also to the subsequent construction phases or enlargements of the pyramid. If this is what happened, the modified orientation, which no longer recorded sunrises on February 11 and October 29 but rather on February 10 and October 30 (see Tables 1 and 2), reflects the priority given by the builders to the sunsets on April 30 and August 13. A special significance of these dates is suggested also by the fact that they are marked by light-and-shadow effects in the so-called astronomical caves 1 and 2 of Teoti-

Table 3. Azimuths (A), horizon altitudes (h), declinations (δ), and sunrise and sunset dates corresponding to the alignment perpendicular to the Street of the Dead, for an observer on top of the Pyramid of the Sun.

A	h	δ	dates
105°28'	2°00'	-13°55'	Feb 11, Oct 29
285°28'	0°20'	14°31'	Apr 29, Aug 14

huacan and in the Cave of the Sun at Xochicalco (Morante 1993:2:79–108, 1996:172, 176–177, 181).

If one group of orientations in the Teotihuacan grid was dictated by what was conceivably the most important temple of the city, it is natural to suppose that the other group was also imposed by a major ceremonial structure. The orientations around 16°30' south of east most probably followed the east-west axis of the Ciudadela. Since the latter became the religious and political center in the Miccaotli and Tlamimilolpa phases (Cowgill 1992:102–108; Millon 1973:54–55; Sugiyama 1993:104), these alignments might be of later origin than those around 15°30' south of east, as already suggested by Millon (1973:53, 56–57).⁹ Possibly the Ciudadela's orientation was intended to replace the sunrise dates corresponding to the Pyramid of the Sun with other dates which, together with those recorded by the Sun Pyramid on the western horizon, composed an observational calendar with intervals easily manageable by means of the formal calendrical system:¹⁰ since the dates of sunset in the axis of the Pyramid of the Sun delimited a 260-day period, from August 13 to April 30, the dates of sunrise registered by the Ciudadela could have served for subdividing it into intervals that were multiples of 20 days (Table 4; Figure 2).¹¹

For the moment it seems impossible to ascertain whether the two Teotihuacan orientations were, indeed, employed simultaneously, as proposed above: if the alignments around 16.5° south of east were introduced later than those skewed about 15.5°,

Table 4. Possible observational calendar for the Pyramid of the Sun and the Ciudadela at Teotihuacan (dates and intervening intervals are to be read in the counter-clockwise direction).

alignment	date	interval (days)	date
		100	
Ciudadela, sunrise	Feb 9	80	Nov 1
Pyramid of the Sun, sunset	April 30	105	Aug 13

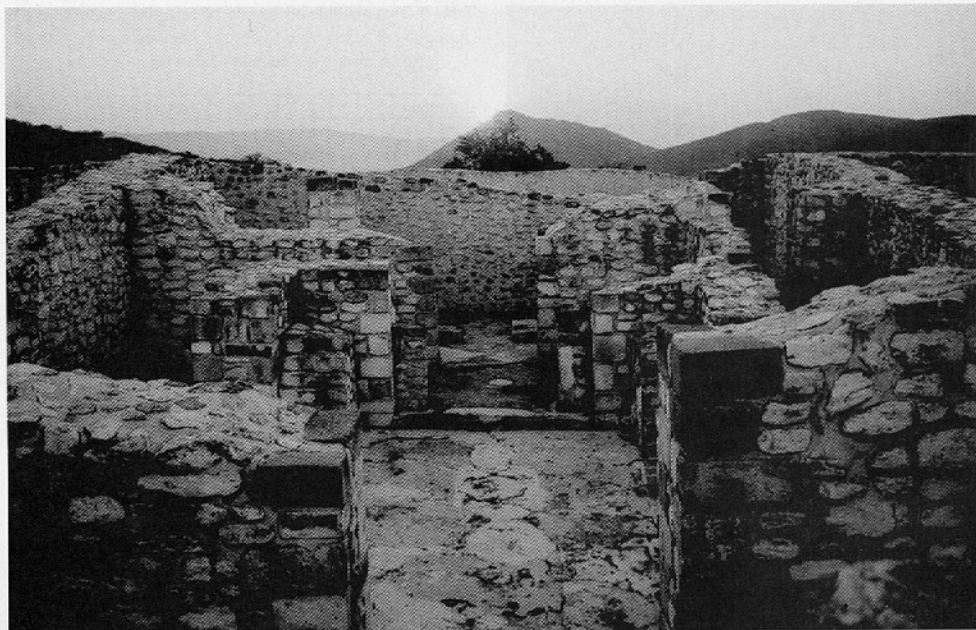


Figure 3. Sunrise on February 11, 1998, observed along the axis of central section of the Acropolis at Xochicalco, Mexico.

the latter's observational function may have been at that time abandoned. However, the occurrence of both alignment groups at several archaeological sites from later periods does suggest their simultaneous use (Šprajc 1999). The best example is the Epiclassic site of Xochicalco, where both orientations are embodied in the Acropolis and associated structures, all of them evidently from the same period (ca. A.D. 700–900). The central and uppermost section of the Acropolis was oriented to sunrises on February 12 and October 30, and to sunsets on May 1 and August 14 (Figures 3 and 4), while the eastern and western sections marked, respectively, sunrises on February 10 and November 2, and sunsets on May 3 and August 11. Here it seems obvious that both pairs of the latter series of dates were relevant: since the elevated central section of the Acropolis blocks the view from the eastern section to the west and from the western section to the east, the orientations of the eastern and western sections could have been functional only to the east and west, respectively (Šprajc 1999). Therefore, two observational calendar schemes could have been used simultaneously (Table 5). At other sites, such as Teotihuacan, only one of the two schemes may have been employed.

The dates registered by both groups of alignments of the 17° family, though perhaps not all of them were equally important, probably marked four critical moments in the maize cultivation cycle, corresponding to preparatory works in the milpa (February), the onset of the rainy season and the time for planting (around May 1), the ripening of the first corn cobs in some areas (August), and the end of the rainy season and the beginning of harvest (around November 1) (see Iwaniszewski 1991). However, the fact that practically the same declinations (dates) are recorded by alignments at a number of sites, even in ecologically different zones, and that traditional festivities with predominantly agricultural symbolism are still celebrated in various indigenous communities around February 10, May 1, August 10, and November 1 (Broda 1993; Iwaniszewski 1993:291; Šprajc 1999), suggests the existence of a *ritual* or *canonical* agricultural cycle: the dates involved must have been canonized precisely because the intervals separating them were easy to handle by means of the sacred 260-day calendar count. The 17°-family alignments can thus be interpreted as marking ritually important moments that introduced particular stages of the maize cultivation cycle, whereas the determi-

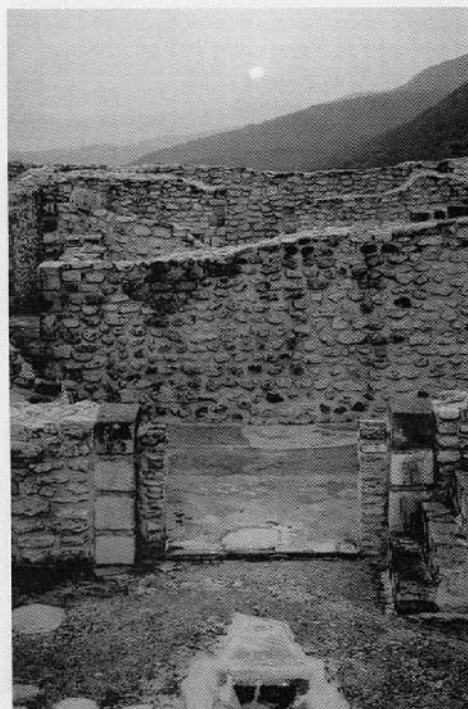


Figure 4. Sunset on April 30, 1998, observed along the axis of central section of the Acropolis at Xochicalco, Mexico.

nation of exact times appropriate for initiating the corresponding agricultural works depended on a variety of other, mostly practical, considerations related to specific environmental circumstances (Šprajc 1999; for ethnographic analogies from the U.S. Southwest, see Zeilik 1985).

Astronomical Motives for the Location of the Pyramid of the Sun

After a cave had been found underneath the Pyramid of the Sun in 1971, Doris Heyden (1973, 1975, 1981:3–4, 28, 1991:502) argued it was this grotto—apparently considered more sacred than other caves in the valley, perhaps because it had a four-petal-flower form—that determined the place where the early teotihuacanos, probably in the Patlachique phase, built a small shrine, which was later covered by the Pyramid of the Sun.

The hypothesis has been widely accepted. However, the results of recently accomplished geophysical research suggest that the cave under the Sun Pyramid, formerly believed to be natural (though artificially

Table 5. Two possible observational calendar schemes for the Acropolis of Xochicalco (dates and intervening intervals are to be read in the counter-clockwise direction).

alignment	date	interval (days)	date
		100	
Acropolis East, sunrise	Feb 10	80	Nov 2
Acropolis Center, sunset	May 1	80	Aug 14
		105	
alignment	date	interval (days)	date
		105	
Acropolis Center, sunrise	Feb 12	80	Oct 30
Acropolis West, sunset	May 3	80	Aug 11
		100	

modified), is rather entirely man-made (Barba 1995:22–23, 73; Manzanilla 1995:156). Barba (1995:23) affirms that, while there is no natural formation process that could account for the presence of a cavity on that spot, a great similarity exists with the excavation techniques attested in other caves in the area.

This discovery has obviously a very important implication: if the cave is artificial, its location could not have been a *determinant* of the place of construction of the Sun Pyramid, but rather must have been *determined* by other motives. According to Barba (1995:22), the cave could have been excavated before, during, or after the building of the pyramid. Even assuming it antedated whatever structure built there, the question remains: why was it excavated precisely on that spot? Barba believes the teotihuacanos had a very clear reason for excavating it there, and I hope to be able to corroborate his opinion.

As already mentioned, the orientation of the north-south axis of the Pyramid of the Sun to the peak of Cerro Gordo to the north is hardly fortuitous. On the other hand, I have argued above that the originally planned east-west axis of the pyramid pointed to sunrises on four dates of the tropical year registered by alignments at various sites. Since the observation points where the four dates can be recorded by a *single* alignment are conditioned by horizon altitudes in both directions of the alignment, the number of points fulfilling the requisite is, in an area with irregular horizon outlines, reduced. If the purpose of the architects was, moreover, to build a temple with its north-south axis aligned to Cerro Gordo, the criteria for selecting an adequate place became highly restricted, particularly if an additional requirement



Figure 5. Sunrise over Cerro Colorado on March 22, 1993, observed from the top of the Pyramid of the Sun at Teotihuacan, Mexico.

was that the building have a rectangular ground plan. The latter, however, was not necessarily one of the goals the builders proposed to themselves, if we consider that ground plans of various prehispanic buildings are far from being perfect rectangles (the Ciudadela of Teotihuacan being the nearest example). In fact, the right angles achieved in the original design of the Pyramid of the Sun may have resulted simply as a consequence of other conditions.

The results of my analysis of the alignment data related to prominent horizon features at a number of archaeological sites in central Mexico suggest that the important ceremonial structures were built on carefully selected places, which allowed certain mountain peaks on the local horizon to be employed as markers of sunrises and sunsets on culturally significant dates (Šprajc 1999). In the light of comparative evidence it seems very likely that the Pyramid of the Sun of Teotihuacan was built on the place from where the sunrises over the mountain top of Cerro Colorado (or Tipayo) visible on the eastern horizon (note that another hill called Cerro Colorado is located west of Teotihuacan) could be observed on March 23 and September 20 (Figures 2 and 5; Table 6). These dates, commonly known as quarter days—because together with the solstices they divide the year into four parts of about equal length

(Somerville 1927:33)—are recorded by orientations at a number of archaeological sites in Mesoamerica (Ponce de León 1982:60; 1991; Šprajc 1990, 1995, 1999; Tichy 1991:56–64). Taking into account a probable connection between the decline of Cuicuilco, which provoked migrations to the north, and the foundation of Teotihuacan (Manzanilla 1993:64; Parsons 1987:68; Sanders et al. 1979:99–107), as well as the similarities in urban configuration of the two centers (Sanders et al. 1979:76), it seems particularly significant that also at Cuicuilco, when observing on the circular pyramid, the Sun rises on March 23 and September 20 above a mountain peak (Cerro Papayo) on the eastern horizon (Broda 1993:278, Figure 9.9; Ponce de León 1982:32, 60; Šprajc 1999).

Table 6. Azimuth (A), altitude (h) and declination (δ) of Cerro Colorado and the corresponding sunrise dates, for an observer on top of the Pyramid of the Sun (if observed at the center of the pyramid's base, i.e., on the ground level, the mountain—having only a slightly greater altitude and declination—marked sunrises on the same dates). The alignment data correspond to the center of the mountain's relatively flat top (whose angular width is 34', almost equalling the Sun disk's diameter).

mountain	A	h	δ	dates
Cerro Colorado (Tipayo)	89°30'	1°55'	1°02'	Mar 23, Sep 20

Consequently, the criteria for the location of the Pyramid of the Sun probably included the desire that Cerro Colorado on the eastern horizon should have marked sunrises on the quarter days of the year. If the mountain, situated at a distance of 20.6 km from the Sun Pyramid, was to serve this end, and if, at the same time, the east-west orientation of the pyramid was intended to register sunrises and sunsets on the four relevant dates discussed above, the observation point could not be located more than about 100 m east or west of the actual center of the pyramid. Observing at whatever spot within the area permissible for the temple's construction, the peak of Cerro Gordo was situated roughly along the perpendicular to the required east-west alignment; it can be imagined that the place, which not only satisfied astronomical criteria but also allowed a building with rectangular ground plan to be oriented in its north-south dimension to the impressive mountain to the north, acquired an enormous symbolic significance (Figure 2).

If the cave underneath the Pyramid of the Sun is, indeed, artificial, the fact that the temple was not built above any of the natural caves in the Teotihuacan Valley would suggest, precisely, that considerations of other kind were more important for the selection of the site; the nature of these considerations is indicated by the properties of the place that was, according to the arguments exposed above, unique as to the combination of significant alignments. If the evidence presented accounts for the location of what must have been the most sacred site of Teotihuacan, it would be understandable that a cave with a symbolically significant form was excavated there, either before or after the construction of a temple. As Barba (1995:23) remarks, the new finding makes the cave unnatural, but it does not diminish its sacredness. Indeed, Heyden (1981:14, 38, 1991:512) mentions that artificial caves or tunnels have been found in the Preclassic pyramid at Totimehuacan, Puebla, under the temples of Mayapan and at other Maya sites. Furthermore, artificial or man-modified caves have been found to mark site centers or places of particular ritual importance at various archaeological sites in the Guatemala Highlands (Brady and Veni 1992). Consequently, the artificial grotto beneath the Pyramid of the Sun of Teotihuacan would not be an exceptional case. On the contrary, upon studying early colonial documents, García-Zambrano (1994:218) concludes that the foundation of prehispanic settlements often included the practice of excavating a cave

and approximating its shape to that of the mythological cave with internal niches.

As Millon (1973:49) put it, "the rise of Teotihuacán, the economic center, cannot be understood without reference to the simultaneous rise of Teotihuacán, the sacred center." Indeed, religion may have played an important role in the foundation and growth of Teotihuacan (Cowgill 1992). If volcanic eruptions occurring during the Late Preclassic in the Sierra de Chichinautzin, which encloses the Basin of Mexico from the south, caused population decline in the area of Cuicuilco and provoked migrations to the north of the Basin, it is possible that both the volcanic phenomena and the consequent ecological disaster produced a strong psychological impact on the immigrants from the south, giving rise to the formation of a specific system of worship. If so, religious concepts and the associated political ideology may have become significant components of social cohesion, necessary for agricultural intensification and political centralization that can account for the massive population nucleation attested in Teotihuacan from 100 B.C. to A.D. 100 (see Barba 1995:69, 72, 74; Manzanilla 1993:64; Millon 1981:235; Parsons 1987:68; Sanders et al. 1979:99–107). Since the site chosen to be the central place of worship had such remarkable properties in terms of astronomy and sacred geography, it may have contributed substantially to the enormous religious significance of Teotihuacan, making it a focus of pilgrimage on an "international" level.

Concluding Remarks

The evidence discussed above suggests that the city layout of Teotihuacan incorporated alignments dictated by the astronomically significant orientations of the Pyramid of the Sun and the Ciudadela, and that the place for the construction of the Sun Pyramid, the oldest and biggest of the main temples, was selected on astronomical grounds, which included the purpose of employing a prominent peak on the local horizon as a natural marker of the Sun's position on the so-called quarter days of the year. The analysis of the alignment data corresponding to the two principal ceremonial and civic structures of Teotihuacan has shown that a solar observational calendar could have been employed, composed of calendrically significant and, therefore, easily controllable intervals. The probability that such was, indeed, the function of these orientations is increased

by the fact that observational calendars with similar structural characteristics have been reconstructed for a number of central Mexican archaeological sites (Šprajc 1999). In view of the distribution of dates involved, they must have had practical uses, allowing an efficient scheduling of agricultural and associated ritual activities in the annual cycle. While some dates frequently recorded by the alignments probably marked crucial moments of a canonic or ritualized agricultural cycle, others must have had "auxiliary" functions. Since the intervals composing observational schemes were multiples of basic periods of the calendrical system, it was relatively easy to predict the most important dates, knowing the sequence of the intervals involved and the mechanics of the formal calendar. This anticipatory aspect of observational calendars must have been of major significance. Important dates, supposing they were related to subsistence activities, had to be announced ahead of time, because the ceremonies officially inaugurating certain stages of agricultural cycle had to be prepared with due anticipation; on the other hand, direct observations on relevant dates may have been obstructed by cloudy weather (Šprajc 1999; see Zeilik 1985).

Notwithstanding, the astronomical alignments cannot be adequately understood in terms of their practical function only. Both at Teotihuacan and at other Mesoamerican sites they are associated with the most important public buildings, revealing that astronomical practices had a paramount role in social, religious, and even political life of prehispanic societies.

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References Cited

Aveni, A. F.

- 1991 *Observadores del cielo en el México antiguo*. Translated by J. Ferreira. Fondo de Cultura Económica, México, D.F.
 1997 Out of Teotihuacan: Origins of the Celestial Canon in Mesoamerica. Paper presented at the Princeton Mesoamerican Archive Conference on "The Classic Heritage: From Teotihuacan to Templo Mayor."
 Aveni, A. F., E. E. Calnek, and H. Hartung
 1988 Myth, Environment, and the Orientation of the Templo Mayor of Tenochtitlan. *American Antiquity* 53:287–309.
 Aveni, A. F., and S. L. Gibbs
 1976 On the Orientation of Precolumbian Buildings in Central Mexico. *American Antiquity* 41:510–517.
 Aveni, A. F., and H. Hartung
 1986 *Maya City Planning and the Calendar*. Transactions of the American Philosophical Society Vol. 76, Pt. 7. American Philosophical Society, Philadelphia.

Barba Pingarrón, L. A.

1995 *El impacto humano en la paleogeografía de Teotihuacan*. Unpublished Ph.D. dissertation, Facultad de Filosofía y Letras, Universidad Nacional Autónoma de México, México, D.F.

Brady, J. E., and G. Veni

1992 Man-Made and Pseudo-Karst Caves: The Implications of Subsurface Features within Maya Centers. *Geoarchaeology: An International Journal* 7:149–167.

Broda, J.

1991 Cosmovisión y observación de la naturaleza: el ejemplo del culto de los cerros en Mesoamérica. In *Arqueoastronomía y etnoastronomía en Mesoamérica*, edited by J. Broda, S. Iwaniszewski, and L. Maupomé, pp. 461–500. Instituto de Investigaciones Históricas, Universidad Nacional Autónoma de México, México, D.F.

1993 Astronomical Knowledge, Calendrics, and Sacred Geography in Ancient Mesoamerica. In *Astronomies and Cultures*, edited by C. L. N. Ruggles, and N. J. Saunders, pp. 253–295. University Press of Colorado, Niwot.

Cabrera Castro, R.

1991 Secuencia arquitectónica y cronológica de La Ciudadela. In *Teotihuacan 1980–1982: Nuevas interpretaciones*, edited by R. Cabrera C., I. Rodríguez G., and N. Morelos G., pp. 31–60. Colección Científica 227. Instituto Nacional de Antropología e Historia, México, D.F.

Cabrera, R., and S. Sugiyama

1999 El Proyecto Arqueológico de la Pirámide de la Luna. *Arqueología: Revista de la Coordinación Nacional de Arqueología del Instituto Nacional de Antropología e Historia*, segunda época, No. 21:19–33.

Cowgill, G. L.

1992 Toward a Political History of Teotihuacan. In *Ideology and Pre-Columbian Civilizations*, edited by A. A. Demarest and G. W. Conrad, pp. 87–114. School of American Research Press, Santa Fe.

Dow, J. W.

1967 Astronomical Orientations at Teotihuacán, a Case Study in Astro-Archaeology. *American Antiquity* 32:326–334.

Galindo Trejo, J.

1994 *Arqueoastronomía en la América antigua*. Consejo Nacional de Ciencia y Tecnología—Editorial Equipo Sirius, México, D.F.

García-Zambrano, A. J.

1994 Early Colonial Evidence of Pre-Columbian Rituals of Foundation. In *Seventh Palenque Round Table, 1989*, edited by V. M. Fields, pp. 217–227. The Pre-Columbian Art Research Institute, San Francisco.

Hartung, H.

1977 Relaciones urbanísticas lineales-visuales en Teotihuacan y su zona de influencia. In *Los procesos de cambio (en Mesoamérica y áreas circunvecinas): XV Mesa Redonda*, vol. 2, pp. 267–275. Sociedad Mexicana de Antropología—Universidad de Guanajuato, Guanajuato.

1979 El ordenamiento espacial en los conjuntos arquitectónicos mesoamericanos: el ejemplo de Teotihuacan. *Comunicaciones, Proyecto Puebla-Tlaxcala* 16:89–103.

Hartung, H., and A. F. Aveni

1991 Observaciones sobre el planeamiento de Teotihuacán: El llamado trazo cuadrícula y las orientaciones a los puntos cardinales. *Cuadernos de Arquitectura Mesoamericana* No. 13:23–36.

Heyden, D.

1973 ¿Un Chicomóctoc en Teotihuacan?: La cueva bajo la Pirámide del Sol. *Boletín INAH*, época II, No. 6:3–18.

1975 An Interpretation of the Cave Underneath the Pyramid

of the Sun in Teotihuacan, Mexico. *American Antiquity* 40:131–147.

1981 Caves, Gods, and Myths: World-View and Planning in Teotihuacan. In *Mesoamerican Sites and World-Views*, edited by E. P. Benson, pp. 1–39. Dumbarton Oaks, Washington, DC.

1991 La matriz de la tierra. In *Arqueoastronomía y etnoastronomía en Mesoamérica*, edited by J. Broda, S. Iwaniszewski, and L. Maupomé, pp. 501–515. Instituto de Investigaciones Históricas, Universidad Nacional Autónoma de México, México, D.F.

Iwaniszewski, S.

1991 La arqueología y la astronomía en Teotihuacan. In *Arqueoastronomía y etnoastronomía en Mesoamérica*, edited by J. Broda, S. Iwaniszewski, and L. Maupomé, pp. 269–290. Instituto de Investigaciones Históricas, Universidad Nacional Autónoma de México, México, D.F.

1993 Mesoamerican Cross-Circle Designs Revisited. In *Archaeoastronomy in the 1990s*, edited by C. L. N. Ruggles, pp. 288–297. Group D Publications, Loughborough, UK.

1994 Archaeology and Archaeoastronomy of Mount Tlaloc, Mexico: A Reconsideration. *Latin American Antiquity* 5:158–176.

Manzanilla, L.

1993 Surgimiento de los centros urbanos en Mesoamérica. In *Antropología breve de México*, edited by L. Arizpe, pp. 57–82. Academia de la Investigación Científica, México—Centro Regional de Investigaciones Multidisciplinarias, Universidad Nacional Autónoma de México, Cuernavaca.

1995 La zona del Altiplano Central en el Clásico. In *Historia antigua de México*, vol. 2: El horizonte Clásico, edited by L. Manzanilla, and L. López Luján, pp. 139–173. Instituto Nacional de Antropología e Historia—Universidad Nacional Autónoma de México—Editorial Porrúa, México, D.F.

Millon, R.

1973 *The Teotihuacán Map*, pt. 1: Text. Urbanization at Teotihuacán, Mexico, vol. 1, edited by R. Millon. University of Texas Press, Austin.

1981 Teotihuacan: City, State, and Civilization. In *Archaeology*, edited by J. A. Sabloff, pp. 198–243. Supplement to the Handbook of Middle American Indians, vol. 1, V. R. Bricker, general editor. University of Texas Press, Austin.

Millon, R., B. Drewitt, and J. A. Bennyhoff

1965 *The Pyramid of the Sun at Teotihuacán: 1959 Investigations*. Transactions of the American Philosophical Society, New Series, Vol. 55, Pt. 6. Philadelphia.

Millon, R., R. B. Drewitt, and G. L. Cowgill

1973 *The Teotihuacán Map*, pt. 2: Maps. Urbanization at Teotihuacán, Mexico, vol. 1, edited by R. Millon. University of Texas Press, Austin.

Morante López, R. B.

1993 *Evidencias del conocimiento astronómico en Xochicalco, Morelos*. Unpublished Master's thesis, Escuela Nacional de Antropología e Historia, México, D.F.

1996 *Evidencias del conocimiento astronómico en Teotihuacan*. Unpublished Ph.D. dissertation, Facultad de Filosofía y Letras, Universidad Nacional Autónoma de México, México, D.F.

Parsons, J. R.

1987 El área central de Teotihuacan: patrones regionales de colonización en el Valle de México. In *El auge y la caída del Clásico en el México central*, edited by J. B. Mountjoy, and D. L. Brocington, pp. 37–75. Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, México, D.F.

Ponce de León H., A.

1982 *Fechamiento arqueoastronómico en el Altiplano de Méx-*

ico. Departamento del Distrito Federal, Dirección General de Planificación, México, D.F.

1991 Propiedades geométrico-astronómicas en la arquitectura prehispánica. In *Arqueoastronomía y etnoastronomía en Mesoamérica*, edited by J. Broda, S. Iwaniszewski, and L. Maupomé, pp. 413–446. Instituto de Investigaciones Históricas, Universidad Nacional Autónoma de México, México, D.F.

Sanders, W. T., J. R. Parsons, and R. S. Santley

1979 *The Basin of Mexico: Ecological Processes in the Evolution of a Civilization*. Academic Press, New York—San Francisco—London.

Somerville, B.

1927 Orientation. *Antiquity* 1:31–41.

Sugiyama, S.

1993 Worldview Materialized in Teotihuacan, Mexico. *Latin American Antiquity* 4:103–129.

Šprajc, I.

1990 El Satunsat de Oxkintok: ¿Observatorio astronómico? In *Oxkintok 3*, edited by M. Rivera, pp. 87–97. Misión Arqueológica de España en México—Ministerio de Cultura, Madrid.

1995 El Satunsat de Oxkintok y la Estructura 1-sub de Dzibilchaltún: unos apuntes arqueoastronómicos. In *Memorias del Segundo Congreso Internacional de Mayistas*, pp. 585–600. Centro de Estudios Mayas, Universidad Nacional Autónoma de México, México, D.F.

1997 La astronomía en Mesoamérica. In *Historia antigua de México*, vol. 4, edited by L. Manzanilla, and L. López Luján. 2nd edition. Instituto Nacional de Antropología e Historia—Universidad Nacional Autónoma de México—M. A. Porrúa, México, D.F., in press.

1999 *Orientaciones astronómicas en la arquitectura prehispánica del centro de México*. Instituto Nacional de Antropología e Historia, México, D.F., in press.

Tichy, F.

1991 *Die geordnete Welt indianischer Völker: Ein Beispiel von Raumordnung und Zeitordnung im vorkolumbischen Mexiko*. Das Mexiko-Projekt der Deutschen Forschungsgemeinschaft 21. Franz Steiner Verlag, Stuttgart.

Tobriner, S.

1972 The Fertile Mountain: An Investigation of Cerro Gordo's Importance to the Town Plan and Iconography of Teotihuacan. In *Teotihuacan: XI Mesa Redonda*, vol. 2, pp. 103–115. Sociedad Mexicana de Antropología, México, D.F.

Zeilik, M.

1985 The Ethnoastronomy of the Historic Pueblos, I: Calendrical Sun Watching. *Archaeoastronomy* No. 8 (Supplement to *Journal for the History of Astronomy* 16):S1–S24.

Notes

1. It should be pointed out that the interpretations offered here apply only to the two orientations dominating the overall urban layout since the Tzacualli phase, while the orientations in the earlier Patlachique phase settlement, located in the north-western sector of the later city, are known to have been different (Millon 1973:51) and must have a different explanation. An early alignment pattern may also be reflected in the substructures recently found in the Pyramid of the Moon, since their orientation seems to differ several degrees from the one adopted by the latest phase of the pyramid and conforming to the post-Tzacualli urban grid (Cabrera and Sugiyama 1999:21–28, Figure 3).

2. It has been argued that Mesoamerican architectural orientations were astronomically functional, as a rule, in the east-west

direction, mostly referring to the Sun's positions on the horizon (Šprajc 1997, 1999); as it is, therefore, unlikely that the orientations of the Sun Pyramid and the Ciudadela were based on astronomical phenomena observable to the north or south, Table 1 includes the data corresponding only to the east-west axes of both structures. The dates given in Table 1, as well as other dates discussed in the paper, are Gregorian and valid for the relevant epoch: due to precessional variations in the obliquity of the ecliptic and in the heliocentric longitude of the perihelion of the Earth's orbit (the latter element determining the length of astronomical seasons), on the one hand, and to the intercalation system used in the Gregorian calendar, on the other, one and the same solar declination does not necessarily correspond in any time span to exactly the same Gregorian date. For details on methods and techniques employed in the alignment measurements and calculation procedures, see Šprajc (1999).

3. Dow (1967:327; see Millon 1973:13) established for the Street of the Dead the deviation of $15^{\circ}25'$ east of north, while Alfonso Rangel (Millon 1973:13) and Aveni (1991:253, 355) obtained the azimuth of $15^{\circ}28'$, which agrees with the results of Morante's (1996:95) and my own measurements.

4. The mean east-west azimuth given in Table 1 ($106^{\circ}26'/286^{\circ}26'$) and based on my own readings along a number of wall faces is very close to the value of 106.3° established by Morante (1996:215) for the compound's central axis, and practically equal to the skew of $16^{\circ}30'$ south of east assigned by Dow (1967:326), Millon (1973:52), Aveni and Gibbs (1976:Table 1) and Aveni (1991:355) to East and West Avenues running in both directions from the Ciudadela. The azimuth of $106^{\circ}55'$ attributed to the Ciudadela by Dow (1967:328; see Aveni and Gibbs 1976:Table 1; Aveni 1991:355; Ponce de León 1982:61; Tichy 1991:Table 12-3) was measured along a single wall (Dow 1967:328) and therefore cannot be considered as particularly reliable.

5. Systematic variations, had they been found, could be interpreted as reflecting precessional shifts in the rising or setting azimuth of a star or asterism, e.g., the Pleiades, whose setting position, according to Dow (1967:328–330), may have dictated the orientation of the Ciudadela.

6. The horizon altitudes given in Table 2 were calculated, using the altitudes measured from the top of the pyramid (Table 3) and allowing for the pyramid's height and the distances to the relevant points of the horizon identified on topographic maps.

7. Since the target declinations were virtually the same during some 1,500 years, we can conclude beyond reasonable doubt that these alignments were intended to record *solar rather than stellar* positions on the horizon: had they referred to the rising or setting point of a star, they would necessarily exhibit a consistent azimuthal increase/decrease as a function of time, corresponding to precessional shifts in the star's position on the celestial vault.

8. The eastern horizon is so far away (ca. 18 km) that its altitude, upon raising the observing point to the pyramid's top,

diminishes only $11'$, resulting in a declination decrease of only $4'$. On the contrary, the western horizon line is much nearer (ca. 4.5 km), so that its altitude diminishes $45'$; the resultant declination decrease is $18'$, large enough for the sunset dates to shift one day with respect to those recorded by the same orientation at the natural ground level (Tables 2 and 3).

9. Assuming that deviations about 16.5° south of east were dictated by the orientation of the Ciudadela, the problem of eventual chronological priority of one group of the Teotihuacan orientations with respect to the other cannot be solved until the earliest structures of this compound and their orientations are known. At the early phase of the Temple of Quetzalcoatl (before the *Adosada* was added), the south face (*tablero*) of the structure's lower body provides the only east-west line whose orientation can be determined with accuracy; its azimuth ($106^{\circ}29'$) suggests that the 16.5° skew was in use at the latest since the Miccaotli phase, when the construction of this building started (Cabrera 1991:35–36; Cowgill 1992:102), but the orientation of its eventual substructure(s) remains unknown.

10. The orientation of the Ciudadela, like that of the Sun Pyramid, can be quite confidently related to the Sun's positions on the horizon, because practically the same declinations as those corresponding to its east-west axis are indicated by alignments at several central Mexican archaeological sites from different periods, without manifesting any systematic time-dependent shifts that could be explained in terms of precessional movements of a star (Šprajc 1999).

11. It may be added that the dates of sunset in the axis of the Pyramid of the Sun fall 52–53 days (ca. four 13-day periods) before and after the summer solstice, and that calendrically significant intervals separate also the dates of solar phenomena observable in some of the Teotihuacan caves (Morante 1996:95–96, 171–182). On the other hand, Aveni (1997) argues that time reckoning by calendrical intervals is attested in the pecked cross-circle designs found at Teotihuacan and elsewhere. Such intervals facilitated *predictions* of the calendrical dates on which certain events would occur: the days separated by multiples of 13 days had the same *trece* numeral, while those separated by multiples of 20 days had the same *veintena* sign of the 260-day count. If two phenomena were separated by an interval of 260 days, they obviously fell on identical dates of the sacred cycle. It should be pointed out, however, that the 260-day intervals marked by alignments—even if they are fixed in the tropical year—by no means support the ideas about a fixed 260-day *calendrical* cycle (see Broda 1993:263–264; Tichy 1991:151–158). It was precisely the *rotating* or *continuous* 260-day cycle, such as is known to have existed, that could have simplified predictive calendrical computations based on known observational schemes (Šprajc 1999).