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The Caracol Tower at Chichen Itza: An Ancient Astronomical Observatory?

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The study of the possible astronomical orientation of man-made structures has received considerable attention in the past decade, particularly with regard to the megalithic sites of Great Britain (*1*). But few systematic studies involving careful measurement have been made in Mexico, where pre-Conquest documents give us reason to believe that positional astronomy may have been widely practiced (*2*, *3*). We have initiated an interdisciplinary approach in order to test certain works of ancient Mesoamerican architecture for astronomical orientation.

The subject of our investigation in this article is the Caracol of Chichen Itza, Yucatan, Mexico (Fig. 1), the appearance of which has elicited some strong feelings (*4*):

> Every city sooner or later erects some atrocious building that turns the stomach: London has its Albert Hall; New York, its Grant's Tomb; and Harvard, its Memorial Hall. If one can free oneself of the enchantment which antiquity is likely to induce and contemplate this building in all its horror from a strictly esthetic point of view, one will find that none of these is quite so hideous as the Caracol at Chichen Itza. . . . It stands like a two-decker wedding cake on the square carton in which it came. Something was pretty clearly wrong with the taste of the architects who built it.

The Caracol's lack of esthetic appeal has led some investigators to suggest functional motivations for its design. It has been designated as a gnomon (*5*) and as a civil or military watchtower (*6*, p. 275). Of the suggested uses proposed for the Caracol, however, none is so successful in accounting for the peculiarities of its structure and orientation as that which associates it with astronomical observations.

The only published analysis of the astronomical aspects of the Caracol pertains to the windows at the top of the tower, which Ricketson (*7*) concluded "could only have been used for making astronomical observations." Yet the building was designated as an observatory as early as 1875 according to a plan prepared by Le Plongeon. The dome-like shape of the ruined tower, which resembles a modern observatory, undoubtedly inspired this identification. The notion of the use of the Caracol as an observatory was preserved without elaboration in the writings of Thompson (*8*) and Morley (*9*). In his definitive work on the archeology of the Caracol, Ruppert (*6*, pp. 274–275) tends to accept earlier evidence of the possible use of the Caracol as an observatory, while still offering the watchtower suggestion cited above.

We have examined the possible astronomical aspects of the principal architectural elements of the Caracol, treating each part in the chronological order in which it was constructed. Figure 2 presents architectural evolutionary stages I–VI proposed by Ruppert (*6*, pp. 271–273) (solid arrows), and those discussed by us elsewhere in detail (dashed and dotted arrows) (*10*). We suggest that astronomical observations made at different times of the year in different parts of the building by astronomer-priests could have been used to warn the population of impending events of religious, civil, or agricultural importance. The flat Yucatecan landscape, free of natural horizon markers for charting the course of the setting sun, moon, and stars, would render sight lines taken through a permanent man-made structure a likely way of keeping a calendar. The many cyclic motions in the heavens, so obvious to conscientious skywatchers, would be too convenient for a people so addicted to the keeping of a calendar to neglect. We further suggest that a likely interpretation of many of the asymmetries associated with the Caracol is that permanent alignments were built into the structure so as to point to astronomical events of special concern occurring along the local horizon. Thus, we view the Caracol as having been both a functioning astronomical observatory and a repository of directions of astronomical significance.

We determined all alignments discussed in this article, unless otherwise noted, at the site with an engineer's transit during January 1973 and March 1974. They are listed in Table 1 and shown in Figs. 2 and 5. The sun was used as an astronomical reference, and Aveni's tables (*11*) were employed to determine possible astronomical horizon events that might correspond to the alignments for A.D. 1000, the estimated date of the completion of the main part of the building. A horizon elevation of 0° was assumed, and a site latitude of 20°41′N was adopted in the calculations.

The Caracol has been considered generally as the first important building of Toltec or "Mexican" influence in Chichen Itza. It is situated in the southern part of the site among several Puuc-style buildings, which seem distributed with no orderly composition as a group (Fig. 3). There is still no convincing argument justifying the particular location of the building; however, there is some architectural evidence that the location and orientation of the Lower Platform were consciously determined. For example, if the Portal Vault at the southeast corner of the Caracol and Sacbe No. 5 (see Fig. 3) existed before the construction of the Lower Platform, the small change in the direction of the Sacbe at the northeast corner may indicate a conscious orientation of the platform. At the same time, there seems to be some evidence that from the established position of the Caracol the lo-

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cations of several structures in the northern part of the site were determined (*12*).

Having determined the principal axes of buildings at Chichen Itza by transit measurements of original walls, we find that most of them are aligned in three distinctly separate directional categories (*13*): (i) 10° to 12° east of north [for example, the Nunnery (site *A* in Fig. 3) and the Red House (*B*), both of the Puuc style]; (ii) 16° to 18° east of north [for example, the Great Ballcourt (*C*), the Tzompantli (*D*), the Platform of Venus (*E*), and the High Priest's Grave (*F*), all belonging to the later period of Toltec influence]; (iii) 21° to 23° east of north [for example, the Castillo (*G*), the Temple of the Warriors (*H*), and the Upper Platform of the Caracol (*I*), constructed during the earliest period of Toltec influence]. Direction (ii) is also incorporated into the plans of a number of sites in Central Mexico, including Teotihuacan, Tula, Tenayuca, and the Casa Tepozteco. An astronomical origin for this direction has already been proposed (*14*) and we have made a detailed investigation (*15*) of this question.

The Platforms

Lower Platform. The Lower Platform, (Fig. 2-I), which is the first building unit of the Caracol, has characteristics similar to the surrounding structures belonging to the Puuc period of Chichen Itza and has been attributed to the end of that period (*16*). It is a large rectangular platform, 6 meters above the flat surroundings and roughly 52 m east-west by 67 m north-south.

Since the northern part of the Lower Platform is in ruins and the rest was recon-

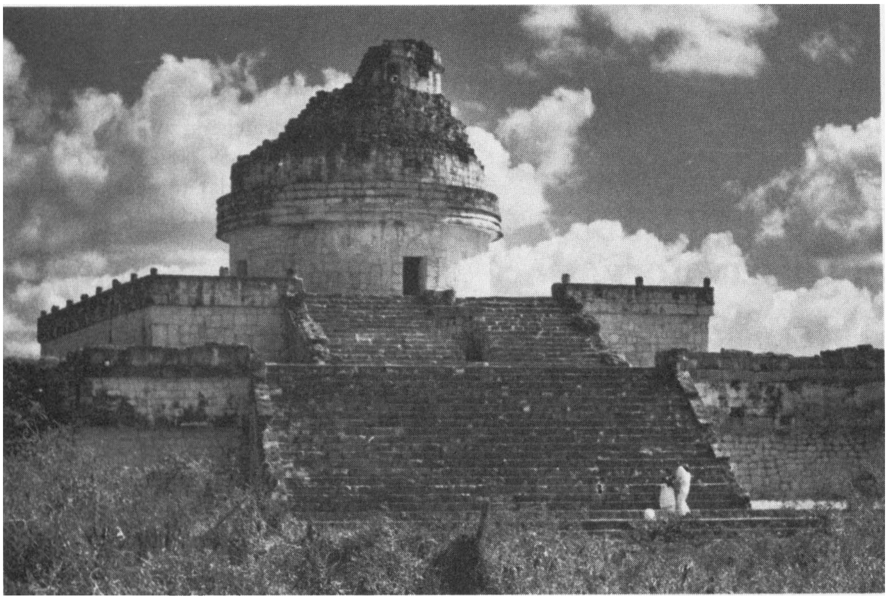
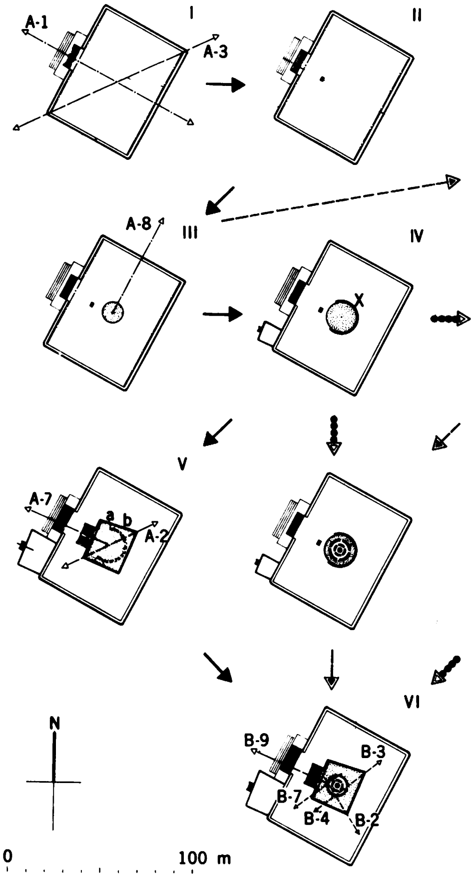


Fig. 1. The Caracol tower, viewed from the west (front).



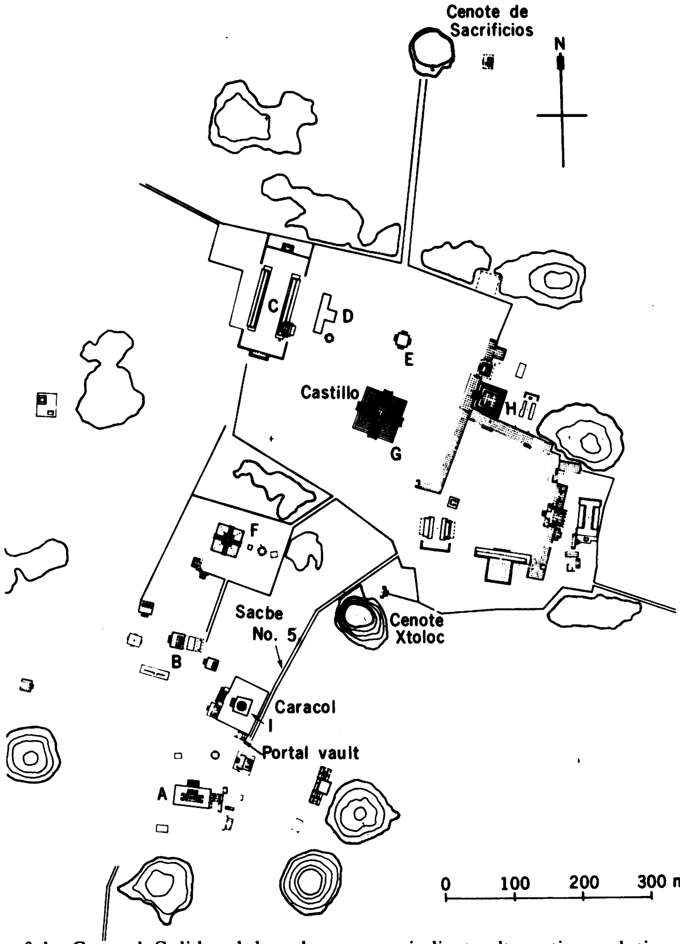


Fig. 2 (left). Architectural plan showing successive stages in the structure of the Caracol. Solid and dotted sequences indicate alternative evolutionary stages. Fig. 3 (right). Plan of Chichen Itza. Simplified redrawing with corrections after Ruppert (*36*).

structed in sections (between 1929 and 1931), no exact alignments can be given. The western side is the most reliable. It permits a check on the alignment of the stairway. Also the south side is fairly trustworthy, but it does not form precise 90° angles with the west and east sides; this may be due to reconstruction or to poor original construction.

We determined that the western front of the Lower Platform faces 27°24′ north of west (*A-1* in Fig. 2), which approximates the sunset position at the summer solstice (25°40′ north of west). At the summer solstice, the sun would set at its northerly extreme along the local horizon. It also seems probable that the orientation of the diagonal southwest-northeast (*A-3* in Fig. 2) constitutes the reason for the proportions in the Lower Platform. It points to within 1.5° of the sunrise position at summer solstice and the sunset position at winter solstice. No astronomical significance can be found for the other (southeast-northwest) diagonal (not shown), which is directed 10°30′ west of north; furthermore, the latter does not coincide with the corresponding line of the Upper Platform.

The front of the Lower Platform also faces the direction of the planet Venus. Venus, exceeded in brilliance only by the sun and the moon, reaches its greatest northerly and southerly extremes along the horizon at regular intervals in the calendar year. During the early period of the construction of the Caracol (about A.D. 850), northern-setting extremes of Venus occurred during the first week of April or the first week of May. The latter time is close to the date of the first annual passage of the sun through the zenith of Chichen Itza (24 May). By A.D. 1000, when the Caracol was completed, the April event had backed up into late March, while the May event remained relatively fixed. Also during this 150-year interval, the extreme northerly setting position of Venus advanced by approximately 0.5° along the horizon. These considerations complicate but do not preclude any attempts to match alignments with setting positions of Venus.

Adopting a building date of A.D. 850 for the Lower Platform, we find that Venus would have set within 1.25° of a perpendicular (*A-1* in Fig. 2) to the base of the platform. The same calculations performed for A.D. 1000 result in a 1.75° tolerance. Other lines directed toward the extreme setting positions of Venus are found from the windows at the top of the tower and the stylobate, which are discussed below.

The stylobate. The authors are inclined to consider the stylobate (Figs. 2-II and 4) as the next unit to be built on the Lower Platform. This structure consists of two columns on a small platform aligned asymmetrically relative to the Lower Platform. The excavation report of the 1929 season at Chichen Itza records that "the northern half of the [stylobate] platform, as well as the column resting on it, was painted black, while the southern half and the southern column were painted red" (Fig. 4) (*17*). The stylobate obviously occupied an important position on the Lower Platform, for its central portion was preserved in a niche in the stairway to the Upper Platform later built in the vicinity.

Ruppert (*6*, p. 275) was the first to suggest an astronomical motivation for the location of the stylobate for the following reason:

> If the tower is to be considered as an astronomical observatory, may not the stylobate, which the writer has suggested may have been the first unit built on the Lower Platform, also have served a like purpose, as, for example, at the time of either equinox a beam of light passing between the two columns at sunset would strike upon some object placed to the east of the stylobate?

Such reasoning does not account for the particular location or orientation of the small platform, since the kind of observation Ruppert describes could have been

Table 1. Alignments of possible astronomical significance associated with the Caracol. The error is the absolute azimuth difference between the alignment measured with a transit and the calculated position of the proposed horizon event.

Alignment	Direction	Correlated astronomical event	Error
A. Platforms			
1. Perpendicular to base of lower platform	27°24′N of W	Sunset, last gleam, at summer solstice	1°44′
		Venus set at maximum northern declination (A.D. 850)	1°13′
2. SW to NE diagonal upper platform	25°30′N of E	Sunrise, first gleam, at summer solstice	0°37′
3. SW to NE diagonal, lower platform	24°00′N of E (estimated)	Sunrise, first gleam, at summer solstice	1°37′
4. SE to NW diagonal, lower platform	10°30′W of N (estimated)	None	
5. SE to NW diagonal upper platform	21°30′W of N (estimated)	None.	
6. Perpendicular to base of stylobate platform	28°N of W (estimated)	Venus set at maximum northern declination	0°37′
7. Perpendicular to base of upper platform	22°54′N of W	Sunset, last gleam, at zenith passage dates	0°31′
8. Line to Castillo	27°24′E of N	None	
B. Doorways			
1. S to W	57°33′N of W	None	
2. W to S	57°33′S of E	Canopus rise	0°03′
3. S to E	36°36′N of E	Castor rise	0°17′
4. E to S	36°36′S of W	Fomalhaut set	0°39′
5. N to E	52°54′S of E	None	
6. E to N	52°54′N of W	None	
7. N to W	33°15′S of W	None	
8. W to N	33°15′N of E	Pollux rise	0°54′
9. W (center) to center of stylobate	22°39′N of W	Sunset, last gleam, at zenith passage dates	0°16′
C. Windows			
1. 1 IR-OL present	0°57′N of W	Sunset, last gleam, at equinoxes	0°32′
2. 1 IR-OL restored	2°27′N of W	Sunset, last gleam, at equinoxes	2°02′
3. 1 IL-OR present	28°53′N of W	Venus set at maximum northerly declination	0°27′
4. 1 Midline present	14°55′N of W	Sunset, last gleam, 28 April and 16 August	
5. 1 Midline present (alternate)	15°40′N of W	Sunset, last gleam, 1 May and 14 August	
6. 1 Midline restored	15°06′N of W	Sunset, last gleam, 29 April and 15 August	
7. 2 IR-OL present	40°55′S of W	None	
8. 2 IL-OR present	27°49′S of W	Venus set at maximum southerly declination	1°00′
9. 2 Midline present	34°22′S of W	None	
10. 3 IR-OL present	2°13′W of S	Astronomical south, magnetic south	
11. 3 IL-OR present	18°27′W of S	Achernar	0°44′
12. 3 Midline present	10°20′W of S	Magnetic south	

made anywhere, incorporating a variety of platform shapes and orientations. If the location and the orientation of the stylobate were not arbitrary, we can suppose that it was placed so as to determine an astronomically related line of sight (*A-7* in Figs. 4 and 5) from the center of the Lower Platform. We note that such a line, if continued westward and tangent to the northern column of the stylobate, points to the sunset position on zenith passage dates at Chichen Itza. This alignment may also have figured prominently in the orientation of the Upper Platform and will be discussed later. The likelihood of an observation toward the west is emphasized by the possibility that the First Circular Platform obscured the view to the east soon after the stylobate was built.

One specific line of sight to the west which can be determined from the remains of the stylobate is that defined by a perpendicular to its western edge. This direction is estimated to be 28° north of west. It seems significant that this line should be displaced so dramatically from a perpendicular to the stairway, in which the stylobate is now housed, and an astronomical motive for such a displacement is not unlikely.

We find that the western edge of the stylobate platform aligns with the face of the Lower Platform, thereby suggesting a close relation to the northern setting extreme of Venus (line *A-6* in Fig. 4). It is possible that small provisional structures or trace lines marked on the floor of the platform existed for astronomical observations relative to the stylobate. Given the preserved traces of paint, it is tempting to speculate that this small construction may have been associated in the Maya mind with the planet Venus. Since red and black are directional colors in the Maya religion, it is possible that the painted stylobate could have served as a monument to Venus in the east as the morning star and in the west as the evening star. A Central Mexican association of the colors red and black with Quetzalcoatl has been pointed out by Caso (*18*).

First Circular Platform. The first circular structure (Fig. 2-III) built on the Lower Platform has a diameter of 11 m and a height of 3.70 m. Its center point is marked by "a vertical shaft having a depth of 69 centimeters and a diameter of 6.3 cm, perhaps where a pole had been set with a string looped over, to serve in describing the circular form of the facing walls during the construction of the inner circular platform" (*6*, pp. 84–85). It is composed of well-cut stones, has upper and lower moldings or "atadura" (unique in Maya architecture), and a tight fill grounded throughout with mortar, which shows that a finished structure was intended and not a provisional building to be covered soon by another one.

The First Circular Platform seems to have had no functional astronomical use and no stairway connected with the top. It has rather the appearance of an independent monument. One may even suggest that the arriving Toltecs wanted to build a monument to Quetzalcoatl in its most representative form as a round building. Round structures like the Caracol appear in Yucatan without any indication of architectural evolution. The historical material offers ample evidence that round temples were erected to Quetzalcoatl, and Landa (*19*) refers to the round structure at Mayapan as having been built by Kukulcan, the Maya counterpart of Quetzalcoatl. Pollock (*20*) concludes that it seems entirely reasonable to attribute both buildings (at Mayapan and at Chichen Itza) to the worship of Kukulcan-Quetzalcoatl. Kukulcan seems originally to have been conceived as a creator god with attributes of motion and wind. In addition, at least in Central Mexico, he was identified with the solar myth and with the morning star (*20*). Quetzalcoatl and his twin brother Xolotl are identified with the planet Venus, Quetzalcoatl with the morning star, and Xolotl with the evening star (*21*). Although the representations are from codices of Central Mexico, one can suppose he possessed similar attributes in Yucatan (*22*). "The cult of Quetzalcoatl seems to have been carried eastward into Yucatan on a wave of cultural influence that apparently originated in Mexico" (*20*, p. 166).

Second Circular Platform. Some time may have passed between the construction of the first and the second platforms (Fig. 2-IV). Then the rest of the building units followed nearly immediately one after the other.

The Second Circular Platform was likely intended to reinforce the first one, in order to support the later tower. A ring of masonry about 2.50 m wide (with a total diameter of 16 m) was laid around and complemented with a bench (labeled *X* in Fig. 2-IV) three-quarters of the way around (the part left vacant is to the west). "In view of the absence of a stairway and of well-finished floors on top and at the base, it is thought that this unit was not completed before construction of the rectangular platform was undertaken" (*6*, p. 271).

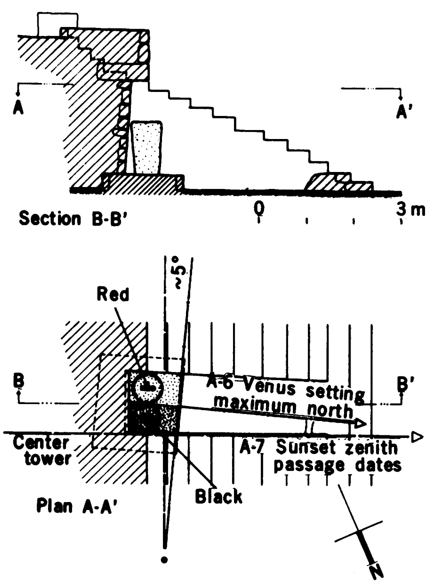


Fig. 4. The stylobate: plan on line *A-A'* and section on line *B-B'*.

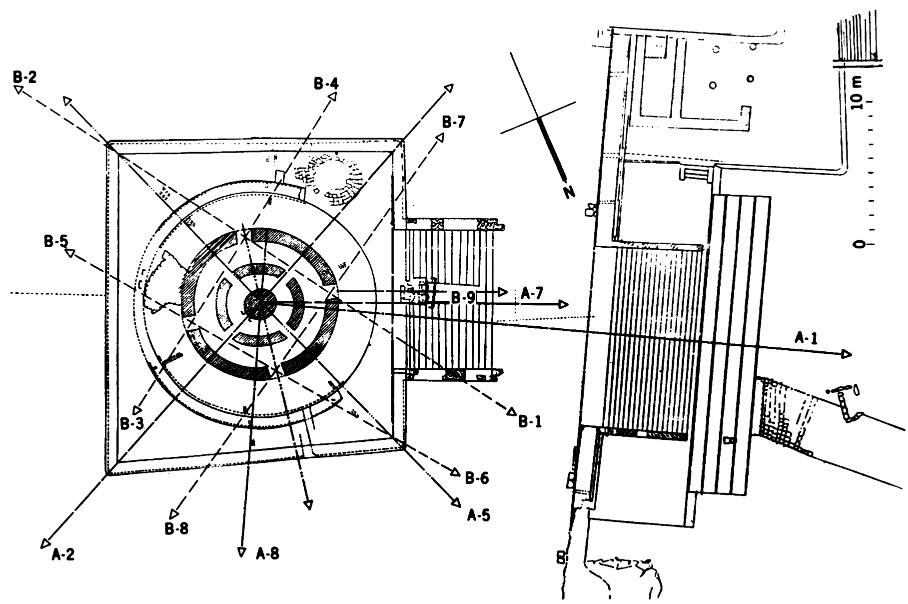


Fig. 5. Plan of the upper platform and stairway of the lower platform of the Caracol as it appears at present, showing alignments measured by the authors.

Upper Platform. The Upper Platform (Figs. 2-V and 5) measures 22 m on the west side and 24 m on the east side, the two sides being nearly parallel; the north and south sides are distinctly antiparallel, but the south side is approximately perpendicular to the east and west sides. The platform was built in two stages (marked *a* and *b* in Fig. 2-V), but "the building of the second or eastern section began before the western section was completed and the two were then finished as a unit" (*6*, p. 272). The western front includes a stairway bounded by Toltec balustrades and incorporating a niche which houses the already existing stylobate. It faces 22°54′ north of west (line *A-7* in Fig. 5); consequently, it is shifted by nearly 5° relative to the base of the Lower Platform. This deviation of the stairway is quite obvious not only in the ground plan but also to an observer facing the front of the building.

The setting position of the sun on the 2 days of the year when it crossed the zenith of Chichen Itza in A.D. 1000 was 22°23′ north of west, 31′ south of the alignment of the front of the Upper Platform. A variety of evidence suggests that zenith passage dates were recognized by the people of Mesoamerica (*2, 23*). In a recent ethnographic study, Girard (*24*) states that, among the Chorti Maya, the night of 30 April–1 May has taken to signal the first passage of the sun across the zenith. The second zenith passage occurs 52 days after the summer solstice. Both dates are marked by important festivals and celestial observations. Having already suggested a possible association between zenith passage sunset and the placement of the stylobate, we note further that a perpendicular to the West Annex, a later addition to the front of the building, also marks this apparently important direction.

The diagonal line from the southwest corner through the center point to the northeast corner of the Upper Platform (*A-2* in Fig. 5) is again a precise indicator of the position of summer solstice sunrise, while the northeast to southwest direction points to the winter solstice sunset position. The opposing diagonal, southeast-northwest, has no apparent astronomical significance.

The Tower

In Ruppert's opinion (*6*, p. 272), the tower (Fig. 2-VI and Fig. 5) may have been built after the Second Circular Platform; but it seems logical to him that the tower was started after the Upper Platform was finished.

Doorways in the base of the tower. Four doorways (see Fig. 5) give access to a cir-

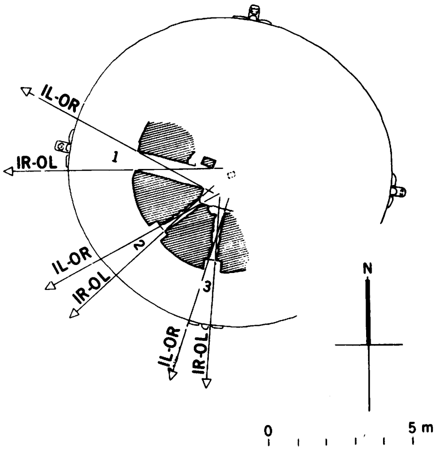


Fig. 6. Sketch of horizontal cross section through the Caracol windows showing windows labeled 1, 2, and 3 and the pairs of diagonal sight lines.

cular passage which also contains four doorways. These in turn open to an inner circular passage surrounding a solid core at the center of the tower. The core contains a passageway, starting 3 m above the floor, which winds up nearly one full turn to a now-ruined chamber at the top of the tower where the "windows" are located. A general view of the tower base reveals that the front outer doorway is not centered relative to the stairway of the Upper Platform. Nor are the outer doorways centered relative to the cardinal directions. The inner doorways, only approximately equally spaced, are placed not quite midway between the openings in the outer chamber. The deviations of the outer doorways from the cardinal points are, from Ruppert's figure 347 (*6*), 10° east of north, 6° south of east, 10° west of south, and 13.5° north of west, averaging 10° in a clockwise direction. The center points of the north and south doorways are on a straight line through the center of the core. The approximate directions of alignments taken from the center point to the midpoints of the inner chambers are, also from Ruppert's figure 347: northeast (23° north of east), southeast (24.5° east of south), southwest (23° south of west), and northwest (20° west of north).

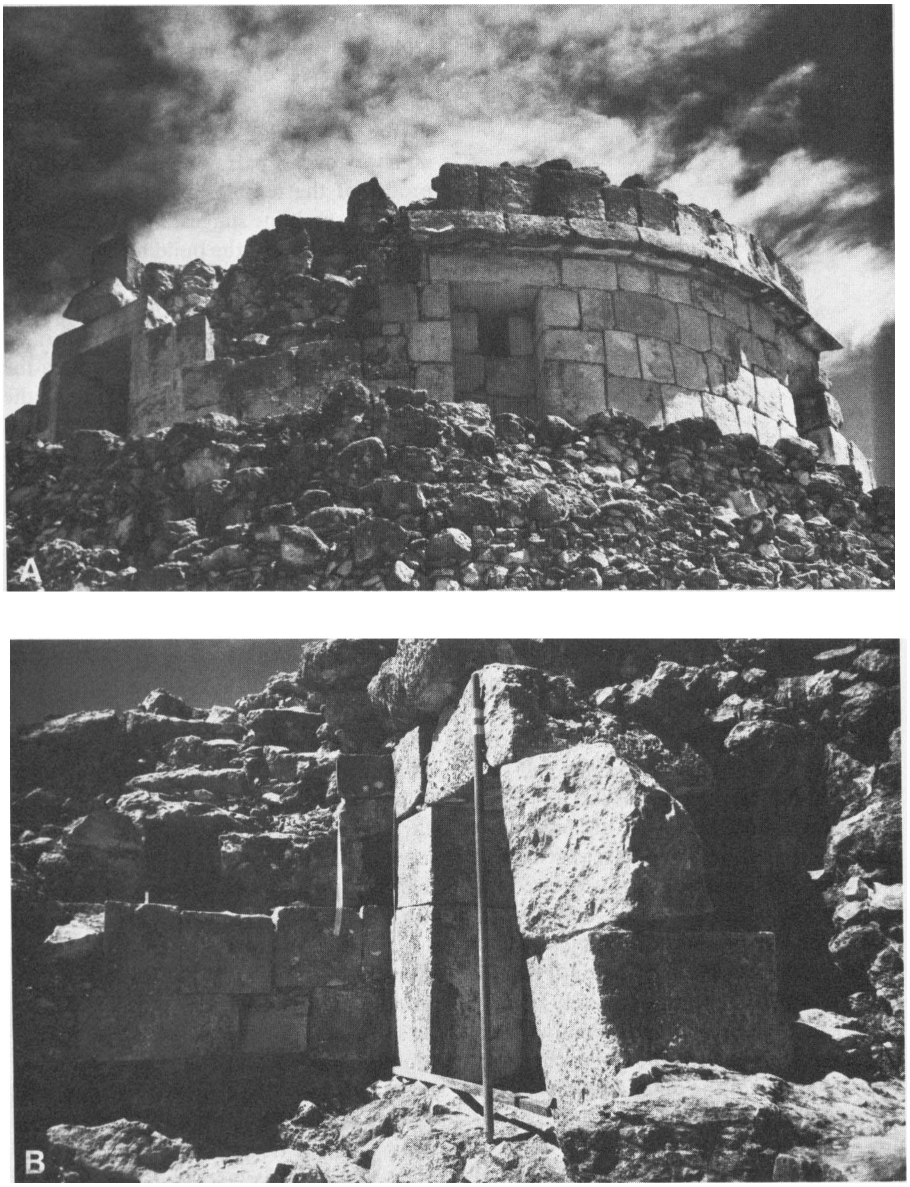
Interdoorway alignments represent a possible astronomical sighting scheme; but before suggesting possibilities we should emphasize that only the north, south, and west doorways were preserved intact and were not moved during restoration activities. The east doorway had fallen in by 1925, and even though it was reconstructed with care, it cannot definitely reflect the intention of its original builders.

That doorways of certain buildings could have been used as astronomical observation posts was suggested long ago by Nuttall (*3*), who, in support of her argument, presents numerous pictures taken from the codices. Perhaps the best known of these (see cover) is taken from the Bodleian Codex (*25*). A priest is depicted in the act of looking through a temple doorway over a pair of notched sticks. The profile of the temple is studded with star symbols, perhaps suggesting a specific astronomical use for the building. At present, an observer stationed outside the south doorway of the Caracol tower can view a 0.25° segment of the northeastern horizon along a line passing obliquely through the south and east doorways. Looking in the opposite direction one views the southwest horizon. The same scheme can be employed by pairing the north and east doorways or by looking through the south and west doorways, although the scheme fails to work with the north and west doorways in their present condition. Table 1 lists the alignments measured through these narrow openings and also gives possible astronomical events which are found to correlate with the directions specified.

Only stellar alignments appear to be significant. Among those we have tabulated, we note that Canopus, the second brightest star in the sky, made its first annual appearance in the eastern sky before dawn on 30 July, 1 week after the second solar zenith passage date. Castor, another bright star which also could be sighted by interdoorway alignment, made its last visible rise after sunset on 17 June, 3 days before the solstice. A significant solar-related date also occurs for Pollux: its last rising after sunset occurred 1 week after the winter solstice. The number of coincidences between heliacal rising and setting dates of bright stars and key solar dates strengthens the possibility that functional interdoorway stellar alignments could have been a motive for locating the outer doorways in their present positions. Again Girard's ethnographic evidence (*24*) is helpful in that it indicates that stellar observations were important at the time of solstice or zenith passage.

There are other alignments of possible astronomical significance in which the doorways may have been incorporated. Adopting the center of the western doorway as an observation point, we note that a line connecting that point to the center of the stylobate (*B-9* in Fig. 5) closely approximates the perpendicular to the base of the Upper Platform (*A-7* in Fig. 5), which has been established as a zenith sunset line.

Windows at the top of the tower. A detailed description of the three surviving windows (Figs. 6–8) is given by Ricketson (*7*, pp. 265–267). We have adopted his nomenclature in labeling them (Fig. 6). The northernmost window (No. 1 in Fig. 6) is



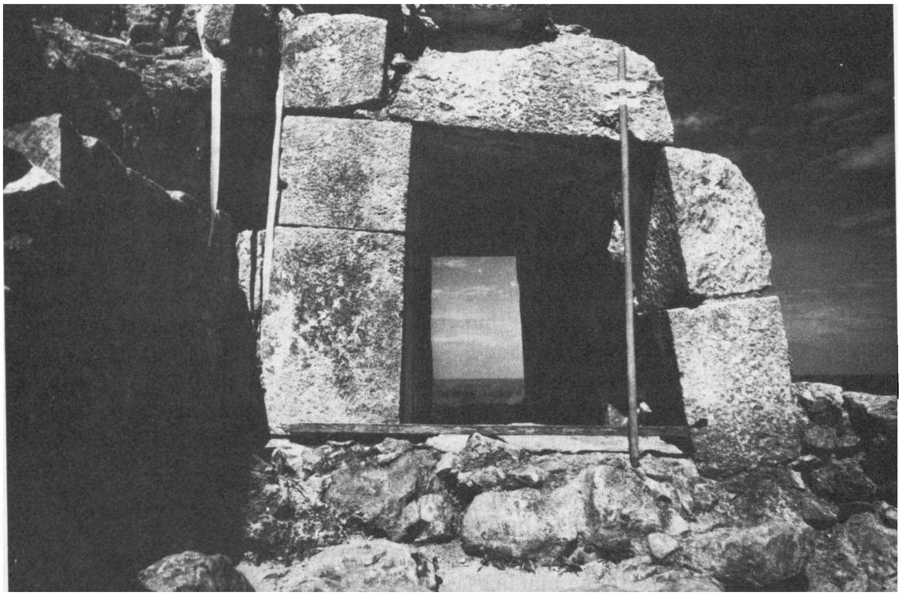


Fig. 7 (top). (A) Caracol windows as they appear at present: outside view from the southwest. (B) View of window 1 from the northeast inside the observing chamber. Fig. 8 (bottom). Window 1, including the authors' restored version, looking west along the midline.

considerably larger than the other two and has been designated as a passageway which connected the east and west sides of the building (*26*, *27*). Ricketson (*7*, pp. 265–267) hypothesized that the windows functioned as astronomical sighting chambers. After taking steps to preserve their condition as he found them, he proceeded to measure the orientation of the midlines and diagonals drawn through the windows to see if they coincided with the occurrence of significant astronomical horizon events. A study of early photographs of the Caracol indicates that the outer recessed ends of windows 2 and 3, while apparently intact in 1889 (*26*, vol. 3, plate XXII), had deteriorated somewhat by the time Ricketson made his measurements (*8*, photo, p. 600). Ruppert (*6*, pp. 189–194) indicates that these recessed ends were not completely repaired until 1930 when "*in situ* stones were so left" and additional stones were added to form the recesses shown in the 1889 photo around the apparently well-preserved outer ends of the windows themselves.

We measured the alignments of the midlines and diagonals of the Caracol windows as they are situated at present and presumably as Ricketson found them (minus the southwest and south recesses) in 1925. These alignments are indicated in Table 1, with the inside-right-to-outside-left diagonal labeled "IR-OL" and the inside-left-to-outside-right diagonal labeled "IL-OR"; however, these alignments may not have been those intended by the builders of the Caracol, since some of the blocks comprising the windows may have shifted slightly from their original positions. In Fig. 8 the inner right jamb of window 1 nearest the observer deviates noticeably from the vertical. Keeping the possibility of a shift in mind, we also determined alignments through a "restored" version of window 1, having extended, through the use of tape and wooden sticks, the straight portions of the original walls in the interior of the window. The vertical stick in Fig. 8 represents the intersection of the extended inner right wall with the vertical plane at the inner opening of window 1. At the level of the base of the window, the right jamb deviates from the vertical by 8 cm, the horizontal distance between the black mark and the stick. Alignments determined along the "restored" portions of the window are labeled in Table 1.

Window 1 IR-OL. Because of the wide field of view included between window jambs, Ricketson suggested that an accurate sighting scheme could be achieved by viewing horizon events obliquely, as illustrated in Fig. 6. He reported (*7*, p. 265) that the IR-OL alignment in window 1 was deliberately designed to point to the sunset a the equinoxes. The alignment he determined is equivalent to our "IR-OL present" in Table 1. On 20 March 1974, we photographed the sun setting along this baseline. The result appears in Fig. 9. The camera was placed in front of the position of the black marker shown in the lower right portion of the figure. Coincidentally, the instant of passage of the sun across the vernal equinox occurred within 10 minutes of the time of sunset on the date of our experiment. The edge of the setting sun lined up nearly perfectly with the narrow opening in the window, as can be seen. A photograph taken from the same position on 18 March failed to register the sun but on 19 March, 24 hours before the vernal equinox, the right (northern) edge of the solar disk was visible for a few minutes. Thus the "IR-OL present" alignment is a remarkably accurate equinoctial day marker. Since the equinox sunset point has not moved appreciably in the ten centuries since the Caracol was erected, we can assume that, if the jambs of window 1 have not shifted, the equinox dates were determinable as accurately then as now, that is, to within a day, by the simple technique of viewing the sunset in the narrow slot. Judging by the difficulty we experienced in obtaining the picture, it would seem that the observation could have been made only in a reclining position, since the 20 March event could be seen only from the floor level.

Fig. 9. Sunset viewed along line C-1, IR-OL (present), on 20 March 1974

In discussing his exploration, preservation, and subsequent measurement of the upper portion of the Caracol, Ricketson (*7*, p. 265) is careful to point out that all stones were cemented in place as he found them, particularly the lowest stone of the right jamb at the eastern end of window 1. As illustrated by Ricketson's drawings and by photos of the present condition of the building, this stone obviously does not align with the rest of the right face of window 1. We have been unable to locate early reports, drawings, or photos of the northeast portion of the Caracol which indicate when this stone might have been turned aside. However, a search of the literature reveals that in 1925, before the excavation of the Upper Platform by archeologists of the Carnegie Institute of Washington, the right jamb of the window was in the same position as we see it today (*6*, figure 137). Describing the situation of window 1 as he found it, Ricketson (*7*, p. 266) states that "the western jamb was found to be leaning toward the west so that it was six inches out of plumb . . . and the northern jamb of the eastern end rested precariously on a single rock, itself without any solid foundation."

It should be noted that the lower block of the IR jamb is not at the level of the supposed floor of the chamber. The situation gives the impression that the lower cornerstone slipped out of a perfectly vertical position. Assuming that window 1 originally possessed a rectangular cross section, we obtain a "restored" IR-OL alignment which can be taken by an observer at any level in the chamber along the vertical stick shown in Fig. 8. Such a line of sight misses the equinox sunset point by more than 2° (approximately 4 solar diameters). The sun would not have been visible along this baseline until 6 to 8 days after the vernal equinox. If window 1 did originally possess a rectangular cross section, then the perfect correspondence between the present IR-OL alignment and the setting equinox sun is coincidental.

Window 1 IL-OR and window 2 IL-OR. According to Ricketson (*7*, p. 266), these alignments (Fig. 6) were intended to point to the setting moon at its northerly and southerly extremes. Such a pair of alignments could function effectively to mark a long period in the Maya calendar. But both the present alignments in windows 1 and 2 that we determined miss the moonset positions by a wide margin (more than 2°, or about 4 lunar diameters). In the former case, the moon falls well outside any possible line of sight through the windows. Thus, it is not even visible at the extreme northerly declination to an observer stationed in the tower. We find a better astronomical match for these lines with the setting extremes of the planet Venus, which would have coincided with 0.5° and 1° of the present alignments in windows 1 and 2.

The likelihood that the Caracol architects could have associated Venus with these directions is further enhanced when we realize that the importance of this planet in their folklore and religion has been clearly documented. The elaborate Venus calendar in the Dresden Codex (*28*), composed in the vicinity of Chichen Itza during the Mexican period, strongly suggests that they followed the motion of the planet and were concerned particularly about its heliacal rising and setting. The first appearance of Venus in the east before dawn was considered an unlucky omen by Mexican worshipers of Quetzalcoatl, who no doubt carried this belief with them to the Yucatan. They had good reasons for watching the movements of Venus on the western horizon, for its last appearance there was the best warning that a heliacal rising would soon occur. By the official calculations represented in the Dresden Codex, heliacal rise followed heliacal set by 8 days; however, its appearance could be hastened or delayed depending on the declination of Venus at the time it disappeared. Its declination is, in turn, reflected in its setting position. When Venus disappears near the western point on the horizon, the duration of its disappearance in front of the sun can vary from 5 to 9 days depending on the time of year. Native astronomers may well have contrasted this variation with the relative constancy of the interval of disappearance noted for Venus at its setting extremes. Having observed Venus disappear in the west at an extreme setting position, an experienced astronomer could predict the date of its reappearance in the east with confidence. The provisions for correction of the formal Venus tables in the Dresden Codex suggest that observations of Venus were indeed made. We may suppose that the Caracol windows were placed to aid such observations and

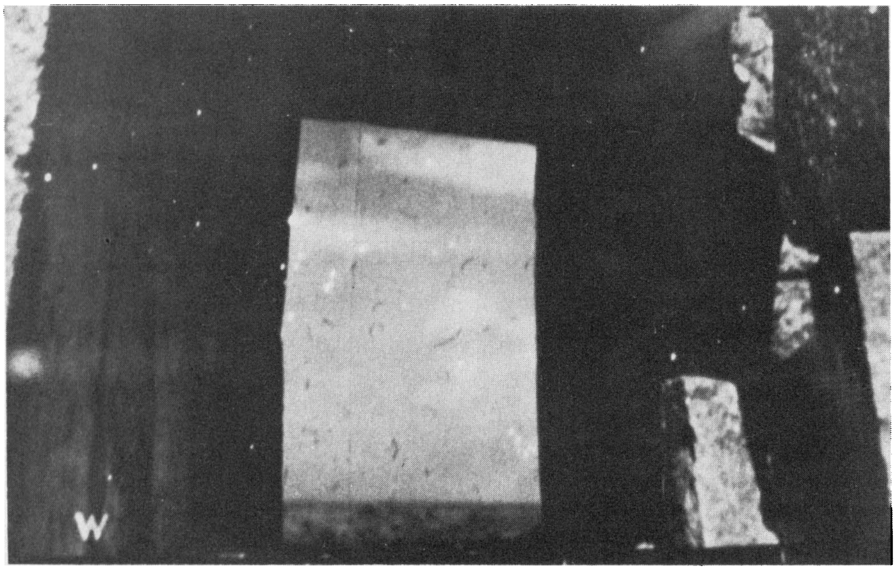


Fig. 10. Planetarium view of the sky as seen through window 1 shortly after sunset, 28 April A.D. 1000. The Pleiades, having passed through the center of the window, are about to set in the lower right corner as the Hyades and the bright star Aldebaran enter at the upper left.

specifically to preserve the direction of the most predictable disappearances of Venus before heliacal rise.

The IL-OR sight line through window 1 (Table 1) coincides, within 1.5°, with the perpendicular to the face of the Lower Platform, thus strengthening the argument that Venus was one of the principal astronomical bodies taken into consideration in the total design of the building. The center line of the Lower Platform (parallel to the eastern and western walls), prolonged northward (*A-8* in Fig. 5), passes through the Castillo (*29*) and runs at right angles to the Venus setting direction observed from Caracol window 1, suggesting that even the placement of the Castillo could have been determined by the setting position of Venus.

An excellent test of the validity of the astronomical sight lines suggested for the three western windows would be provided by the discovery of similar lines through windows fronting the eastern facade of the tower. Unfortunately, such windows, if they ever existed, have fallen away completely. Maudslay (*26*, vol. 3, p. 21) tells of "an upper storey furnished with what looked like six small doorways facing outwards. Of these, the doorway immediately over the lower doorway 'A' is the entrance to a small passage, 3 feet high, [window 1] which probably passed right across the building to a doorway on the other side." Ruppert (*6*, figure 292) presents a hypothetical reconstruction of the top of the tower based upon this idea, but it would be much too speculative to attempt to determine astronomical orientations on the basis of such a hypothetical sketch.

Alternate uses for the windows. Since the setting sun can be viewed through window 1 for about half of the year, it is worth exploring other sunset sight lines of possible significance through this window. After the initial sunset appears in the south side of the window on the first day of spring, the sunset position progresses northward, reaching the present midline of the window about 28 April. Finally, on the summer solstice, the sun sets 3° south of the IL-OR alignment, after which it begins to turn around and progress southward, passing the midline a second time on 16 August and disappearing from view about the time of the autumnal equinox, when once again it is viewed along the IR-OL line of sight. It is conceivable, as Ricketson (*7*, p. 267) suggested, that impermanent markers could have been placed on the windowsill to denote the exact date of the year, but what of the period from autumnal to vernal equinox when the sunset was not visible through any of the existing windows? Perhaps alignments on sunrise positions in eastern windows took care of this.

The IR-OL sight line through window 3, which is directed 2° or 3° west of astronomical south, is worthy of note. Ruppert (*6*, p. 236) suggests that the direction of magnetic south is close to this value (we measured 4.5° in 1973). The deviation of the compass needle from astronomical north-south is strongly time-dependent; therefore, it would be dangerous to conclude that ten centuries ago it was the same as that at present. On the other hand, there is some evidence to suggest that Mesoamerican people may have known of the concept of a magnetic compass (*30*). Moreover, the plans of a number of important sites in southern Mesoamerica are known to possess orientations directed slightly east of astronomical north, close to the present compass direction (Uxmal, Copan, and Dzibilchaltun are examples). John Carlson (*31*) has been investigating the magnetic properties of a fragment of a pre-Columbian magnetite bar to try to determine whether it may have functioned to indicate the compass directions. Another possible magnetic direction indicator is the 10°20′ west of south alignment of the midline of window 3, which coincides closely with the 10° west of south and 10° east of north alignments through the outer doorways mentioned earlier. Furthermore, this general orientation is also evident in the Puuc structures in the vicinity of the Caracol, such as the Nunnery and the Red House. Other alignments of possible astronomical significance are listed in Table 1. They are discussed in detail in a separate publication (*10*).

One must not overlook the possibility that entire constellations or star groups could have been viewed through the windows. The wide field of view of window 1 (which exceeds 25° horizontally) supports such a hypothesis. Figure 10 depicts the western sky as it would have appeared to an observer looking down the midline of window 1 shortly after sunset on 28 April A.D. 1000, the day the sun set along the midline of the window. To make the photo, a transparency of the window was projected onto the dome of the planetarium of the University of South Florida, and the stars were allowed to pass through. The *W* in the figure marks the west point of the flat horizon. The conspicuous group of stars about to pass out of view at the lower right is the Pleiades, one of the most important groups in Mesoamerican star lore (*2, 14, 32*).

The bright star Aldebaran, which marks the upper left part of the V-shaped Hyades group, is seen at the upper left of the window. Marquina and Ruiz (*14*) have assigned the Hyades and Aldebaran to the Aztec constellation Mamalhuaztli, the viewing of which also played an important role in the calendar. Girard (*24*) finds that the modern Chorti Maya are as interested in observing constellations as were their Mesoamerican ancestors. The Pleiades are still watched carefully on the dates of zenith passage, although precessional changes have elevated other star groups (like Orion's belt) to a calendric significance they may not have possessed in the 11th century.

Conclusions

Although our investigations reveal a number of significant astronomical events coinciding with many of the measured alignments presented in Table 1, not every alignment appears to have an astronomical match which we can recognize. It may be that only some of the sighting possibilities we have discussed were actually functional. Moreover, our search of significant astronomical events to match the alignments has included only those which seem of obvious functional importance to us: sun, moon, and planetary extremes and the setting positions of the brightest stars. We have emphasized those celestial bodies which are documented in the literature as having been of importance. Perhaps hitherto unrecognized constellations were sighted in the windows, perhaps fainter stars, the heliacal rising and setting times of which could have served to mark important dates in the calendar.

While we propose no grand cosmic scheme for the astronomical design of the Caracol it can be inferred that the building, apart from being a monument related to Quetzalcoatl, was erected primarily for the purpose of embodying in its architecture certain significant astronomical event alignments, in the same sense that a modern astronomical ephemeris exhibits information of importance to us in the keeping of the current calendar. There are examples in the Mesoamerican historical literature of deliberate attempts to align buildings with astronomical directions of importance. For example, Maudslay (*33*) quotes Father Motolinia, who tells us that in Tenochtitlan the festival called Tlacaxipeualistli "took place when the sun stood in the middle of Huicholobos, which was at the equinox, and because it was a little out of the straight, Montezuma wished to pull it down and set it right." According to Maudslay, worshipers were probably facing east to watch the sun rise between the two oratories on the Great Temple of Tenochtitlan at the time of the equinox.

The directions of the faces of the Lower and Upper platforms of the Caracol seem to have been laid out deliberately to point to horizon events involving the sun and the planet Venus. Of the lines taken through the windows, the Venus setting points seem most plausible to us in view of both the accuracy with which they fit the architecture and the historical evidence bearing upon the importance of Venus to the Mesoamerican people. A specific connection between the Venus calendar in the Dresden Codex and the sighting of the extreme positions of the planet along the horizon, however, is yet to be established. It is especially significant that alignments in both the base and the top of the tower relate to Venus. The solar equinox alignment in window 1 remains problematical, although the arrangement probably functioned as an approximate means of determining the first day of spring and the first day of autumn. Lines pointing to individual bright stars undoubtedly should be given lower value. If one is willing to carry the matching game to its ultimate completion, a stellar object can always be found which, although very obscure, will fit an alignment. In our consideration of the problem we have attempted to single out bright stars which appeared or disappeared on significant calendar dates.

Other round structures resembling the Caracol exist in Mesoamerica (*20*), although there are comparatively few built by the Maya. Nearly all can be attributed to the cult of Quetzalcoatl (*34*). To our knowledge none have been carefully measured and analyzed for astronomical orientations. The ruined tower Q-152 at Mayapan bore distinct similarities to the Caracol, both in shape and structure. It probably contained only a single doorway which faced west. Both structures possessed circular corridors. A circular tower is still standing at Paalmul on the coast of Quintana Roo north of Tulum. Pollock (*20*, p. 115) states that it has a single room in the turret. A window similar to No. 1 in the Caracol faces northwest, the same direction as the base of the front of the structure. It may be astronomically significant that the Yucatecan towers fronted in approximately the same direction.

Andrews (*34*) reports the existence of a curious circular building located at Puerto Rico, Campeche, near Xpujil. His cross-sectional view of the tower bears a close resemblance to Ruppert's sketch (*6*, figure 293) of a horizontal section taken through the windows remaining at the top of the Caracol. Hartung (*12*) has suggested a possible astronomical use for the Puerto Rico tower, but no analysis of the orientation of its "windows," which are much smaller than those of the Caracol, has yet been conducted. Other circular buildings are reported at Ake (*20*, p. 113) and Isla Cozumel (*35*, p. 557). We hope that future investigations of the remains of Yucatecan towers will shed further light upon the significance and use of the Caracol as an astronomical observatory.

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