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MAYA ASTRONOMY

By John E. Teeple, Ph.D.

With nineteen figures

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PREFACE

It is the purpose of this book to give such information as we have or can deduce from the Maya inscriptions and the *Dresden Codex* concerning the numerical system of the ancient Maya and their observational astronomical knowledge.

The Maya had a well-developed civilization, including agriculture, domestic animals, large cities, rather magnificent temples and other buildings, and a written language. They had made remarkable progress in sculpture, painting, jewelry, and the art of the goldsmith. But in one field they were far ahead of any other people of their own time in the whole world. They had worked out simple symbols for numbers, were familiar with the use of position to give value to the numbers, and had developed the necessary concept of Zero and its use, at least a thousand years before any of these things were known or used in Europe and at least five hundred years before it was done anywhere else in the world. Their astronomical tables at least equalled those of any people on earth at that time.

It is not our aim to discuss here anything but numbers and astronomy, but it seems worth while to point out at least three things which indicate that this civilization rose in America and was not dependent on any civilization that had developed anywhere in the Old World. First, the Maya domesticated animals and cultivated extensive crops, but so far as I can learn no single domestic animal, except the dog, and no single crop was identical with that developed or used by any civilization of the Old World. Second, their knowledge of numbers and of astronomy could not have come from any other civilization, as no people of the Old World had anything to teach them in this field; and third, the knowledge of the wheel as a mechanical tool, which had been common for thousands of years to every known civilization of the Old World, seems to have been absolutely unknown in America. These three extreme divergences in knowledge and in ignorance would almost preclude the possibility of contact with any known civilizations of the Old World before the arrival of the Spaniards.

The Maya were completely devoted to numbers and to astronomy, probably from religious motives. This is fortunate in one way, as it will ultimately enable us to correlate their chronology with ours so that we may definitely date their monuments and ascertain the extent of their knowledge at any given time in comparison with that of the Old World. In another way, however, it is unfortunate, because I can foresee the clear possibility that when the Maya inscriptions and codices are completely deciphered we may find absolutely nothing but numbers and astronomy, with an intermixture of mythology or religion.

When a man leaves his own private pasture for the moment and breaks into an entirely foreign field of work he is not always assured of the cordial and generous welcome that I have received from the workers in the field of Maya archæology. Many of the workers have formed the habit of sending me drawings, photographs and descriptions of their discoveries before publication. To all of these I am deeply indebted, but more especially to Dr. Sylvanus G. Morley, of Carnegie Institution of Washington, who has frequently taken much time and pains to reinspect and redraw inscriptions for me.

On going over the final proof of this book I am forced to conclude that several pages relating to the tropical year may be unintelligible except to one already familiar with the Maya inscriptions and their subject matter. Others must study this section step by step and work out each problem just as one did in algebra, or else must assume that the proof is adequate and accept the conclusions. Read in the ordinary manner, I fear that it is little more than a conglomeration of figures and dates, although to specialists the discussion will be clear.

John E. Teeple

September 1929

MAYA ASTRONOMY

Did you ever try to work out a problem in multiplication or long division on paper, using Roman numerals? Try it some time; then you will see why the calculating machine called the abacus was so necessary to business houses some centuries ago, and why it was such a tremendous advance in convenience and saving in time when someone invented the Zero and the method of using position to indicate the value of symbols.

Take the symbol 9 for example. At the extreme right of a number it means 9; two places to the left it means nine hundred, and five more places to the left it means ninety million. It seems very simple to us to express any number by using only ten symbols, but the concepts of Zero and of position value had to be developed first before some unknown Hindu began using our "Arabic" numerals about 600 A.D. From the Hindus the system spread to the Arabs after 700 A.D., and finally reached Europe about the twelfth century. Compare DCCCLXXXVIII with 888. The Roman in this number used six different symbols and a total of twelve characters to express what we do with one symbol repeated three times. Some nations went through their whole alphabet and started through a second time in order to have symbols enough.

So far as we know these "Arabic" numerals, invented about 600 A.D. in India and first used in Europe several hundred years later, were the first in the Old World to have a Zero and a fully developed use of position value.[1] The Maya, however, were using the position system at least as early as the time of Christ—several hundred years before the Old World used it. Since they had a vigesimal system instead of a decimal one, they required twenty digits, but as a matter of fact these twenty digits were themselves built up of bars and dots, each bar representing 5 and each dot representing 1. Consequently they required only three digits, the bar, the dot, and the symbol for Zero, to express any number, no matter how large.

In our Arabic system of notation, ten units in any position is the equivalent of one unit in the next higher position. That is, ten tens make 100, ten one hundreds make 1000. The vigesimal system is similar except that twenty units in any position are required to equal one unit in the position next higher. Our numerals are written from left to right, the highest position being at the left and the units at the right. Maya numerals were usually written vertically, the highest position at top and units at bottom.

If we take a fairly large number, like 426,358,971, in our Arabic notation it would be written as given here. In the Maya vigesimal system it would

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[1] Sumerian numerals attempted a positional notation and after 250 B.C. Babylonian numerals contained a symbol for zero, but the system was never fully developed so that a number could be read with certainty. See Science, vol. 71, p. 110, (1930).

be written as shown in figure 1, which we may transliterate for convenience as 6.13.4.14.17.8.11. This latter number is made up as follows, beginning at the right of the transliteration and at the bottom of the figure:

11 units	11
8 twenties	160
17 four hundreds	6,800
14 x 8000	112,000
4 x 160,000	640,000
13 x 3,200,000	41,600,000
6 x 64,000,000	384,000,000
	426,358,971

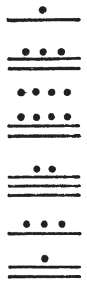
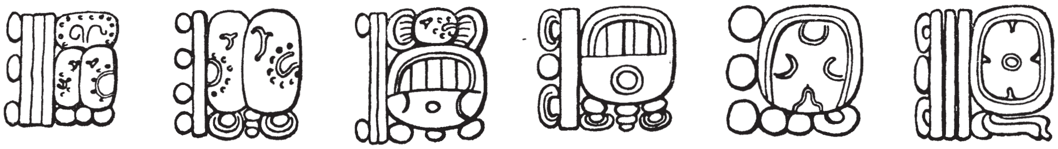


FIG. 1. Maya number composed of seven orders.

The Maya vigesimal system may possibly be a little more cumbersome than the Arabic decimal system, but not very much. It is just about as easy to think in twenties as it is in tens if you have always been accustomed to doing it. This devising a system which gave position value to numerals, and its correlative, a knowledge of the use of Zero, was an outstanding achievement in the matter of numeration, and was apparently accomplished by the Maya some time before it was reached anywhere else in the world. It is a curious fact that, say 2000 years ago, the Old World had been familiar with the use of the wheel, a mechanical invention, for some thousand years, but had never developed such abstract concepts as the idea of Zero, or place position for numerals. They were still content with exceedingly cumbersome mental tools in the matter of numbers. On the other hand, at least one people of the New World, the Maya, were masters of these abstract ideas. They had an excellent system of numbers, but knew nothing of the use of the wheel. Possibly a psychologist can make something of this.

In the Maya records that are left to us, the most frequent use of numerals is for counting of time. Here the chronological unit is the tun, a period of 360 days. It is obviously a purely arbitrary unit having no relation to any natural phenomenon. We may compare it, however, with our year as a chronological unit, from which it differs by only a little over five days. Twenty tuns make one katun, the next higher unit. Twenty katuns = 400 tuns = 1 baktun. Twenty baktuns = 8000 tuns = 1 pictun, etc. (fig. 2).



Pictun Baktun Katun Tun Uinal Kin

FIG. 2. Glyphs for the first six orders of time periods.

In using the year chronologically we add the months and days as separate items. For example, Christmas of this year may be written 1929–12–25. Here we have three separate units, the year, the month and the day, none of which has a true decimal relation to the other two, but it is essentially a year count, and a month and day are used only for fractions of a year. In the same way the Maya used their main unit, the tun, and expressed portions of a tun in two separate units, the uinal and the kin. The kin is the same as our day—20 kins = 1 uinal, and consequently 18 uinals = 1 tun. A day like 1.18.5–3–6, then, would be 765 tuns, 3 uinals, 6 kins; or 765 tuns, 66 kins. Some writers have expressed the idea that the Maya chronological unit is the kin rather than the tun, and that the whole number is a count of days in the vigesimal system with the exception that the second position from the right requires only 18 instead of 20 units to make one unit of the third position. This idea seems to me quite wrong. It would be just as accurate to say that our Christmas date above is a count of days in the decimal system with two exceptions, one being that the first place to the right requires 28, 29, 30 or 31 days to make one unit of the second position, and the second position requires 12 units to make one of the third. I feel sure we have to do here with a tun count, not a kin count, as was first called to my attention by Mr. William E. Gates, and that the Maya system of counting time as well as other units is purely vigesimal.

Two other points should be noticed. First, the start of our Christian chronology is a definite date in historical times, a little over 1900 years ago. The starting point for Maya chronology, so far as the ordinary records are concerned, was just as definite a date at the end of a Baktun 13, something over 5000 years ago. That date, however, must have been traditional, mythological, or astronomical. It is not conceived as being an historical date. The second point of difference is that we count in current time, while the Mayas counted in elapsed time. The first day A.D. in Christian chronology was January 1 of the year 1, that is, the first day of the first month of the first year, which we might write as 1–1–1. The first day of Maya chronology would have these corresponding parts written 0–0–0 because no single day had yet elapsed, and consequently they still had 0 kins 0 uinals and 0 tuns. It will be helpful if we remember that the Maya counted time just as the meter on a motor car counts miles. It does not register one mile until the whole mile has been run. While Christian chronology, like a taximeter, registers a unit the instant it starts.

The point in time from which most Maya dates are computed was called Baktun Thirteen, 13.0.0–0–0, but practically we may regard it as Zero since the next baktun after it is Baktun One, 1.0.0–0–0. For the purpose of this book we may regard this Baktun Thirteen, their Zero point, as equivalent to about August 12, 3113 B.C. following the correlation proposed by Goodman[1] and revived by Martinez[2] and by Thompson.[3] It should be clearly understood, however, that neither this correlation nor any other as yet has met

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[1] J. T. Goodman, *Maya Dates*, Amer. Anthropologist, n. s., vol. VII, 1905.

[2] Juan Martinez Hernandez, *Paralelismo entre los Calendarios Maya y Azteca*, Diario de Yucatan, Feb. 7, 1926.

[3] J. Eric Thompson, *A Correlation of the Mayan and European Calendars*, Pub. 241, Field Mus. of Nat. Hist., 1927.

with general acceptance. It is very useful to have some definite dates for purposes of comparison, so this will do as well as any other, being quite surely within about plus or minus 250 years of the real date, and possibly being in fact the exact date. I use this correlation because it is the only definite one so far proposed for which I have not been able to find serious astronomical evidence discounting its validity. That negative evidence, however, is far from being sufficient for proof. A part of our purpose in presenting the astronomical data that follow is to the end that other workers may view it as a whole and determine whether it alone is sufficient to establish a correlation. It will probably be insufficient, but there will be enough to furnish a rigid check on any correlation that may be proposed.

So when we say that a certain date, 9.16.4–10–8, is equivalent to November 8, 755 A.D. in the Julian calendar, we mean only that in comparison with other dates in this book that statement is true. That may in fact be its exact equivalent, but also conceivably the day, month, year, or century, or all four may be in reality incorrect without in any way affecting the validity of the evidence we hope to present. Let us postpone conclusions on this point till the evidence is all in hand.

The statement of dates in terms of the number of tuns that has elapsed from the Zero date is termed the "Long Count." This form of counting is used on Maya monuments from about 8.14.0–0–0 to 10.3.0–0–0, *i.e.*, from 3480 tuns after the Zero date to 4060 tuns after it, or in our chronology from 317 to 889 A.D. Strictly speaking the numerals on the monuments do not have position value, because they nearly all have symbols for the tun, katun, baktun, etc., as we might use symbols for the terms thousand, hundred, etc., but they use a symbol for Zero which is an essential part of the position value system from the earliest dates, and there is one date in 162 A.D. using a pure position value system. Further, in the *Dresden Codex* probably dating from about 1100 A.D. nearly all numerals are to be read from position value only.

THE CALENDAR

There is only one Maya calendar, just as we have only one in the United States. We speak often of the Maya lunar calendar and their Venus calendar, and I have been one of the worst offenders in this respect, but this is an error which only leads to confusion. Their astronomers had lunar tables and Venus tables, and probably solar tables of varying degrees of accuracy, at different times, just as ours have, but like us they had but one calendar in use. This calendar was not solar; it made no attempt to keep itself adjusted to the seasons, as our calendar does by inserting leap year days. Nor was it lunar, being kept adjusted to moon movements as are the Mohammedan and Jewish calendars. It was simply an arbitrary and orderly succession of days and months in regular order, going on forever without regard to any natural phenomenon. We can infer that they knew the length of a year to be 365 days or better, but beyond this the term "accuracy" is meaningless in connection with the Maya calendar, just as meaningless as to speak of the accuracy of our seven-day week. While we shall give a short description of the calendar, the reader is advised to consult some book, such as Morley's *An Introduction to the Study of the Maya Hieroglyphs*, for forms of glyphs and methods of computing and checking readings. A set of Goodman's tables, the *Archaic Annual Calendar*, will also be found convenient.

We must consider the calendar in two parts. First, the tzolkin, including the day names and day numbers, and second, the vague year, including the names of the months and positions in the month.

THE TZOLKIN

We have only seven names for days, Sunday, Monday, Tuesday, etc., and these seven names or their equivalents have been following one another without a break in the series for several thousand years. The Maya had twenty names for days, arranged in a similar never varying series: Imix, Ik, Akbal, Kan, Chicchan, Cimi, Manik, Lamat, Muluc, Oc, Chuen, Eb, Ben, Ix, Men, Cib, Caban, Eznab, Cauac, Ahau. This succession of twenty names was supposed to have been rolling on since the beginning. In addition to the names there were thirteen numbers applied to the day names in regular order from 1 to 13. These thirteen numbers likewise follow each other endlessly, and neither series influences the other. Since each day has both a number and a name, there will be no exact repetition for 13 × 20 = 260 days. If today is 12 Caban we shall have other Cabans at twenty-day intervals and other twelves at thirteen-day intervals, but no 12 Caban for 13–0 (Maya notation).

TABLE 1—*First Year*

	Names of Days	Names of Months																		
		Pop	Uo	Zip	Zotz	Tzec	Xul	Yaxkin	Mol	Chen	Yax	Zac	Ceh	Mac	Kankin	Muan	Pax	Kayab	Cumhu	Uayeb
0	Ik	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10
1	Akbal	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11
2	Kan	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12
3	Chicchan	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13
4	Cimi	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1
5	Manik	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	
6	Lamat	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	
7	Muluc	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	
8	Oc	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	
9	Chuen	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	
10	Eb	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	
11	Ben	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	
12	Ix	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	
13	Men	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	
14	Cib	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	
15	Caban	3	10	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	
16	Eznab	4	11	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	
17	Cauac	5	12	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	
18	Ahau	6	13	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	
19	Imix	7	1	8	2	9	3	10	4	11	5	12	6	13	7	1	8	2	9	

This 260-day period in which no day, number and name is exactly the same as any other is called the tzolkin (fig. 3). The numbers 13, 20 and 260 are all entirely arbitrary, having no relation to any natural occurrence, but it happens that 2 tzolkins, 1–8–0, 520 days, is nearly the same as three eclipse periods. This correspondence, however, is accidental and not intentional.

THE VAGUE YEAR

The other half of the Maya calendar is simply a 365-day year divided into 18 months of 20 days each, and a last short month, Uayeb, of 5 days (Table 1). This 365-day period is frequently called the "haab," but Mr. R. C. E. Long says that is not its Maya name, so there is nothing left to call it but the vague year; vague because it does not reproduce the seasons at the same date each year as we do in having the vernal equinox fall about March 21. The months in order are Pop, Uo, Zip, Zotz, Tzec, Xul, Yaxkin, Mol, Chen, Yax, Zac, Ceh, Mac, Kankin, Muan, Pax, Kayab, Cumhu, closing with the 5-day month Uayeb. The positions in each month are numbered 0 to 19, except Uayeb which is 0 to 4. This series of months and month positions likewise rolled on endlessly with no change, so far as we know, 0 Pop the beginning of the year recurring every 365 days. Since there are 20 day names and 20 positions in a month it follows that if the day Ik falls on 0 Pop in any given year it will also fill the Zero position in every month during that year, but the 5-day month Uayeb beginning with Ik will end with Cimi, so Pop of the next year has Manik in the Zero position. The third year begins with Eb, the fourth with Caban, and the fifth with Ik again. The number 365 is divisible by 13 with a remainder of 1, so if a year begins with 1 Ik 0 Pop it will end with 1 Cimi 4 Uayeb, and the next day will be 2 Manik 0 Pop beginning a second year. The third year begins with 3 Eb, the fourth with 4 Caban, the fifth with 5 Ik . . . , the fifty-second with 13 Caban—ending a period of 4 day names x 13 numbers, or 52 vague years, after which the series begins with 1 Ik again, and repeats. In ignorance of the Maya name for this 52-year period we call it the "Calendar Round."

A complete Calendar Round date, then, consists of a day number (1 to 13), a day name (one of 20), a month position (0 to 19) and a month name (one of 19), as 4 Ahau 8 Cumhu. Such a complete date can repeat only once in 52 vague years or 18,980 days, because that is the least common multiple of 13 day numbers, 20 day names, and 365 positions (month position and month name) in the year; 52 vague years are less than 52 tropical years (from season to season) by the 12 or 13 leap year days which we would have inserted in our calendar during that time to keep the beginning of Spring always falling near March 21.

In the Maya calendar if the vernal equinox this year fell on 8 Cumhu, then four years hence it would be at 9 Cumhu, in eight years at 10 Cumhu, and at the end of a calendar round of 52 vague years it would be at 0 Uayeb or 1 Uayeb. In the course of 29 calendar rounds or 1508 vague years the season would have made about one complete circuit through the vague year,

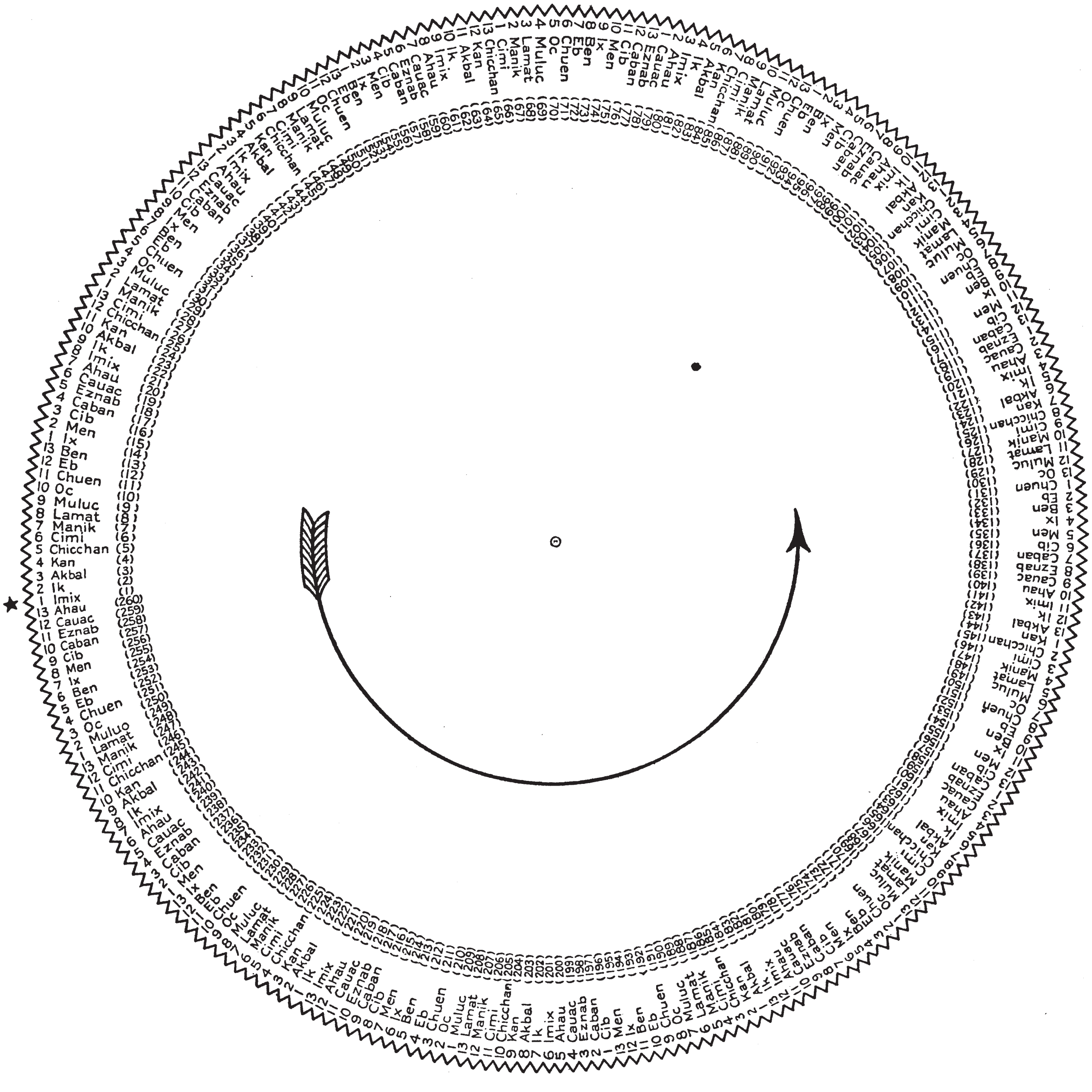

FIG. 3. The Tzolkin.

finishing 1507 tropical years at 8 Cumhu again. We know this 1507-year period, but whether the Maya knew it, or what they thought the relation of vague to tropical year was, is another story which we can discuss in later pages.

We see the Maya calendar then as a purely mechanical contrivance of 13 day numbers, 20 day names, and 365 positions in the vague year rolling on forever, quite independent of each other, and just as independent of any natural phenomenon. With the exception of the fact that a year is probably about 365 days long, the calendar itself yields not the slightest evidence of any astronomical knowledge on the part of the Maya. It only remains to gear the annual calendar or Calendar Round dates into the Long Count, which is easy to do. In the Long Count the Zero date, about 3113 B.C. was 13.0.0–0–0, 4 Ahau 8 Cumhu, that is it fell on date 4 Ahau 8 Cumhu in the annual calendar. The next four days would be

13.0.0–0–1,	5 Imix	9 Cumhu
13.0.0–0–2,	6 Ik	10 Cumhu
13.0.0–0–3,	7 Akbal	11 Cumhu
13.0.0–0–4,	8 Kan	12 Cumhu

and so the series of 13 numbers, 20 names, and 365 positions in the year go on forever. The date 13.0.0–0–12, 3 Eb 0 Uayeb would begin the last month of the year, the five unlucky days, 13.0.0–0–16, 7 Cib 4 Uayeb being the last day of the year, and 13.0.0–0–0–17, 8 Caban 0 Pop, New Year's day, the beginning of the new year at August 29, 3113 B.C., as we have been counting. Remembering that the vague year is 1–0–5, 1 tun 0 uinals and 5 kins, 365 days, we may write the first days of the next 4 vague years as

13.0.1–1– 2	9 Ik	0 Pop	Aug. 29, 3112 B. C.
13.0.2–1– 7	10 Manik	0 Pop	Aug. 29, 3111 B. C.
13.0.3–1–12	11 Eb	0 Pop	Aug. 29, 3110 B. C.
13.0.4–1–17	12 Caban	0 Pop	Aug. 28, 3109 B. C.

Four hundred vague years would be 400 tuns plus 400 x 5 days = 2000 days = 5–10–0, making a total of 1.0.5–10–0. Measuring that distance from the first New Year would give its date 1.0.5–10–17, 5 Caban 0 Pop, May 24, 2713 B.C. and 3200 vague years still later would take us well into the time of the Maya inscriptions at date 9.2.10–0–17, 7 Caban 0 Pop, April 9, 485 A.D. Do not pay too much attention to the April 9 or the 485 A.D.; remember that they are here only for comparison, and to show how a date like 0 Pop in the Maya calendar retrogresses in our own Gregorian calendar, through August 29, August 28, May 24, and then passing through our calendar twice backward is found at April 9. Conversely a date like May 24 would be found at 0 Pop in one year, at 1 Pop four years later, at 2 Pop eight years later, etc. Our calendar is adjusted approximately to the tropical or seasonal year. The Maya calendar is not adjusted to anything. It is simply a computing machine which counts off tuns and fractions of tuns in the Long Count, and day numbers, day names, and positions in the vague year, in the Calendar Round count.

Given a date like 9.16.12–5–17, 6 Caban 10 Mol, the Long Count tells us that it is 3932 tuns and 117 days from the Zero 4 Ahau 8 Cumhu. From this information alone we could reproduce its position 6 Caban 10 Mol in the Calendar Round dating, but given 6 Caban 10 Mol we can not reproduce the corresponding Long Count position. The date 6 Caban 10 Mol recurs every 52 vague years, so the position in the Long Count may be 9.16.12–5–17, or it may be any other 6 Caban 10 Mol, some multiple of 2.12–13–0 from this in either direction. Complete dating with both the Long Count and Calendar Round date was common practice until about 9.19.0–0–0, 9 Ahau 18 Mol—say about 810 A.D.; after that, Long Count dates became very infrequent and we have mainly only Calendar Round dates like 9 Ahau 18 Mol with very little to indicate which of the many 9 Ahau 18 Mols is intended; or we have short statements, such as 9 Ahau end of a katun. By the time the Spaniards came, it took the simple form of Katun 9 Ahau. If the Maya had maintained the Long Count system only until the Spaniards arrived, there would be no difficulty in dating their monuments exactly, but as it is we are left to guess what position in the Long Count the Katun 2 Ahau, Katun 13 Ahau, etc., of early Spanish times occupied.

Just one other point and we shall have finished with the calendar. During the time of the inscriptions and Long Count the important part of the count was the katun. The ends of katuns and half katuns were times for erecting monuments, and comparatively little stress was placed on New Year's day. By Spanish times the position seems to have been reversed. During the inscriptions, New Year's day was 0 Pop, and a year beginning at 9 Ik 0 Pop was said to have 9 Ik as its year bearer or to be the year 9 Ik. Only Ik, Manik, Eb and Caban could fall on 0 Pop, so these four days, permuted with the possible 13 numbers for each, made the 52 different year bearers for a Calendar Round before repetition occurred. At a later date after the inscriptions had largely ceased, but before the Spaniards arrived, it seems that 1 Pop had become New Year's day. We find this evidence in the codices where the year bearers are the days that could fall on 1 Pop, *i.e.*, Akbal, Lamat, Ben and Eznab. Finally, in the sixteenth century we find the Maya using for year bearers only the days that could fall on 2 Pop, *i.e.*, Kan, Muluc, Ix and Cauac, but through some change or accidental slip the month positions had changed one day, and these days were recorded as falling on the first of Pop, instead of on 2 Pop.

There is no astronomy in the Maya time count, except the passage of the day and a vague idea that a year is about 365 days long, and there is no accuracy about it except the accuracy of a machine that does not slip a cog and miss the count. To me it is simply a huge meter that records the passage of time on four different dials. Let us say the Mayan has been passing the day and night of 9.14.13–4–17, 12 Caban 5 Kayab in his usual vocations, whatever they were. The sun rises, another day is done and recorded, the meter clicks and everything goes forward one point to 9.14.13–4–18, 13 Eznab 6 Kayab. The Long Count has added one day of the 360 in a tun, the day number has advanced to the next of the 13, the day name advances to the next of the 20, and the position in the year advances to the next of the 365. It clicks again and we have

9.14.13–4–19, 1 Cauac 7 Kayab
9.14.13–5– 0, 2 Ahau 8 Kayab and so on relentlessly forever, regardless of seasons, moons or planets.

THE SUPPLEMENTARY SERIES

GLYPH G

We have not yet finished with the elaborate Maya time meter, however. There is another group of six or eight glyphs commonly called the Supplementary Series, which immediately follows all or most of a date such as we have given in the preceding section (fig. 4). Mr. J. T. Goodman, who did a great deal toward reading face numerals and explaining Maya time counts, drew figure 4B[1] and commented that the Supplementary Series

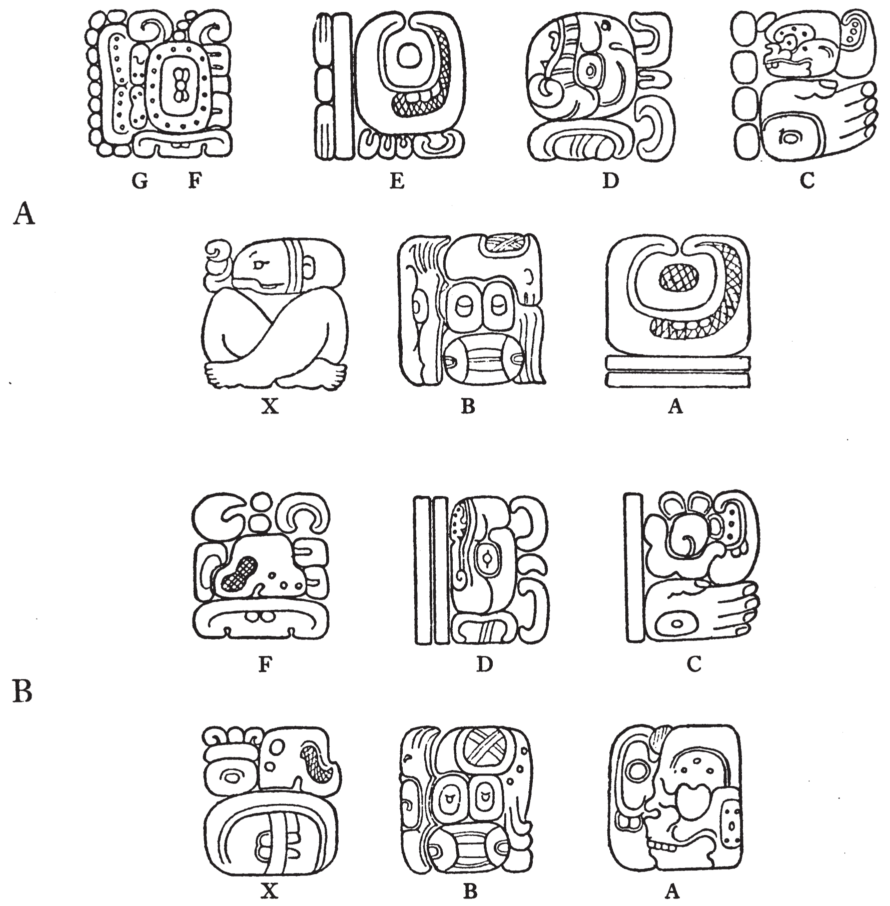

FIG. 4. Two Supplementary Series from Palenque.

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[1] J. T. Goodman, *The Archaic Maya Inscriptions*, p. 118, 1897.

"is the most exasperating if not the most perplexing feature in all the inscriptions." By a peculiar chance the particular example that Mr. Goodman drew, together with the first one, A, in figure 4, were the very ones out of nearly 150 now known which most surely yield the explanation of the most difficult part of the Series, as will be explained in the next section.

In a complete Supplementary Series there are eight glyphs, but frequently one to three of them are omitted. Following Dr. Morley's suggestion they are referred to by letters, beginning at the right, as A, B, X, C, D, E, F, G. Seven of these refer entirely to the moon and will be discussed in following chapters, but Glyph G, the one at the extreme left in figure 4A, is an integral part of the time count, and its discussion following will finish our consideration of the time machine.

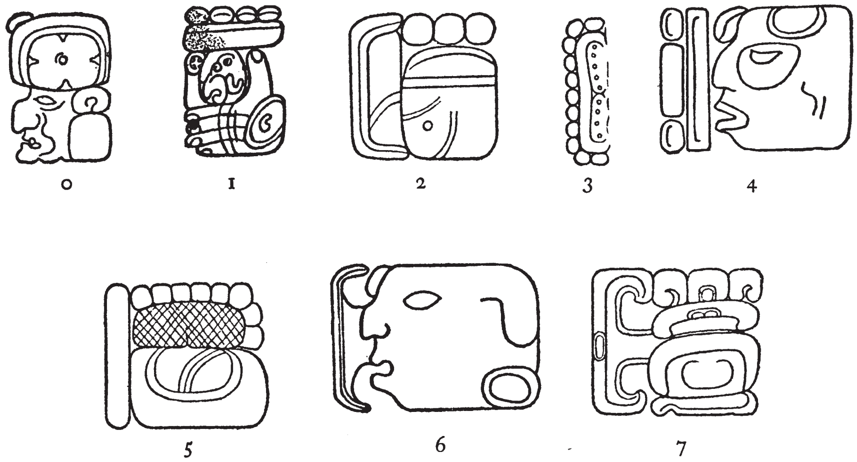

FIG. 5. Forms of Glyph G.

The explanation of Glyph G is entirely due to Mr. Eric Thompson.[1] He finds that there are nine forms of the glyph representing the Lords of the night who are occasionally referred to in Aztec writings, but only infrequently in Maya references. These nine Lords follow each other in regular order, invariably each ruling a single night. We are concerned here, however, with only the mechanics of Glyph G, and the dates where a certain form of G is to be expected. Figure 5 shows these nine forms in order, except one, the form for 8, no example of which is surely known.

Since we have to do with a series of nine, it follows that whatever form of Glyph G occurred for example at date 9.16.4–0– 0 it will recur at
9.16.4–0– 9
9.16.4–0–18
9.16.4–1– 7, etc., indefinitely. Also since the 360 days of a tun are divisible by 9 without a remainder, it follows that whatever form of Glyph G is used at the end of any tun will recur at the end of every other tun. This is the form marked 0 in figure 5. The

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[1] J. Eric Thompson, *Maya Chronology: Glyph G of the Lunar Series*, Amer. Anthropologist, vol. 31, p. 223, 1929.

others follow on succeeding days in regular order, 1, 2, 3, 4, 5, 6, 7, 8, 0, 1, etc. Since tun endings all have the 0 form, it is easy to find which form fits any date by converting its uinals and kins into days and dividing by 9; the remainder represents the form which fits that day. For example, in a date like 9.14.13–4–17, the 4–17 represents 97 days; dividing by 9 leaves a remainder of 7, so we know the Lord which follows date 9.14.13–4–17 is the one numbered 7 in figure 5.

The great majority of Maya dates where Glyph G is shown are tun endings, so we have an adequate number of examples of the form 0, and very few of the other eight forms, only about 1 to 5 of each. Glyph G will often prove helpful in reading partly obliterated texts, and every example found that is not the Zero form should be carefully drawn and made a matter of record. We have no examples of No. 8, only one clear one of No. 2, only two of No. 6, etc.

The Maya seemed to delight in varying the form of a glyph while retaining certain specific features which would make it recognizable. Mr. Thompson indicates the following essential features for each form of G, but it should be remembered that in some cases these descriptions may be changed slightly when added examples are known.

0 Kin sign, often with added maize or maize deity sign.
1 Hand with coefficient 9.
2 Probably the bracket prefix.
3 Considerable group of circles or dots.
4 Tassel on forehead and usually coefficient of 7.
5 Coefficient of 5, crosshatching and dots.
6 Ear flap and circle below it.
7 Sacred flame.
8 Unknown

This finishes the discussion of the Maya time meter with its interminable series. To recapitulate, we have

1 The 360 day series making up the tuns of the Long Count.
2 The 13 day numbers.
3 The 20 day names.
2, 3 } A combination of Nos. 2 and 3 giving the 260-day tzolkin.
4 The 365 positions that a day can occupy in the Vague Year.
5 The 9 Lords of the Night.

Given No. 1, the Long Count, we can deduce all the others. A date 9.14.13–4–17 in the Long Count must be 12 Caban 5 Kayab with Glyph G of form number 7. There is no question of approximation here. The 12 must be exactly 12 and not 11 or 13. The Lord of the night must be No. 7 and no other. It is a purely arbitrary arrangement of series entirely uninfluenced by seasons, moon, sun, planets or tides. You can not argue with a machine.

By way of contrast to the preceding arbitrariness, everything that follows in later sections is based on observation of natural phenomena which do not fit exactly into the time machine, so hereafter we shall be dealing with computation, adjustments, approximations—more or less successful endeavors to determine and express the movements of seasons, moon and planets in terms of the time machine. We can trace differences of opinion in different cities, and in the same city at different times, until at the climax of intellectual activity, probably in Copan, we shall find a degree of accuracy had been achieved that is really startling.

GLYPHS E AND D

We come now to matters of astronomical observation. After Glyph G, which is a part of the arbitrary time machine, all the seven remaining glyphs of the Supplementary Series are devoted to the moon, and two of them, Glyphs E and D, are used for recording the age of the moon. The glyph for D is usually a flexed hand followed by one form of the moon sign (fig. 6a), but at Palenque it is often a grotesque head (fig. 6b); at Yaxchilan it has a shape that I can not surely distinguish from E (fig. 6c), and there are several other forms.[1] Glyph E is much more regular, being nearly always one particular form of the moon sign, not the one used in D (figs. 7a and b), but sometimes it is modified into a face (figs. 7c and 7d).

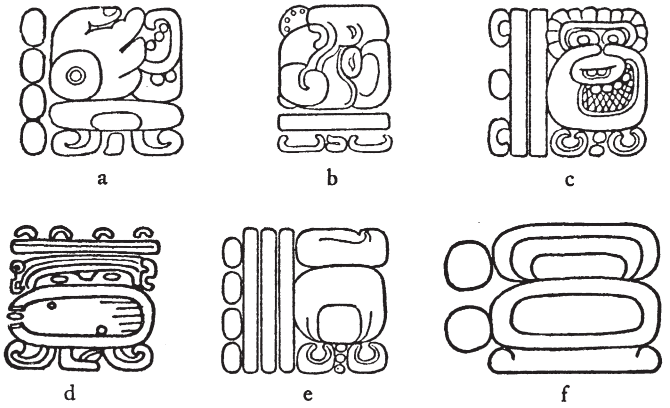

FIG. 6. Forms of Glyph D.

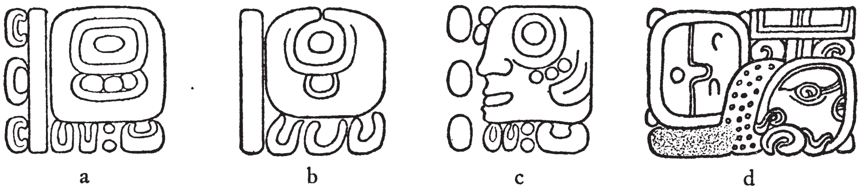

FIG. 7. Forms of Glyph E.

The concept of a "moon" as a time cycle of 29 or 30 days is probably one of the first time units, after the day, that forced itself into man's consciousness, and it has persisted to the present time. The Chinese, Arabic and Hebrew calendars of today are still based on the "moon" as their fundamental unit, although other influences have tended to make them

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[1] For many drawings of all Supplementary Series glyphs, see S. G. Morley, *The Supplementary Series in the Maya Inscriptions*, Holmes Anniversary Volume, Washington, 1916.

somewhat artificial. Our own year was originally composed of "moons" or months, but these have long since been stretched about a day from a 29½-day average to about a 30½-day average, in order to adapt them to the sun's movements, and our month is now an arbitrary unit no longer having any definite relation to the position or motion of the moon.

A modern city dweller will have difficulty realizing how important "moons" were to primitive man. The city man does not need the moonlight, since because of artificial light his nights are often brighter than day. His horizons bounded by tall buildings never show him a moon rise, or a sunset and new moon. His sky of fog and smoke, when he does happen to see the moon, converts her radiance into a dull gloom. For the hour of the night he looks at his watch, and for direction and guidance he consults a policeman. Yet the country boy of only fifty years ago depended on her for light and for the hour of the night, could tell his direction from her and the stars, knew her age within a day or two, could tell whether two weeks from tonight would be moonlight, and if so about what time the moon would rise or set, and took her into account when planning his night adventures just as his elders did in planning any night work that might be necessary.

The age of the moon is simply the number of days that have elapsed since last new moon. To the astronomer new moon is the conjunction of sun and moon, that is the point where the moon, in pursuing the sun along their paths toward the east through the stars, overtakes the sun and rests on the same meridian circle. To the layman, and probably to primitive man, new moon occurs on the first night that he can see the moon crescent in the west just after sunset. This is a few hours or maybe a day later than the astronomer's new moon, or sun-moon conjunction.

The average length of a "moon," that is the average time from one new moon to the next, according to astronomers is 29.53059 days, so if there is a new moon on July 1 you will expect the next one may be on July 30, maybe on July 31, depending on the time of day that the first one occurred. In the former case we have a "29-day moon," in the latter a "30-day moon," not indicating anything of course about the actual length of the moon in days and hours, but only showing whether the interval between new moon days was still only 29 in spite of the half-day fraction, or whether the fraction postponed the event till the next day. After the deadly monotony and accuracy of the Maya time machine, it is a little relief to find something added which is not so rigid and infallible—something that may vary by at least a day. Of course if we take two moons = 59.06 days, the fraction is so small, less than 1½ hours as an average, that we may be reasonably sure of a 59-day interval for two "moons," never a 58-day interval, and only very rarely a 60-day.

Three other factors may be noted, that make for indefiniteness in moon statements. The second one is lack of uniformity in the apparent motions of the sun and moon through the stars. The average "moon" is easily known to five decimal places as 29.53059, but any actual "moon" may vary from this by a couple of points in the first decimal place. For example, an eclipse of the sun occurs on April 28, 1930, and sun eclipses can occur only at a sun-moon conjunction, which is the astronomer's new moon. Six moons later a second eclipse occurs, on October 21, 1930, and six moons still later a third one on April 18, 1931. The first six-moon interval requires 176 days 2 hours, and the next one 178 days 4 hours, over two days actual difference between the first half and the last half of a given lunar year of 12 moons. So if we start at a given date and over a series of years compare real new moons with those computed from the average moon we would find frequent discrepancies of one or two days, now in one direction, now in the other, but if our average is correct the difference is not cumulative, and after a thousand years we would still find observation agreeing with computation within a couple of days in either direction.

A third cause of inexactness is human frailty in observation. Suppose you are a keen observer looking for new moon in a clear western sky, and you get a glimpse of it just after sunset. A few miles away, I, not quite so good an observer, am looking for it on the same night, but my western sky is hazy or foggy and I fail to see it. You record new moon as occurring tonight, I record it as not occurring until tomorrow night, and we have another slight discrepancy. If we disagreed on this moon we should probably agree on the next. In nations where the month began with new moon it was a matter of considerable importance that there should be agreement throughout the kingdom or nation, so as a practical expedient it was not uncommon to alternate the 29 and 30-day moons arbitrarily where there was doubt among the moon watchers.

There is a fourth possible cause of inexactness in the Maya records which I have never seen discussed, but which should probably be considered. Suppose I had been the temple priest in charge of the record and I was recording the day 9.16.0–0–0, 2 Ahau 13 Tzec. Remember this is only a counting machine and there is nothing in the sky to assure me that it is 2 Ahau 13 Tzec. Possibly I was not myself one day and forgot to score a day by whatever method of scoring was in use; then today is really 3 Imix 14 Tzec; or possibly in a dazed condition that day I scored twice; in that case today is really 1 Cauac 12 Tzec. Such things must have happened, and how were they rectified? Probably by conferences between cities where doubt existed.

Martinez[1] translates a passage from one of the late books of Chilan Balam written in Spanish times, which indicates that an assembly of priests met at Bacalar and, after consulting the ancient records, determined that a certain day was 11 Chuen 18 Zac. They proceeded later to correlate that date with the Spanish calendar, but one receives the clear impression that their first job was to decide what the Maya date was.

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[1] Juan Martinez Hernandez, *Paralelismo entre los Calendarios Maya y Azteca,* Diario de Yucatan, Feb. 7, 1926.

These four causes of inexactness are inserted here to impress on you that the inflexibility of the Maya time count ended at Glyph G, and that beginning with Glyphs E and D we may expect two or three days fluctuation from a calculated mean, and not exactness. In practice I have considered that discrepancies up to 3 days might be covered by the four causes discussed; over 3 days a discrepancy should be regarded with considerable suspicion.

Referring now to figure 4A it will be found that it is the Supplementary Series attached to a date 1.18.5–3–6 and records Glyph E with coefficient of 6 and Glyph C with coefficient of 4. Figure 4B is a Supplementary Series attached to date 1.18.5–4–0 and records Glyph D with coefficient 10 and Glyph C with coefficient 5. We may write these

1.18.5–3–6, 4C, 6E

1.18.5–4–0, 5C, 10D. These dates are only 14 days apart. What plausible explanation will convert the 4C, 6E of the upper date into 5C, 10D of the lower one in a 14-day interval? It soon becomes obvious to you that 4C probably means 4 moons and 5C means 5 moons, and that 6E represents some number of days after the fourth moon, which 14 days later will become a number of days after the fifth moon represented by 10D. Clearly then Glyph E probably represents 20 and 6E is probably 26. So we have 26 days after the fourth moon, which 14 days later will naturally be either 10 or 11 days after the fifth moon; in this case 10 days. These two dates so close together were the ones that finally gave the clue for interpreting Glyphs C, D and E definitely, and on checking through about 150 known Supplementary Series the interpretation is found to be correct. Glyphs D and E are used to give the age of the moon in days from last new moon. Glyph D with coefficients up to 19 is used for ages less than 20 days, and E with coefficients 0 to 9 is used for 20 days and over. If either E or D is without coefficient it should be ignored, and if both are present without coefficient that signifies new moon day. In Table 2 is given a list of a few katun endings with the age of the moon, first as recorded on some Maya monument and second as computed from one of the dates using the average moon.

TABLE 2—*Moon age at katun endings*

Date	Recorded	Computed
8.16.0–0–0	25	25
9. 3.0–0–0	17	17
9. 4.0–0–0	13	11
9. 5.0–0–0	5	6
9. 7.0–0–0	25	25
9. 8.0–0–0	19	19
9. 9.0–0–0	13	13
9.10.0–0–0	8	8
9.11.0–0–0	4 and 5	3
9.12.0–0–0	28	27
9.14.0–0–0	17	16
9.15.0–0–0	10	10
9.16.0–0–0	5	5
9.17.0–0–0	0	0
9.18.0–0–0	24	24

Notice that there is frequent discrepancy of a day, that twice it rises to 2 days, that in Katun 4 the record is 2 days more than we compute, and in Katun 5 it is in the opposite direction, *i.e.* less than we compute. This short table with its limits over 400 years apart would be sufficient proof of itself that E and D record the age of the moon, counted from some phase of it. But what evidence have we that the count is from new moon and not from full moon or first quarter, or some other phase? The statement that the count is from new moon is based on four points:

1. Bishop Landa, probably our chief authority in such matters in early Spanish times, states explicitly that the count was from the time when the new moon rises till it disappears.
2. It is the custom with most primitive peoples to make their count from new moon.
3. The Maya Venus count we know was from the time the new Venus appeared after conjunction with the sun, and by analogy we expect the moon count to be from new moon immediately after conjunction. Probably likewise the day began at sunrise.
4. There is a moon-eclipse table in the *Dresden Codex*, where the count is from eclipses, therefore from new or full moon; but internal evidence shows that the eclipses are solar, so the count must be from new moon.

Our conclusion then is that Glyphs D and E show the age of the moon counted from last new moon. Whether the count is from the astronomer's new moon or from the layman's visible new moon is not important and would make a difference of only a few hours, or a day at most. If this is true, as I believe is fully shown, then we have one first simple test to be applied to any proposed correlation. For example, Dr. Spinden has proposed a correlation which has been quite widely used without any very critical examination. This correlation presumes to be correct to a day. It places date 9.17.0–0–0 on day March 25, 511 Julian, which is 10 or 11 days after new moon. But we know from Maya monuments themselves that 9.17.0–0–0 was at new moon. Here is a discrepancy of 10 days. If our analysis of Glyphs E and D is correct then his correlation can not possibly be correct. If he could shift his correlation 10 or 11 days, we could find no fault with it so far as the moon age is concerned, but this he can not do without losing connection with the supposed equinoxes, solstices, "sun dial at Copan," and "Farmers Year" on which he now depends as props or proofs. As a way out of his dilemma, Dr. Spinden has suggested that Glyphs D and E are not a record of observed moon ages, but are taken from some formal lunar calendar which was started ages before, had a certain cumulative inaccuracy, and that this inaccurate record was still being made continuously, quite regardless of the real position of the moon. This suggestion does not seem plausible for several reasons: first we have no evidence indicating the existence of any such formal lunar calendar during the time of

TABLE 3—*Recorded moon ages and moon numbers*

Number	Monument	Site	Date	E and D	C	A
1	Stela 18	Uaxactun	8.16. 0– 0– 0	25	1	
2	Lintel 21	Yaxchilan	9. 0.19– 2– 4	7	3*	29
3	Stela 20	Copan	9. 1.10– 0– 0	25	2	
4	Stela D	Pusilhá	9. 3. 0– 0– 0	17	4	30
5	Stela 6	Xultun	9. 3. 7– 0– 0	25	4	
6	Stela 3	Uaxactun	9. 3.13– 0– 0	2	5	30
7	Stela 6	Tikal	9. 4. 0– 0– 0	13	5	
8	Stela 30	Piedras Negras	9. 5. 0– 0– 0	5	5	30
9	Stela E	Copan	9. 5.10– 0– 0		4	30
10	H. S., Date 1	Copan	9. 5.19–13– 0	25	5	29
11	Stela 17	Tikal	9. 6. 3– 9–15		4	
12	Stela 9	Copan	9. 6.10– 0– 0	25	5	30
13	Stela O	Pusilhá	9. 7. 0– 0– 0	25	6	
14	H. S., Date 3	Copan	9. 7. 5– 0– 8	2	2	29
15	Stela 7	Ichpaatun	9. 8. 0– 0– 0	19		
16	Stela 25	Piedras Negras	9. 8.10– 6–16	3	3	29
17	Stela 7	Copan	9. 9. 0– 0– 0	13	4	30
18	Stela P	Copan	9. 9.10– 0– 0	9	3	30
19	Stela 6	Macanxoc	9. 9.10– 0– 0	9	2	30
20	H. S., Date 5	Copan	9. 9.14–17– 5	23	4	30
21	Stela 26	Piedras Negras	9. 9.15– 0– 0	13	5	29
22	Stela 1	El Pabellón	9.10. 0– 0– 0	8	5	30
23	Stela 4	Altar de Sac.	9.10. 3–17– 0	11	4	29
24	Stela 31	Piedras Negras	9.10. 5– 0– 0		3	30
25	Stela 36	Piedras Negras	9.10. 6– 5– 9	4	4	29
26	Stela D	Pusilhá	9.10.15– 0– 0	3	3	30
27	Stela Y	Pusilhá	9.10.15– 0– 0	3	3	
28	Stela 23	Copan	9.10.18–12– 8	5	1	30
29	Stela 10	Copan	9.10.19–13– 0	23	6	29
30	Stela 19	Copan	9.10.19–15– 0	4		29
31	Stela H	Pusilhá	9.11. 0– 0– 0	4	3	29
32	Stela 13	Copan	9.11. 0– 0– 0	5	3	29
33	Stela 1.	Macanxoc	9.11. 0– 5– 9		1	30
34	Stela 6	Yaxchilan	9.11. 3–10–13	26	2	29
35	Lintel 2	Piedras Negras	9.11. 6– 2– 1	19	5	29
36	Stela 35	Piedras Negras	9.11. 9– 8– 6	14		
37	Stela 5	Macanxoc	9.11.10– 0– 0	0	1	29
38	Stela 8	Piedras Negras	9.11.12– 7– 2	6	5*	30
39	Altar St. 5	Copan	9.11.15– 0– 0	28	3	29
40	Stela 1	Copan	9.11.15–14– 0	12	5	
41	Stela K	Pusilhá	9.12. 0– 0– 0	1	3	29
42	Stela 37	Piedras Negras	9.12. 0– 0– 0	28	5	29
43	Stela 1	Piedras Negras	9.12. 2– 0–16	28	3	30
44	Stela 3	Piedras Negras	9.12. 2– 0–16	27	2*	29
45	Stela I	Copan	9.12. 3–14– 0	0	4	
46	Stela 39	Piedras Negras	9.12. 5– 0– 0	27	1	30
47	Stela 1	Palenque	9.12. 6– 5– 8	19	5	30
48	Altar H'	Copan	9.12. 8– 3– 9	22	5*	29
49	Altar 44	Yaxchilan	9.12. 8–14– 1	27	4	29
50	Stela 6	Copan	9.12.10– 0– 0	22		30
51	Stela 38	Piedras Negras	9.12.10– 0– 0		2	
52	Stela T8	Toniná	9.12.10– 0– 0	22		30
53	Stela 24	Naranjo	9.12.10– 5–12	18	1*	
54	Stela 29	Naranjo	9.12.10– 5–12	19	6	
55	Stela B	Tilá	9,12.13– 0– 0	9 or 14	3	30
56	Stela 6	Piedras Negras	9.12.15– 0– 0	25	4*	29
57	Stela 22	Naranjo	9.12.15–13– 7		1	
58	Altar K	Copan	9.12.16– 7– 8	0	2	29
59	Stela 2	Piedras Negras	9.13. 5– 0– 0	21	6*	
60	Stela J	Copan	9.13.10– 0– 0	18	1*	30
61	Stela 4	Piedras Negras	9.13.10– 0– 0	20	1*	30
62	Stela 1	Piedras Negras	9.13.15– 0– 0	17 to 19	2*	29
63	Stela 5	Copan	9.13.15– 1– 0	8	3*	29
64	Lintel 29	Yaxchilan	9.13.17–12–10	15	5*	30
65	Stela 3	Piedras Negras	9.14. 0– 0– 0	17	3*	30
66	Stela M	Pusilhá	9.14. 0– 0– 0	16		
67	Stela 30	Naranjo	9.14. 3– 0– 0	4	4*	
68	Stela 5	Piedras Negras	9.14. 5– 0– 0	over 10	4*	29
69	Stela 7	Piedras Negras	9.14.10– 0– 0	14	5*	30
70	Stela E	Quirigua	9.14.13– 4–17	7	3*	30

TABLE 3 (Continued)

Number	Monument	City	Date	E and D	C	A
71	Lintel 26	Yaxchilan	9.14.17–12– 0	28	4*	30
72	Stela 23	Piedras Negras	9.14.15– 0– 0	13	6*	
73	Stela A	Copan	9.14.19– 8– 0	15	6*	29
74	Stela 11	Piedras Negras	9.15. 0– 0– 0	10	1*	30
75	Stela 9	Piedras Negras	9.15. 5– 0– 0	9	2*	
76	Stela D	Copan	9.15. 5– 0– 0	9	2*	
77	Lintel Berlin Mus.	Yaxchilan	9.15. 6–13– 1	11	5*	30
78	Stela 10	Piedras Negras	9.15.10– 0– 0	9	3*	30
79	H. S., Date 11	Copan	9.15.12–10–10	24		
80	Lintel 46	Yaxchilan	9.15.14– 8–14	29	3*	30
81	Stela 40	Piedras Negras	9.15.14– 9–13	over 10	4*	
82	Stela S	Quirigua	9.15.15– 0– 0	5	4*	30
83	Stela H	Quirigua	9.16. 0– 0– 0	5	5*	30
84	Altar 2	Piedras Negras	9.16. 0– 0– 0		5*	
85	Lintel 1	El Cayo	9.16. 0– 2–16	23	1*	30
86	Stela 11	Yaxchilan	9.16. 1– 0– 0	12	5*	
87	Stela 11	Yaxchilan	9.16. 1– 0– 0	12	4	
88	Stela M	Copan	9.16. 5– 0– 0	5	5	30
89	Stela J	Quirigua	9.16. 5– 0– 0	4	6*	29
90	Stela 1	Yaxchilan	9.16.10– 0– 0	3	1*	30
91	Stela N	Copan	9.16.10– 0– 0	1	1	30
92	Stela F	Quirigua	9.16.10– 0– 0	3	6	30
93	Temple 11	Copan	9.16.12– 5–17		6	
94	Stela D	Quirigua	9.16.13– 4–17	24	4*	
95	Stela D	Quirigua	9.16.15– 0– 0	1	1	30
96	Stela 16	Piedras Negras	9.16.15– 0– 0	1	2*	29
97	Stela 7	La Honradez	9.17. 0– 0– 0		3*	30
98	Stela E	Quirigua	9.17. 0– 0– 0	0	2	29
99	Stela 13	Piedras Negras	9.17. 0– 0– 0	0		
100	Stela A	Quirigua	9.17. 5– 0– 0	28	2	30
101	Stela 2	Ixkun	9.17. 9– 0–13	5	3	30
102	Stela 13	Naranjo	9.17.10– 0– 0	27	4*	29
103	Zoomorph B	Quirigua	9.17.10– 0– 0		1 or 2	29
104	Stela 1	Los Hijos	9.17.10– 7– 0	18		30
105	Stela 14	Naranjo	9.17.13– 4– 3		3	29
106	Zoomorph G	Quirigua	9.17.15– 0– 0	23	5*	30
107	Stela 1	Ixkun	9.18. 0– 0– 0	24	6*	29
108	Stela 14	Piedras Negras	9.18. 0– 3– 1	26	2*	29
109	Stela 12	Piedras Negras	9.18. 5– 0– 0	23	6	30
110	Stela 8	Naranjo	9.18.10– 0– 0	21	2*	29
111	Stela 13	Uaxactun	10. 0. 0– 0– 0	over 10	5	30
112	Tem. In't'l. Ser.	Chichen Itzá	10. 2. 9– 1– 9	25	5	30

the inscriptions; second, there is no evidence of a cumulative error from beginning to end of the inscriptions; third, a formal calendar would keep a definite relation to an average moon, instead of wobbling 2 or 3 days now in one direction, now in the other, as the records do and as we would expect real observations to do; and fourth, such discrepancies as Piedras Negras recording 9.13.10–0–0 as 20 days after new moon while Copan records it 18 days, and many similar ones, would be quite impossible with a formal calendar, but would be natural and to be expected if the record had been made from observation.

This matter is of sufficient importance to warrant careful consideration. The recorded age of the moon can be checked on more Maya inscriptions than all other astronomical data combined. If we accept the record of E and D as showing moon age, we must of course reject any correlation that does not fit it. Only one correlation so far suggested passes this first simple test, and this is Goodman's, which places 11.16.0–0–0 13 Ahau 3 Xul equivalent to November 3, 1539 of the Julian calendar. This correlation makes 9.17.0–0–0 fall on January 20, 771 Julian, a new moon day, as the inscriptions require. This is the correlation used in this book for comparison, but it should always be kept in mind that passing the simple test of agreement with Glyphs D and E is far from proof of correctness.

In Table 3 we give a list of inscriptions where date and Supplementary Series can be read clearly or with little doubt. At this point we are concerned only with the column E and D, the moon age; the other columns will be used later. A blank space means that the number is not legible. All the dates of the 112 inscriptions in this table are quite surely correct. The moon age in most cases is given clearly, but in No. 55 one can not be sure whether 9 or 14 is intended. Either would be fairly good since an average moon at this point calls for about 11. In No. 68 the age is surely over 10 and not over 15, while 15 is expected. In No. 81 the age is over 10 and less than 20, while 18 is expected. In No. 111 the age is over 10 and not over 15, while 13 is expected.

No single recorded moon age in this list differs as much as 4 days from what one would compute using an average moon, with the possible exception of No. 94 where the expected age is about 27 or 28 days, instead of 24 days. This is remarkable agreement when we consider that the list covers 21 archæological sites in Honduras, Guatemala, British Honduras, and Mexico, while in time it extends well over 500 years.

TABLE 4—*Recorded moon ages and moon numbers corresponding to doubtfully deciphered dates.*

Number	Monument	Site	Date	E and D	C	A
1	Stela 3	Copan	9. 0. 0– 0– 0	1	1	30
2	Stela 16	Copan	9. 4.15– 0– 0	5		
3	Stela E	Pusilhá	9.10. 0– 0– 0	11	4	29
4	Stela 2	Copan	9.10. 0–10– 0	0	1	30
5	Stela 12	Copan	9.10.15– 0– 0	3		30
6	Stela 3	Copan	9.11. 0– 0– 0		3	30
7	H. S., Date 26	Copan	9.13. 3– 7– 8	10	4	
8	Stela 23	Naranjo	9.13.18– 4–18	15	5	30
9	Stela T9	Toniná	9.17. 0– 0– 0[1]	0	3	30
10	Temple 11	Copan	9.17. 7–13– 0	5		30
11	Stela T28	Toniná	9.17.15– 0– 0	23	5	30
12	Tem. In't'l Ser. 15	Holactun	9.16.14– 0– 9	2	2	30

Table 4 gives a further list. In this table the moon age recorded in each case agrees well enough with the date given, but there is some doubt whether the date has been definitely read correctly. For example No. 3 in Table 4 is either 9.10.0–0–0 or 9.15.0–0–0. Unfortunately the moon age does not help very much here because two dates just 5 katuns apart differ in moon age by only 2 or 3 days at most, and this is within our limit of variation.

There follows in Table 5 a small group which can be clearly read, but the moon age given does not agree with that expected. This is probably

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[1] Initial Series destroyed, supplied by author.

due to errors in the inscriptions, and even so the percentage of error is very small. Number 1 should be about 7 days; No. 2, 12 days, and here the form of G is also wrong, thus indicating that 9.7.12–6–7 was probably not the date intended; No. 3, 23 days, which could be accounted for as an error in writing 3D instead of 3E; No. 4 should be about 21 days; No. 5 should be about 20 days, and No. 6 about 19 days. With the exception of these four late dates at Quirigua, then, we have only two that are irreconcilable—Stela 3 at Tikal and Stela H at Pusilhá.

TABLE 5—*Recorded moon ages which disagree with the corresponding dates.*

Number	Monument	Site	Date	E and D	C	A
1	Stela 3	Tikal	9. 2.13–0–0	17	3	29
2	Stela H	Pusilhá	9. 7.12–6–7	4	5	30
3	Zoomorph P	Quirigua	9.18. 5–0–0	3	4	29
4	Stela I	Quirigua	9.18.10–0–0	11	1	29
5	Stela K	Quirigua	9.18.15–0–0	0	3	30
6	Struct. 1	Quirigua	9.19. 0–0–0	2	4	

We have demonstrated, then, that E and D give the age of the moon counted from new moon, that it is an observational record, and that it may be relied on to give the exact position of the moon at any date with an error of observation not exceeding 2 or 3 days. We will not consider any correlation possible, therefore, which does not place date 9.17.0–0–0 at new moon or within a couple of days of it.

GLPYH C

Glyph C bears some resemblance to Glyph D; the moon sign is the same in both cases, but the hand is extended in C instead of flexed, and above the hand is usually a face (fig. 8 a, b, c); sometimes the face is replaced by another design (fig. 8d, e). Dr. Morley thinks the faces represent different numerals or Gods, but their significance is not surely known. The coefficients of Glyph C range from 2 to 6 only, and in addition it is frequently shown without coefficient, in which case it is understood to be 1.

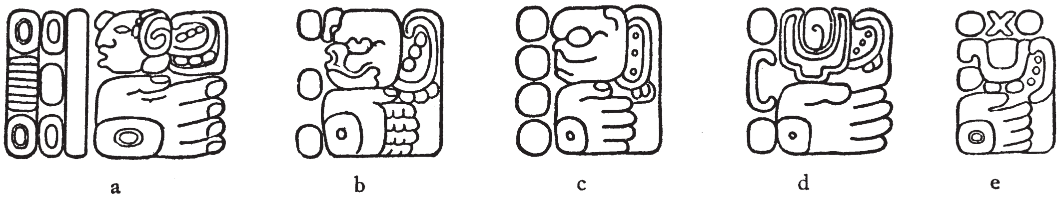

FIG. 8. Forms of Glyph C.

Glyph C has proved to be the most interesting of all the glyphs of the Supplementary Series, because it indicates the arrangement of moons in groups, and this arrangement underwent at least two very definite changes. We can not only trace these changes, but we are also able to deduce something of the probable causes of change in each case. One change took place very sharply in all cities about 9.12.15–0–0 (687 A.D.). The second was much more gradual, starting at Copan in 9.16.5–0–0 (756 A.D.) and not reaching some of the other cities till after 9.18.0–0–0 (790 A.D.).

The middle period between these two changes is the one best known to us and likewise it was about the time that the Maya reached the peak of their intellectual and artistic activity. During this middle period, or Period of Uniformity as I have termed it, the moons were numbered in groups of six, running 1, 2, 3, 4, 5, 6, 1, 2, 3, etc., continuously, and every city agreed on the number of any given moon. If Quirigua wrote 9.16.0–0–0 as 5 moons and 5 days after the new moon that began this group or ended the last one, then you may be sure that every other city wrote the date exactly 5 moons and about 5 days. In Table 3 the moon numbers belonging to the uniform period are starred. Notice that the contemporary series begins with No. 56 at 9.12.15–0–0, and after No. 58, 9.12.16–7–8, not another date in any city varies from the regular series until we reach No. 87, and this is only a double date written correctly according to the uniform series in No. 86 and rewritten in No. 87, presumably according to the series that was in use before uniformity began. There are five dates before 9.12.15–0–0 agreeing with the uniform series, Nos. 2, 38, 44, 48 and 53, but these dates are all on monuments erected after 9.12.15–0–0, *i.e.*, during the Period of Uniformity, and are evidently computed.

It is easy to follow the numbers during this period if we remember that a hotun, 5–0–0, is only 1 or 2 days less than 61 moons (10 groups of 6, and 1 moon over). So if 9.13.0–0–0 is 5 moons and 22 days we expect

9.13.5–0–0	6 moons	20 days
9.13.10–0–0	1 moon	19 days
9.13.15–0–0	2 moons	17 days
9.14.0–0–0	3 moons	16 days, etc.

We can easily predict C exactly, and D and E within a day or two for any date during the Period of Uniformity. A group of 6 moons makes exactly half of a natural lunar year, and 2 groups or 12 moons equal 1 lunar year of 354 or 355 days. So from 9.12.15–0–0 till the system was abandoned in each city the Supplementary Series for any date shows the position of that date in a natural lunar half-year, that is the number of moons (Glyph C) and days (Glyph E or D) that have elapsed since the half-year began. Now a count in natural lunar years is very common practice and the Maya, who used the moon a great deal in extended astronomical computations, were quite familiar with the lunar year; but in a continuous count of lunar years there is no natural starting point—no new moon which is the obvious end of one lunar year and beginning of another. The selection of this Zero new moon is purely arbitrary, and the characteristic of the Period of Uniformity from 9.12.15–0–0 on was the absolute agreement among all the cities in selecting the same new moon to start each lunar half-year. The agreement covers every archæological site in Honduras, Guatemala and the

State of Chiapas, Mexico, from which we have known Supplementary Series during the Period of Uniformity. There is none from Yucatan or Quintana Roo. In British Honduras the situation is interesting. Stela M from Pusilhá 9.14.0–0–0 does not have a legible Glyph C. Stela E, Pusilhá, is doubtful; it may be 9.10.0–0–0 or it may be 9.15.0–0–0. The moon series is clearly 4C 11D. For 9.15.0–0–0 the uniform series would be 1C and about 11D, and for 9.10.0–0–0 we have no way of predicting the coefficient of Glyph C, but Glyph D should be about 8, and the recorded 11 is just within our 3-day limit. So we have two possibilities; if the reading is 9.15.0–0–0, then Pusilhá, although very close to the Guatemala border, was not in the confederacy or association where uniformity prevailed; or if Pusilhá was within the limits of that association, then the date must be 9.10.0–0–0. The matter probably can not be brought to a definite decision, but I incline to the belief that the date is 9.10.0–0–0. So much for the Period of Uniformity, which lasted in different cities from 65 to over 100 years after 9.12.15–0–0.

The whole period previous to 9.12.15–0–0, I have called the Period of Independence, which simply means that there were not always 6 moons to a group and that the cities often did not agree on the moon number at a given date. To illustrate the first point, Copan records 9.10.19–13–0 as 6 moons 23 days and 9.11.0–0–0, just 100 days later, as 3 moons and 5 days. But 100 days is a distance of 3 moons and about 12 days. If we add this amount to 6 moons 23 days we should expect to reach 4 moons and 5 days instead of the 3 moons 5 days recorded. To illustrate the second point, the date 9.9.10–0–0 is recorded at both Copan and Macanxoc, in the first as 3 moons, in the second as 2 moons; while if the uniform method of numbering had been in use, we should expect 4 moons. These are the evidences of independent action in the different cities, but I do not know the actual method of numbering used in any city before 9.12.15–0–0. I am inclined to think that Palenque used exactly 6 moons to a group, but their moon number at any date would have been 1 less than the uniform count called for, *e.g.*, 9.13.0–0–0 would have been written 4 moons instead of 5 moons. There are not enough contemporary dates, however, to prove this. So the fact remains that while we can always predict D or E very closely for any time in Maya inscriptions, and while we can predict C exactly for the Period of Uniformity after 9.12.15–0–0, we can make no prediction at all about Glyph C during the Period of Independence before 9.12.15–0–0, with the possible exception of Palenque.

The adoption of the uniform method about 9.12.15–0–0 by the different cities was evidently regarded as a matter of grave importance. We can only follow it clearly in the 5 cities from which we have a sufficient number of dates, *i.e.*, Piedras Negras, Naranjo, Yaxchilan, Copan and Quirigua, but of these five, the first three each chose a certain date and wrote it twice, once with Glyph C numbered according to the uniform system and again with a different coefficient, presumably according to the system that city had used before the Period of Uniformity. The first three give a date earlier than the monument on which it was placed and carefully record C with the coefficient we would expect under the uniform system.

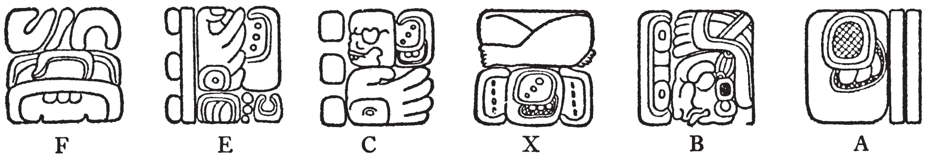

FIG. 9. Stela 1, Piedras Negras.

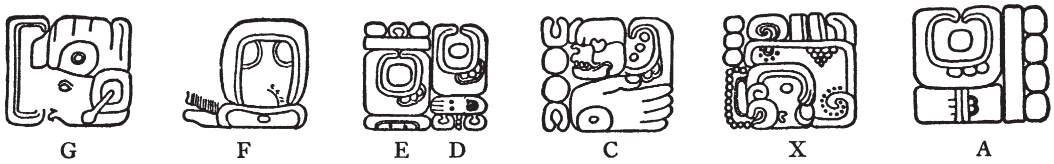

FIG. 10. Stela 3, Piedras Negras.

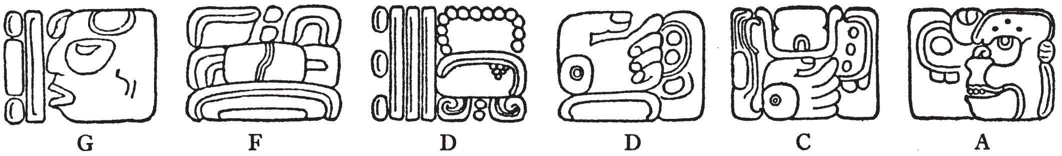

FIG. 11. Stela 24, Naranjo.

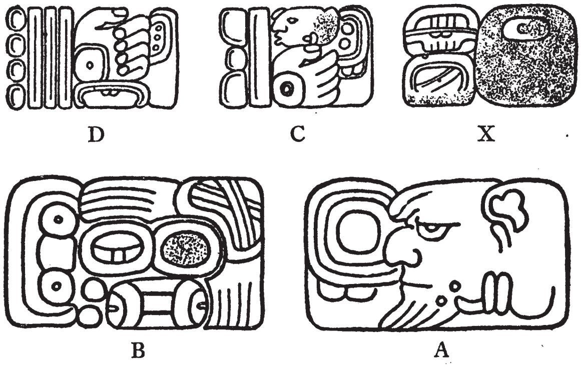

FIG. 12. Stela 29, Naranjo.

Considering first the three double dates: Piedras Negras selected 9.12.2–0–16, 2 Cib 14 Yaxkin and upon Stela 1 erected in 9.13.15–0–0, they recorded 9.12.2–0–16 as 3 moons 28 days, which was incorrect according to the uniform system but may have agreed with their former independent system (fig. 9). On Stela 3 erected in 9.14.0–0–0, they recorded 9.12.2–0–16 as 2 moons 27 days correctly by the uniform numbering (fig. 10). Naranjo selected the date 9.12.10–5–12, 4 Eb 10 Yax and on Stela 24 erected in 9.13.10–0–0 the date 9.12.10–5–12 is recorded correctly in the uniform series as 1 moon 18 days (fig. 11). On Stela 29 erected in 9.14.3–0–0, it is recorded 6 moons and 19 days, probably according to the independent method formerly in use in this city (fig. 12). Note that at Piedras Negras the uniform method calls for 2 moons instead of 3 moons, *i.e.*, one less than would have been used independently, while at Naranjo it calls for 1 more—1 moon instead of 6 moons. Both these cities reduce the moon age by 1 day also, possibly changing the beginning of the count from astronomer's new moon to the layman's new moon, or possibly for some other reason unknown to us. The third double date is at Yaxchilan where, on Stela 11, the date 9.16.1–0–0, 11 Ahau 8 Tzec is written twice, once on the front as 4 moons 12 days by the old method (fig. 13), and once on the side as 5 moons 12 days by the uniform method (fig. 14). At just about the same time Lintel 21 at Yaxchilan was erected and on it was given a date over 300 years in the past, *i.e.*, 9.0.19–2–4, 2 Kan 2 Yax, correctly computed by the uniform system as 3 moons 7 days.

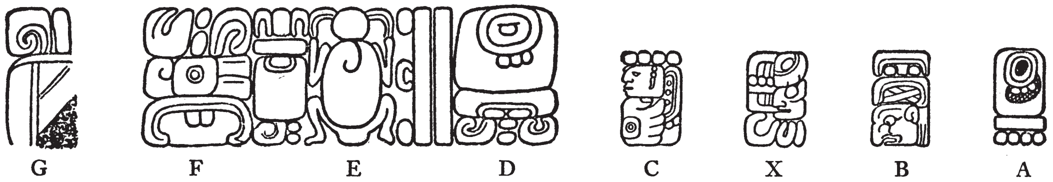

FIG. 13. Stela 11, Yaxchilan, first Supplementary Series.

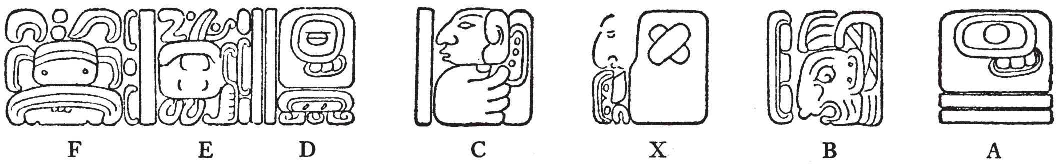

FIG. 14. Stela 11, Yaxchilan, second Supplementary Series.

At Copan in 9.13.0–0–0 two Altars, H′ and I′, were erected and a date 9.12.8–3–9, just 144 moons or 12 lunar years in the past, is given with the proper record of 5 moons 22 days required by the uniform system. At Quirigua the earliest date, 9.14.13–4–17, is given correctly according to the uniform series as 3 moons 7 days, but oddly enough it is given on Stela E erected in 9.17.0–0–0 after the uniform system had been abandoned, and the main contemporary date of the monument is accordingly not given in the uniform system. An examination of Table 3 will show what the other cities were doing. It is very evident that they were all impressed with the solemnity of the change, which makes one believe that the change combined religion and astronomy. I think ultimately it had to do with the length of a lunar year, hence secondarily with the length of a tropical year and the celebration of anniversaries, as will be shown in later pages. We will see there that Palenque and Copan differed by 1 moon in the count of lunar years during the 3800 years or so, since their Zero point at 13.0.0–0–0, 4 Ahau 8 Cumhu. The difference was somewhat like that which formerly existed between the Catholic and the Greek Orthodox Church regarding the time of celebrating Easter and Christmas, only it was much more serious. Palenque was a leading city, possibly the most important city of the Maya in its time, but it disappears from history, its inscriptions entirely cease just about the time that the other cities all agree on the uniform system. The question of Glyph C, the moon number, was only one part of the contest; Palenque was on the losing side and ceased to be of importance, or disappeared. Then Copan assumed the leadership and carried it forward with great brilliance. Further information may give us an entirely different picture, but this summary will do for the present.

TABLE 6—*Moon numbers recorded at Piedras Negras and as computed according to the uniform system.*

Number	Monument	Date	Glyph C given	Glyph C expected
		I. Period of Independence		
1	Stela 30	9. 5. 0–0– 0	5	5
2	Stela 25	9. 8.10–6–16	3	5
3	Stela 26	9. 9.15–0– 0	5	5
4	Stela 31	9.10. 5–0– 0	3	1
5	Stela 36	9.10. 6–5– 9	4	5
6	Lintel 2	9.11. 6–2– 1	5	6
7	Stela 35	9.11. 9–8– 6		5
8	Stela 37	9.12. 0–0– 0	5	1
9	Stela 1	9.12. 2–0–16	3	2
10	Stela 39	9.12. 5–0– 0		2
11	Stela 38	9.12.10–0– 0	2	3
		II. Period of Uniformity		
1	Stela 8	9.11.12–7– 2	5	5
2	Stela 3	9.12. 2–0–16	2	2
3	Stela 6	9.12.15–0– 0	4	4
4	Stela 2	9.13. 5–0– 0	6	6
5	Stela 4	9.13.10–0– 0	1	1
6	Stela 1	9.13.15–0– 0	2	2
7	Stela 3	9.14. 0–0– 0	3	3
8	Stela 5	9.14. 5–0– 0	4	4
9	Stela 7	9.14.10–0– 0	5	5
10	Stela 23	9.14.15–0– 0	6	6
11	Stela 11	9.15. 0–0– 0	1	1
12	Stela 9	9.15. 5–0– 0	2	2
13	Stela 10	9.15.10–0– 0	3	3
14	Stela 40	9.15.14–9–13	4	4
15	Altar 2	9.16. 0–0– 0	5	5
16	Stela 16	9.16.15–0– 0	2	2
17	Stela 13	9.17. 0–0– 0		3
18	Stela 14	9.18. 0–3– 1	2	2
		III. Period of Reseparation		
1	Stela 12	9.18. 5–0– 0	6	1

We can probably get a clearer picture of the Period of Independence followed by the Period of Uniformity by listing the moon numbers as shown in inscriptions at Piedras Negras and as computed for the uniform system. In the column "Glyph C Expected" (Table 6) it is of course understood that we do not really expect the numbers given, except during the Period of Uniformity; at all other times before or after this period we do not know exactly what to expect. Many of these dates and readings are from still unpublished work of Dr. Morley, who has given much care and time to making the Supplementary Series complete.

We come now to the second change in moon numbering, when the cities abandoned the uniform system and some confusion arises. The second change began at Copan. For over 60 years every city had been in exact agreement, so far as we know, but in 9.16.5–0–0 (756 A.D.) Copan erected Stela M and recorded 5 moons for a date when every other city would have recorded 6 moons. Five years later Stela N at 9.16.10–0–0 was recorded as 1 moon, because both the new Copan system and the uniform system agreed at this date. A little later in Temple 11, however, the date 9.16.12–5–17 was recorded 6 moons when the uniform system called for 5.

Monument	Date	Given	Uniform System
Stela M	9.16. 5–0– 0	5	6
Stela N	9.16.10–0– 0	1	1
Temple 11	9.16.12–5–17	6	5

I think this represents a change from the regular 12-moon lunar year to an eclipse moon system which starts each half-year near an eclipse conjunction and so must occasionally use a group of 5 moons instead of 6. We have three reasons for considering that this is a change to a lunar eclipse system: First, we know that at a later date the Maya were perfectly familiar with such a system as shown on pages 51 to 58 of the *Dresden Codex* where a Table of Moons grouped in sixes and fives is given, so arranged that each group always starts and ends near an eclipse conjunction. This table covers a period of about 33 years. Second, the date 9.16.5–0–0 on Stela M, the first date of the change is recorded as 5 moons and 5 days (152 or 153 days) from the beginning of the group, which would place the beginning at 9.16.4–10–8, 12 Lamat, or 9.16.4–10–7, 11 Manik. Now the date 9.16.4–10–8, 12 Lamat is prominent on page 52 of the Eclipse Table in the *Dresden Codex*, and the Table itself starts from a Zero date 11 Manik or 12 Lamat. Third, the four dates which we can deduce at Copan as the start of moon groups

9.16. 4–10–8, 12 Lamat
9.16. 9–16–9, 9 Muluc
9.16.11–14–7, 11 Manik
9.16.12– 5–4, 6 Kan

are so situated that it is possible for them all to be the end of moon groups directly adjacent to ecliptic conjunctions. The number of dates is too small to make the proof complete, but it lends a strong probability to the supposition that here in Copan, in 9.16.5–0–0 (756 A.D.) the knowledge of eclipses was sufficient to permit the construction of ecliptic conjunction lunar tables, and to change the record of the moons from a uniform lunar year to a lunar eclipse year arrangement.

It is a step that definitely marks Copan as the intellectual leader of the Maya. In this change of moon numbers there seems to be no underlying religious motive; it is a purely scientific arrangement to begin lunar years at the occurrence of natural phenomena, the ecliptic conjunctions. After 9.16.12–5–17 at Copan there are no more dates given in the Long Count and no more Supplementary Series; indeed there are no more extended computations. The numbers of the moons are no longer related to the Zero point at 13.0.0–0–0, 4 Ahau 8 Cumhu, the length of a moon is known, the length of a tropical year is known, everything is settled and one no longer had occasion to write cumbersome Long Count dates. End of Katun 17 13 Ahau 18 Cumhu gives all the requisite information, and in future computations there is no need to reinvestigate the past; it is sufficient to take the data for 9.16.12–5–17 (763 A.D.) as established and compute from there on. This must have given the literati of Copan a remarkable feeling of self satisfaction. Altar Q and Temple 11 present in enduring stone the sessions of the Copan Academy of Sciences. We can forgive their appearance of smugness, however, because, as we shall see later, they had attained a really wonderful degree of accuracy.

Quirigua was a flourishing and beautiful city not far from Copan, probably more artistic and less intellectual than its great neighbor. The progress at Copan was sure to have an effect on Quirigua, but far from following the lead of Copan, Quirigua turned reactionary and reverted apparently to the ideas that Palenque had maintained and possibly had caused her downfall some 70 years before. So far as Glyph C was concerned, Palenque we think had insisted that the moon number used in the uniform system was too large by 1, so in 9.16.10–0–0 Quirigua recorded Glyph C as 6 while the uniform system called for the next moon number 1. The next few monuments at Quirigua are shown below.

Monument	Date	Recorded Glyph C	Expected Glyph C
Stela F	9.16.10–0–0	6	1
Stela D	9.16.15–0–0	1	2
Stela E	9.17. 0–0–0	2	3
Stela A	9.17. 5–0–0	2	3

We will find that Quirigua was following Palenque in other matters besides moon number. For a few years after this the count is irregular and we can not deduce the method. The last two or three return to the uniform system of moon numbers, but the moon age is given either incorrectly or not at all.

Monument	Date	Recorded Glyph C	Expected Glyph C
Zoomorph B	9.17.10–0–0	1 or 2	4
Zoomorph G	9.17.15–0–0	5	5
Zoomorph O	9.18. 0–0–0		6
Zoomorph P	9.18. 5–0–0	4	1
Stela I	9.18.10–0–0	1 or 2	2
Stela K	9.18.15–0–0	3	3
Struct. 1	9.19. 0–0–0	4	4

In Piedras Negras the last positive date that surely agrees with the uniform series is 9.16.15–0–0, but the first one that surely disagrees is 9.18.5–0–0. At Ixkun there is a disagreement in 9.17.9–0–13, but a later monument in 9.18.0–0–0 still agrees with the uniform series. In Naranjo also there is a first disagreement in 9.17.13–4–3, but the date 9.18.10–0–0 is given correctly according to the uniform series. It is possible that the last dates at Naranjo and at Piedras Negras are intended to follow the lead of Copan in using the Lunar Eclipse Table, but the last ones at Quirigua and at Ixkun do not, and the last ones at Uaxactun and Chichen Itzá (878 A.D.) do not agree with either the uniform series or the lunar eclipse series in numbering Glyph C.

The Long Count dates and Supplementary Series are very rare after 9.18.10–0–0 and we can not follow the matter further to determine surely what each city is doing, and our next information about the moon comes from the *Dresden Codex*, probably after 1100 A.D. This shows a fully developed Lunar Eclipse Table evidently like the one started at Copan in 9.16.5–0–0 (756 A.D.).

Of the two changes discussed in this section, the first at 9.12.15–0–0 having a religious basis was sudden and extensive; the second, started in 9.16.5–0–0, having only a scientific basis was very slow and we do not know its extent.

GLYPHS F, X, B and A

Glyph F has no specific meaning to us. We recognize it in a general way as an introductory character which notifies us that moon age and number discussions follow, and this is true not only in the Supplementary Series but also in the body of the text where it is occasionally found. If Glyph F carries any further information we have not learned it. The meaning conveyed to us by a Supplementary Series is just the same whether F is present or absent.

Glyph X on the contrary seems capable of conveying considerable information of which we know only a part. This glyph is subject to wide variation in character, which led to hope that it might be astronomical, but apparently it is not. Two or three forms of it appear many times, but their appearance is not related to the year or to any other natural phenomenon. The only relation so far discovered lies between its form and the coefficient of Glyph C, the number of the moon, which as we have learned is rather arbitrary. The most common form of Glyph X happens to be the grotesque face shown in figure 10X. This face is the symbol of the God of the North Star, which Dr. Schellhas calls God C. In Table 3 this form of X occurs in inscriptions Nos. 28, 30, 44, 46, 50, 61, 85, 90, 91, 95, 96, 100 and 103. In every one of these cases where Glyph C can be read at all, it is either 1 moon or 2 moons. Another common form of Glyph X contains a pair of crossed legs, as illustrated in figure 9X. This form occurs in Table 3 in inscriptions Nos. 2, 9, 17, 43, 64, 68, 78, 80 and 102; in Table 5 as Nos. 1 and 5, and in the Palenque inscription shown in figure 4A. Every one of these is recorded as 3 moons or 4 moons, with the single exception of No. 64. Why that one is an exception I do not know. The form of X in inscription No. 3 of Table 3 occurs also in No. 98 and in the Temple of the Cross, but always after 2 moons. The form in figure 4B occurs also in No. 12 of the table, but only after 5 moons. The form in figure 12X occurs only after 6C. The upper left part of this glyph, sometimes referred to as the sky sign, occurs on the Leyden Plate and seems also to be the characteristic mark which appears on the face numeral for 12. Glyphs much like it are frequently found in the body of inscriptions, where, I have supposed, they represent some form of a count by lunar years. The form of Glyph X in figure 13X, a tun sign or Zero sign before a face, usually accompanies 4 moons or 5 moons.

We observe the same form of dependence on examining the double dates recording the change from the independent system to the uniform system of writing Glyph C. In figures 9 and 10 a change of 3C to 2C caused a change of Glyph X from crossed legs to North Star God. In figures 13 and 14 a change from 4C to 5C likewise caused a change of Glyph X, although there was no change of date in either case. Likewise in the 14 days between figures 4A and 4B, the moon number changed from 4 to 5, and consequently Glyph X changed from crossed legs to a form characteristic of 5 moons.

While we can trace these relationships between the form of Glyph X and the coefficient of Glyph C, we actually know nothing of the real significance of Glyph X. It may give a name to the moon or to two succeeding moons. Since the form of X is dominated by the moon number, which is arbitrary and unrelated to any natural phenomenon, we may guess that the significance is religious rather than scientific.

Glyph B occurs in only two forms and yields very little information. It consists of an elbow, on the joint of which is a cross. This elbow may represent a house. As a prefix or superfix to this we usually find a curved bar with a couple of dots, the conventional sign in Maya for ending, finishing, termination. Within the "house" is the only real variation; sometimes we find here an animal head, possibly that of an agouti (figs. 9, 13, 14), at times the face of the North Star God; at other times we find simply an ellipse with two circles above it (figs 4A and 4B, and 12). The concept of the moon residing in different houses in the sky on different nights is a rather common one, and the only interpretation that I find for Glyph B is the statement that this moon ends its residence in its last house in either 29 days or 30 days, whichever is shown by Glyph A. That is, B and A together simply state whether the current moon is a 29 or a 30-day one.

Glyph A consists of a moon sign, the same one ordinarily used in Glyph E, and attached to it is a number which is always 9 or 10, and which is placed to the right or below the glyph, instead of to the left or above as numerals usually are. The moon glyph itself represents 20 just as it does in Glyph E; adding the 9 or 10 coefficient gives 29 or 30 days for the duration of the particular moon. Of course, in figure 10 for example, we have no means of proving whether the 29 days refer to the current moon, to the number 2 moon which ended 27 days ago, or the number 4 moon which is to follow, but the probability is, I think, that it gives the expected length of the current moon. Taken with Glyph B then, it reads, "This present moon will leave its final house when 29 days old."

There is a regularity about the 29 and 30 of Glyph A that makes one believe it is a predicted and not an observed figure. Whenever Glyph C has an odd coefficient, 1, 3 or 5, the chances are about three to one that Glyph A will show 30 days; whenever Glyph C has an even coefficient, 2, 4 or 6, the chances are about three to one for a 29-day Glyph A. This goes beyond the bounds of probability for observation, hence I regard Glyph A as a more or less arbitrary prediction of the length of the current moon. The three double dates are also interesting in this connection. At Piedras Negras (figs. 9 and 10), a change of Glyph C from odd to even changed Glyph A from 30 to 29. At Naranjo (figs. 12 and 11) and Yaxchilan (figs. 13 and 14) change of Glyph C from even to odd changed Glyph A from 29 to 30.

Just one other matter and we shall have finished with the Supplementary Series. In figure 13 you will notice two glyphs between Glyph F and Glyph D. The first has a coefficient of 6 and the next looks like some kind of a beetle. Again in figure 14 there is another glyph between F and D, with coefficient of 6. These glyphs are very common at Yaxchilan; they also occur in the two inscriptions from Ixkun, in the one from Holactun, and in one from Copan, and apparently nowhere else. I have not the faintest idea what they signify. The meaning of these inserted Yaxchilan glyphs should be worked out by some one. Other matters that still require investigation are the meaning of the faces in Glyph C; the essential characteristics that identify Glyphs E and D at Yaxchilan and in some cases at Piedras Negras; the definite distinguishing marks for all forms of Glyph G excepting the Zero form used at tun endings; an analysis of all forms of Glyph X to see whether a fuller meaning can be deduced for it; and the meaning if any of the occasional coefficients of Glyph G. A complete Maya Initial Series date is a very cumbersome record, and yet the only astronomical information we have been able to extract from it is the age of the moon. Take a date such as that on Stela J at Copan and Stela 4 at Piedras Negras. This date is 3870 tuns (about 3815 years) after the Zero date at 4 Ahau 8 Cumhu. Given the 3870 tuns we can deduce all the rest, but the Maya tendency was to write it all out in full in pairs of glyph blocks with a huge introducing glyph, which itself might occupy the spaces of four glyph blocks. The full date, reading from left to right and top to bottom, might look something like this:

9 baktuns	13 katuns
10 tuns	0 uinals
0 kins	7 Ahau
Glyph G Glyph F kin-Maize form.	0 Glyph E
Glyph D Glyph C	Glyph X Glyph B North Star God.
Glyph 10 A	3 Cumhu

A free reading would be, "This date is 9.13.10–0–0 (3870 tuns) after our Zero point at 4 Ahau 8 Cumhu; it is the day 7 Ahau and the month position is 3 Cumhu; the Lord of the Night is the kin maize deity; the age of the moon is 20 days from last new moon, and it is 20 days and 1 moon since this lunar half-year began; we are in the period controlled by the God of the North Star; and this present moon will probably end as a 30-day moon." Using face numerals this would require about 24 glyphs. The information it contains which is useful to us will usually be expressed: 9.13.10–0–0, 7 Ahau 3 Cumhu, 1 moon 20 days.

The Piedras Negras monument gives the moon age as 20 days, and that of Copan records it as 18 days.

THE SYNODICAL MONTH

There are only about 150 complete Initial Series dates, such as we have been discussing, still left in condition to be partly or wholly deciphered. Originally there must have been many hundreds, possibly even thousands. Some of them were broken up by the Maya themselves, some were defaced by religious zealots who regarded the monuments as idols, some have been re-used for building stone for nearby villages or even burned to furnish lime for mortar; some were crushed in the accidents of the forest, and time and the weather have made the rest indecipherable.

But the Maya astronomer of about 9.12.0–0–0 (672 A.D.) was surrounded by them. He had but to walk from one stela to another to read observations on the moon extending over hundreds of years. We do not know how far back his observations went, but we have a monument dated 8.16.0–0–0 (357 A.D.), over 300 years before his time. The observations themselves might be a day or so in error, and the moon moved irregularly just as it does today, but a curious mind had plenty of data for approximating the average length of a moon—the time from one new moon till the next. He would soon observe that 2 moons were nearly 59 days, 6 moons 177 days, 17 moons 502 days, 21 moons 620 days, but other observations over the long period available would show him that none of these approximations was exact. So far as we know the Maya did not deal in fractions, so his problem would be to find an integral number of moons which should exactly equal an integral number of days, then he could use this result for the long computations extending far into the past and future.

We do not know the various early approximations that satisfied the Maya, but there is a possible one on what Maudslay calls the inscribed stairway of Palace House C at Palenque. On a shield is written the number 11–11–13, 4193 days, which is a very good approximation for 142 moons. It gives a figure for the average moon of 29.528 compared with our modern figure of 29.530 days—an error of less than one-four-hundredth of a day. This is not at all bad for 9.8.9–13–0 (603 A.D.), but we can not be sure that this is the meaning of this number, so we pass at once to a case that is certain and also a very much better example.

There are four dates at Palenque on monuments erected within a few years of 9.12.0–0–0, all of which give moon positions. One is contemporary and gives the observed position, and the other three are computed dates thousands of years in the past. These are

Stela 1	9.12. 6–5–8	(678 A.D.)	5 moons 19 days
Temple of the Cross	12.19.13–4–0	(3120 B.C.)	2 moons 5 days
Temple of the Sun	1.18. 5–3–6	(2359 B.C.)	4 moons 26 days
Temple of the Foliated Cross	1.18. 5–4–0	(2359 B.C.)	5 moons 10 days

There is sufficient data here to deduce the factor used at Palenque in computation; it is 81 moons = 6–11–12 = 2392 days. This factor will connect any one of the four dates with any other, exactly to within a fraction of one day. Here is no leeway of 2 or 3 days in either direction, such as we expect in observation, but rather the machine-like precision of computation. The moon numbers also occur exactly as we should expect if they were considered as arranged in lunar half-years of 6 months. The difference between the first and fourth dates using the factor 6–11–12 = 81 moons will be found to be 37560 moons and 9 days within a fraction of a day. 37560 being divisible by 6 without remainder, the moon numbers are identical and if the first date is 5 moons 19 days, the fourth should be 5 moons 10 days as recorded. Of course for remainders less than 81 moons, the nearest whole number of days must be used. For example, 5 moons are between 147 and 148 days, and we do not know which the Maya would normally use, but this fraction of a day is the only doubtful part of the computation. In fact such accuracy differentiates computation from observation, and we realize at once the impossibility of considering the moon ages recorded on Maya contemporary monuments as the product of any formal calendar or other method of computation. Their very frequent variations of a couple of days actually demonstrate their observational character.

By the use of the factor 6–11–12 = 81 moons we can determine what the Palenque people supposed was the moon position in dates of their distant past and what they expected in the future. Their Zero point, 13.0.0–0–0, 4 Ahau 8 Cumhu was to them 6C 4E—that is 24 days after the sixth moon. Of course it was not in reality, because their yardstick was a little too long and they were in error about 12 or 13 days in the 3800-year computation back to 4 Ahau 8 Cumhu, but still we must consider the result remarkably good for the time and the degree of civilization. According to their computation, 12.19.13–4–0, 8 Ahau 18 Tzec in their distant past, and 1.0.0.0–0–8, 10 Ahau 8 Yaxkin in their more distant future, were just 8134 lunar years apart. Now 6–11–12 = 2392 days = 81 moons gives a length of 29.53086 days per moon as compared with our modern computation of 29.53059. This factor of moon length was a part of the dispute which led to the adoption of the uniform moon number period in 9.12.15–0–0 and to the disappearance of Palenque. At that time a change was made to another factor which was not quite so accurate, but the original one recurs several hundred years later in the *Dresden Codex* in the form of 1.13–4–0 = 405 moons. Prior to 9.12.15–0–0 we do not surely know the factor used in moon computations in any other city than Palenque.

In 9.13.0–0–0, two altars which record some interesting computations were erected at Copan, giving the first date we have from that city in the Period of Uniformity. We may summarize the numerical part as follows:

Altar H′		
9.12. 8– 3– 9	5 moons 22 days	(680 A.D.)
2.13– 4– 4	(649 moons within a day)	
9. 9.14–17– 5	(4 moons 22 days)	(628 A.D.)
9.12. 8– 3– 9	5 moons 22 days	(680 A.D.)
1–14–11	(22 moons within a day)	
9.12.10– 0– 0	(3 moons 22 days)	(682 A.D.)
Altar I′		
9.12. 8– 3– 9	5 moons 22 days	(680 A.D.)
11–14–11	(144 moons within a day)	
9.13. 0– 0– 0	(5 moons 22 days)	(692 A.D.)
9.12.10– 0– 0	3 moons 22 days	(680 A.D.)
2.10.16– 3– 0	(12388 moons)	
7. 1.13–15– 0	(5 moons 22 days)	(320 B. C.)

The parenthetical parts in this summary represent my comments. Since this is the beginning of the uniform series at Copan and since the moon number of the first date is recorded 5 as the series requires, I have made all moon numbers agree with the series; only the first one of course is actually given on this monument.

Considering now the first pair of dates, the 9.12.8–3–9 is recorded here as 22 days and the 9.9.14–17–5 is again recorded as Dates 4 and 5 on the Hieroglyphic Stairway. The moon age given there is not fully legible but is either 22 or 23 days. The second pair repeats the 9.12.8–3–9 which is 22 days and gives 9.12.10–0–0 which is recorded on Stela 6 at Copan as 22 days. The third pair repeats the 9.12.8–3–9, a 22-day date, and adds 9.13.0–0–0 of which the age is not definitely given anywhere at Copan, but by calculation it must be 21 or 22 days. Now these three pairs of dates all record moon observations, not calculations, and evidently the dates are selected with an eye toward the 22-day moon age, that is, the computation is by integral numbers of moons; so when we come to the fourth pair where one of the dates obviously must have been computed, we are justified in assuming that the computer is expecting to reach a moon age of 22 days by deducting an integral number of moons. We are dealing in this pair with a distance of more than a thousand years, which gives opportunity to determine the factor used with considerable accuracy. It proves to be 149 moons = 12–4–0 = 4400 days. When we go a step farther and find that the last date given, 7.1.13–15–0, by the use of this same factor is also exactly an integral number of moons (34547) from the Zero date 4 Ahau 8 Cumhu, and of course that 9.12.10–0–0 is also (34547 × 12388 = 46935 moons), we feel sure that our decipherment of the record here is correct.

At Copan then 149 moons = 12–4–0 was the factor for moon computation and an exceedingly convenient one too, since if taken 9 times it reduces to the form 1341 moons = 5.10–0–0 and 2682 moons = 11.0–0–0. Since 2682 is divisible by 6 without remainder, it follows that according to this computation dates just 11 katuns apart should have the same moon number and moon age. So the date 9.7.0–0–0 (17 × 11 katuns) should be the same as 4 Ahau 8 Cumhu, and 9.12.10–0–0 (5.10–0–0 later) should have the same moon age as 4 Ahau 8 Cumhu but should differ in moon number by 3 (1341 divided by 6 leaves 3 remainder). So if 9.12.10–0–0 was 3 moons 22 days, they must have considered 13.0.0–0–0, 4 Ahau 8 Cumhu, to be 6 moons 22 days, instead of 6 moons 24 days as it was computed at Palenque. So far as we know, every Maya city during the Period of Uniformity from 9.12.15–0–0 onward agreed with this computation and with the formula 149 moons = 12–4–0, because every uniform date can be reproduced from 4 Ahau 8 Cumhu 6 moons and 22 days by this formula, exactly as to moon number and—within the 2 or 3 day error of observation and moon variation—as to moon age. At Copan, then, and at all other cities using the uniform numbering for C they would compute

9.12. 8– 3– 9	5 moons	22 days
1–14–11	22 moons	
9.12.10– 0– 0	3 moons +	22 days

At Palenque it would have been

9.12. 6– 5– 8	5 moons	19 days
3–12–12	45 moons +	3 days
9.12.10– 0– 0	2 moons +	22 days

At Palenque 9.12.10–0–0 was 2 moons plus the moon age; at all cities using uniform numbering it was 3 moons plus moon age. This difference came because they could not agree on which moon factor to use and consequently on the length of a moon. At Palenque the factor was 81 moons = 6–11–12, which we can interpret as 1 moon = 29.53086 days. At Copan and the other cities of the Period of Uniformity it was 149 moons = 12–4–0, which we may write 1 moon = 29.53020 days. The actual length is 29.53059. Both figures are surprisingly good but neither is right, and the successful one in the contest in 9.12.15–0–0 was not quite so good as the rejected Palenque one. Palenque made an error of 12 or 13 days in computing back the 3800 years to 4 Ahau 8 Cumhu, because its yardstick was too long, but Copan and the other cities made a similar error of 18 days in the other direction, because their measure was too short. This made the two computations about one moon and a couple of days apart, say 31 days. From 9.12.10–0–0, 2 moons 22 days, Palenque could compute back 46934 moons to reach 4 Ahau 8 Cumhu at 6 moons 24 days, while Copan, starting at 9.12.10–0–0, 3 moons 22 days, deducted 46935 moons to reach 4 Ahau 8 Cumhu at 6 moons 22 days.

We do not know just why this difference of a moon and a couple of days was so terribly important, but it and the matter discussed later (pages 70 and 75) seems to have furnished a large amount of literature, at least at Palenque and Copan, during the 40 years from about 9.11.0–0–0 to 9.13.-0–0–0, and without being able to read all of it one gets the feeling that the writing is decidedly polemical.

There is a little evidence from another city, Macanxoc in Yucatan, during the Period of Independence. On Stela 1 the date 9.11.0–5–9 is written 1 moon and a number of days which is now obliterated but must have been near 22 days and was probably observed as 23 days. From this observation they compute the moon position for 4 Ahau 8 Cumhu 3765 years before, and record it on the same monument as 1 moon 23 days. They apparently compute that just 3881 lunar years had elapsed, and if so they were using the Palenque formula, 81 moons = 6–11–12, but they give 4 Ahau Cumhu a different moon number.

We come now to the Period of Uniformity after 9.12.15–0–0, during which no one seems to question either the Copan formula 12–4–0 or the 6 moon 22-day record for 4 Ahau 8 Cumhu. Copan abandoned the uniform system in 9.16.5–0–0 (756 A.D.) and we have nothing to show whether they changed their opinion regarding the moon formula either then or later. We think their change of moon numbers was to the lunar eclipse system, and when we find that system later in the *Dresden Codex* (probably after 1100 A.D.) it is accompanied by the formula 405 moons = 1.13–4–0, which it will be seen is simply the Palenque formula multiplied by 5.

Quirigua abandoned the uniform system in 9.16.10–0–0, and the moon numbers for 15 or 20 years afterward seem to indicate a reversion to the

Palenque formula; these numbers are all just 1 less than we expect for the uniform system. On Stela C, 9.17.5–0–0 (771 A.D.), there is a computation which includes 13.0.0–0–0, 4 Ahau 8 Cumhu, apparently given as 3 moons and 26 days, and 9.1.0–0–0 and 9.17.5–0–0. No Supplementary Series are given for the two latter dates, but the moon age must have been 26 to 28 days in each case. On another monument, Stela A, the latter date is given 2 moons and 26, 27 or 28 days. I can not deduce any conclusion from the computation. By the Palenque formula if 13.0.0–0–0 is 3 moons 26 days, then 9.1.0–0–0 would be 3 moons 28 days, and 9.17.5–0–0 would be 5 moons and 26 or 27 days. But Stela A records 9.17.5–0–0 as 2 moons 26 days. It seems probable, therefore, that Quirigua reverted to the Palenque formula at 9.16.10–0–0 and about 20 years later probably came back to the Copan or uniform formula, but the moon information given on late Quirigua monuments is very much confused.

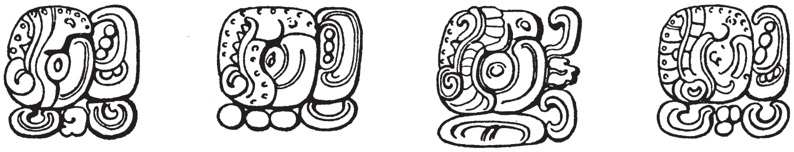

FIG. 15. Glyphs for same moon age or new moon day.

To summarize then, we find that for several years before 9.13.0–0–0 (692 A.D.) Palenque computed 81 moons = 6–11–12, or 1 moon = 29.53086 days, and 4 Ahau 8 Cumhu was computed as 6 moons 24 days. So far as we can see, this view was dominant in Maya territory. Some time before 9.13.0–0–0 some other city, possibly Copan, had developed another computation making 149 moons = 12–4–0, or 1 moon equal to 29.53020 days, and 4 Ahau 8 Cumhu was computed as 6 moons 22 days. About 9.13.0–0–0 this view became prevalent throughout Maya territory and Palenque disappeared. The next change 70 to 100 years later, when the different cities abandoned the uniform system, is not clear. Probably many cities reverted to the Palenque formula. In any case a few hundred years later the *Dresden Codex* shows no evidence of any moon computation except the 81 moons = 6–11–12, in the form 405 moons = 1.13–4–0. If they ever reached a more accurate knowledge we do not know, nor do we know just why Macanxoc once regarded 4 Ahau 8 Cumhu as 1 moon 23 days, or why Quirigua once wrote it 3 moons 26 days.

Much of the Maya computation recorded in inscriptions is by moons. If you are alert for it, you will be surprised to find how many Secondary Series connect dates having the same moon age, or connect a date with another one which is a new moon day. Glyphs closely resembling some forms of Glyph D are used in the texts to indicate this fact, and are quite common, but unfortunately I can not yet distinguish clearly between the form for "same moon age" and that for "new moon day," and so am obliged to interpret them from the context and the result (see fig. 15).

THE TROPICAL YEAR

AT COPAN

We have seen in the previous pages that the priests at Palenque and Copan could compute the lunar year with a total error of only 12 and 18 days respectively over a period of about 3800 years. Of course if we compare this with Oppolzer's *Canon der Finsternisse*, in which we expect almost deadly accuracy over about the same period, the result does not seem so startling. But compared with other people of their own time or of preceding times it is remarkable. The two cities differed from each other in the length of an average synodical month by less than a minute, and the less accurate of the two figures was within 34 seconds of our present-day computation. Probably few other people had ever been interested enough to bother with such minute accuracy.

What about their knowledge of the length of the tropical year, or solar year? We should naturally expect here also something like the same degree of accuracy, and possibly also two different schools of thought, one at Palenque and the other at Copan. In deducing the lunar year, our knowledge of the Supplementary Series enabled us to select those inscriptions which would yield the information needed. We have nothing similar to guide us in determining which inscriptions deal with the solar year. There are probably over 2000 separate dates recorded on Maya monuments which would be an average of 5 or 6 or 7 for each day in the year. So if one starts with any assumed correlation, it is fairly easy to find Maya dates which coincide with his ideas of solstices and equinoxes. It would be just as easy, allowing a day or two leeway, to find 20 or 25 dates proving that the Maya celebrated Washington's Birthday or Yom Kippur. That does not look like a feasible method for producing convincing evidence. We have no real knowledge that the Maya were interested in equinoxes and solstices any more than they were in the Fourth of July. Possibly their check on the passing of a year was the day when the sun exactly overhead cast no shadow at noon; possibly it was the heliacal rising of some star. Inquiries made of people who have been long in the tropics, however, do not indicate that modern Indians are especially interested in equinoxes, solstices, vertical sun or heliacal rising of stars. It seemed very difficult to find a sure starting point for our calculations. I even tried to imagine how I should view the question of a seasonal year if I were a Maya priest. You remember Kipling's captain who always found the codfish by introspecting to determine where he would be if he were a codfish, but even that method did not seem entirely satisfactory. The one helpful thought that came from this process was that the Maya would probably be interested in the position of katun endings in the tropical year, as compared with their respective positions in the tropical year at 4 Ahau 8 Cumhu, and this idea was only partly correct.

The solution finally came from Stela A at Copan. This stela has a lengthy inscription but it contains only three dates; one at the beginning 9.14.19–8–0, 12 Ahau 18 Cumhu; the most important one, 9.15.0–0–0, 4 Ahau 13 Yax, the end of the 20 tuns that were comprised in Katun 15; and an intermediate one, 9.14.19–5–0, 4 Ahau 18 Muan. Now this intermediate number is of peculiar interest. Stela A was erected as a memorial to Katun 15 just closing, and 9.14.19–5–0 is 19 years from Katun 14 as near as may be approximated in whole numbers. Nineteen years is the Metonic cycle, the oldest real cycle we know connecting the moon and the solar year and known to Babylonia and western Asia for centuries before Meton gave his name to it in 433 B.C. Nineteen years very nearly equals 235 moons, so if in 1908 a new moon occurs on January 3, we expect to find one on January 3, 1927, January 3, 1946, etc., and all the new moons in 1946 will fall on just about the same days of the month that they did in 1908 and 1927. We immediately wonder whether the Maya had recognized this 19-year cycle, and we remember that the 19-year distance 19-5-0 is not uncommon between Maya dates, and that the 19-year cycle equal to 235 moons occurs in the *Dresden Codex* Lunar Eclipse Table, but is not especially emphasized there. Further, in examining the inscription on Stela A we find several glyphs in the body of the text which remind us forcibly of Supplementary Series glyphs (fig. 16). Figure 16a is the Glyph F; fig. 16c is much like 9 Glyph E; and fig. 16d is a form sometimes used for Glyph A. Figure 16b is a combination of day Imix and day Ahau, beginning and end, with a superfix of day Lamat and day Ben, a type of glyph which usually seems to refer to a year; and finally fig. 16e is the glyph for the sun and fig. 16f the glyph for the moon. We probably are not forcing the interpretation if we assume that we have here a definite statement that at 9.14.19–5–0, 19 years after Katun 15 began, the sun and the moon are in the same relation to each other that they were at the end of Katun 14, *i.e.*, that 235 moons are exactly equal to 19 years. The 19–5–0 is of course only the closest approximation and might sometimes be given as 19–4–19; the real equation is between the moons and the years.

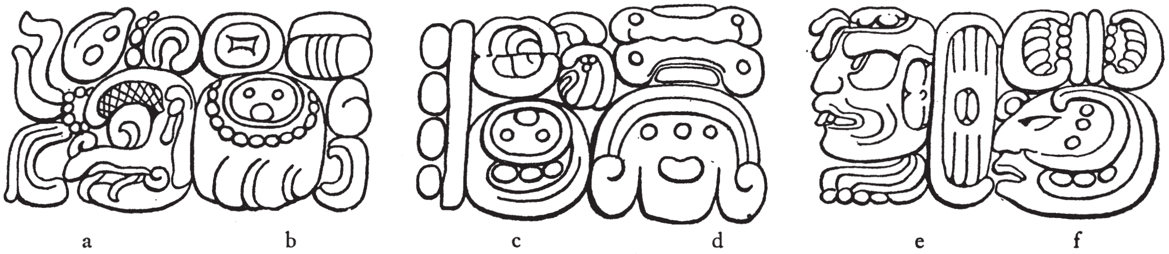

FIG. 16. Glyphs from Stela A, Copan.

The suggestion is at least plausible enough to warrant a trial; perhaps it will give a meaning to the other two dates. Now Katun 15 (731 A.D.) is about 3844 years from 13.0.0–0–0, 4 Ahau 8 Cumhu (3113 B.C.) and this

distance is of course quite independent of any assumed correlation; but 3844 years is 202 times 19 years plus 6 years more. Further 3838 years = 202 × 235 moons = 47470 moons. At Copan the formula was 149 moons = 12–4–0, so 3838 years = 47470 moons = 9.14.13–15–19
6 years more = 6– 1–11

3844 years = 9.14.19–17–10

Now the seasonal year advances through the Maya vague year at the rate of about 1 day in 4 years; its real circuit of the 365 days takes 1507 years. During the 3844 years from 4 Ahau 8 Cumhu it has completed 2 circuits, 730 days, and is over halfway through the third circuit. The anniversary of the original 8 Cumhu after these 3844 years, according to Copan computation, is now at 9.14.19–17–10, 7 Oc 3 Yax, just 200 days after 8 Cumhu. So the real year has advanced a total of 930 days through the vague year. This 200 days is the figure the computer wanted to know, and we can now see the form in which his question has been propounded. "Katun 15 ends at 13 Yax. Of what month position in the calendar in the time of 4 Ahau 8 Cumhu will this 13 Yax be the anniversary?" He deducts 200 days from 13 Yax and gets the result 18 Cumhu. 9.15.0–0–0, 4 Ahau 13 Yax is the same season of the year, the anniversary of 13.0.0–0–10, 1 Oc 18 Cumhu. So in the inscription the first date 9.14.19–8–0, 12 Ahau 18 Cumhu, gives what might be called the vague year anniversary of the first 18 Cumhu, whose real anniversary is given by the last and important date 9.15.0–0–0, 4 Ahau 13 Yax, while the intermediate date 9.14.19–5–0, 4 Ahau 18 Muan, is used to show the formula 235 moons = 19 years. This all sounds plausible, so suppose we try it on some other monuments.

During Katun 16 there are few dated monuments at Copan; the computations may be on the Hieroglyphic Stairway, though I have not found them. Most of this stairway unfortunately was destroyed. During Katun 17, however, we have many records and many repetitions of one date. Katun 17 was to end on 18 Cumhu. The priests selected a time 3876 years after 4 Ahau 8 Cumhu to make the computation, this being exactly 204 × 19 years, or 47940 moons. According to Copan 47940 moons = 9.16.12–7–18. So 9.16.12–7–18, 8 Eznab 11 Yax was the anniversary of 4 Ahau 8 Cumhu and the year had traveled twice through the vague year plus the distance from 8 Cumhu to 11 Yax = 208 days. So in this thirteenth year of Katun 17, 18 Cumhu, which was to end Katun 17, was the anniversary of a day 10 Mol in the calendar 3876 years before; 18 Cumhu − 208 days = 10 Mol. The vague year anniversary of this same date was 9.16.12–5–17, 6 Caban 10 Mol. From the middle of Katun 17 to the latest monuments this date, repeated over and over, is the most prominent one at Copan. Apparently the astronomical congresses had done their work so thoroughly that on later monuments it was only necessary to take the established data for 6 Caban 10 Mol and make a short computation to get the necessary correction.

While we may visualize these dates as anniversaries, to the Maya mind they were probably simply a basis for numbers, a method of recording how many days the tropical year had advanced through the vague year at any given time on its third circuit of the vague year. At 9.14.19–8–0 it had advanced from 18 Cumhu 200 days to 13 Yax (selected because it ended Katun 15). At 9.16.12–5–17 it had advanced from 10 Mol 208 days to 18 Cumhu (selected because it ended Katun 17).

Sometimes the order is reversed. Instead of the question, what day at the Zero point was where 18 Cumhu is now, the answer being 10 Mol in 9.16.12–5–17, the question may be, what day now is where 18 Cumhu was at the Zero point. In 9.16.12–5–17 the answer would be 208 days after 18 Cumhu = 1 Zac. We find this question 6 years later on Altar Z Copan when the distance has increased to 209 days and the result is 18 Cumhu plus 209 days = 2 Zac, the date being 9.16.18–9–19, 12 Cauac 2 Zac.

Katun 18 ended 9.18.0–0–0, 11 Ahau 18 Mac, so on Altar R we have 9.18.2–8–0, 7 Ahau 3 Zip (3906 years from the 4 Ahau 8 Cumhu period), and the computation is 3 Zip plus 215 days = 18 Mac. In the same year there is a similar computation on Altar U, only here neither date is a katun ending. The dates are 9.18.2–5–17, 3 Caban 0 Pop, and a date near it 9 Ik 10 Mol, the computation being 10 Mol plus 215 days = 0 Pop, the same as on Altar R. These dates are probably selected to indicate that the original position of 10 Mol, which by 9.16.12–5–17 had advanced 208 days to 18 Cumhu, has now in 9.18.2–5–17, some 29 years later, advanced 7 days more to 0 Pop.

On Altar Q there is only one date definitely fixed, 9.17.5–0–0, but there are three Calendar Round dates, 5 Cuban 15 Yaxkin, 8 Ahau 18 Yaxkin, and 5 Ben 11 Muan. The intention here is not clear; if they are intended for computations, the results would be 11 Muan plus 209 days = 15 Yaxkin, which would fit a date just before 9.17.0–0–0, about the same as Altar Z; and 11 Muan plus 212 days = 18 Yaxkin, which would be true about 12 years later, say approximately at 9.17.10–0–0. More probably the 15 Yaxkin and 18 Yaxkin are meant to be related with 8 Cumhu. Position 15 Yaxkin at Baktun 13 had the same position in the year that 8 Cumhu 213 days later has now. This would be true for about 9.17.15–0–0 5 Ahau 3 Muan. Again 18 Yaxkin at Baktun 13 had the position in the year now held by 8 Cumhu 210 days later. This would be true for about 9.17.0–0–0, 13 Ahau 18 Muan, a date given on the altar. This altar, however, is too indefinite to use as a part of the proof.

After Katun 15, possibly after Katun 13, we have the following clear statements of days progress made by the year through the vague year since 4 Ahau 8 Cumhu. We have added the 2 full circuits (730 days) already completed during the first 3000 or more years.

Altar Q would probably come between Altars Z and U with 940 and 943 days, respectively, but we do not know its exact date. The Maya days of progress through the vague year correspond, of course, exactly with the leap year days we add to our calendar to prevent such progress. It will be seen that the Maya computation was far better than that of the Julian calendar, which was used in our country until after 1700 A.D., dnd in fact is almost identical with our present Gregorian calendar.

No.	Monument	Date	Years	Days Maya	Days Gregorian	Days Julian
1	Stela A	9.14.19–8–0	3844	930	932	961
2	Temple 11 and others	9.16.12–5–17	3876	938	940	969
3	Altar Z	9.16.18–9–19	3882	939	941	970
4	Altar U	9.18. 2–5–17	3906	945	946	976
5	Altar R	9.18. 2–8–0	3906	945	946	976

The period from Katun 15 to Katun 18 under discussion here is the most advanced period of the most intellectual Maya city. It might be well to compare the accuracy as to the length of the tropical year achieved by these several systems.

Present year length	365.2422 days
Length 600 A. D.	365.2423
Julian year	365.2500
Gregorian year	365.2425
Copan Maya year	365.2420

The Maya year is a little too short, the Gregorian a little too long, and both have about the same degree of accuracy, but the Maya figure was reached a full 1000 years at least before the Gregorian one. Of course we are compelled to admit that this extreme accuracy was partly due to the small error in the Copan moon formula; as 19 years do not exactly equal 235 moons, being about 0.087 days short of 235 moons, and the Copan formula 149 moons = 4400 days was also too short by about 0.091 days per 235 moons. Hence a combination of the two formulæ practically cancelled the error in each and gave an exceedingly exact figure for the tropical year. If in Copan a correct figure had been used for the average synodical month then the figure for the tropical year length would have been far less accurate than our Gregorian calendar gives, and if they had used the Palenque moon formula then their year would have been as much in error as the year of the Julian calendar was.

Our knowledge, then, of what Copan believed regarding the length of the tropical year is fairly satisfactory after Katun 15. Going backward from Stela A, however, the situation is not so clear. Did the 19-year formula originate with Stela A, or had it been used years before? We do not surely know. We have already mentioned two monuments, Altars H′ and I′ erected at Katun 13 (see pages 66, 67). The 9.12.8–3–9 date there, 17 Mol, may have been used to show the length of the tropical year just as we saw 6 Caban 10 Mol and 12 Ahau 18 Cumhu used on later dates. But unfortunately there are too many dates on these two monuments. We do not know whether they are intending to compare 17 Mol with 18 Kayab, 8 Cumhu, 13 Cumhu, or the 8 Uo which ends Katun 13, all of which would be usual things for them to do. We could prove almost anything desired by citing the proper one of these dates, but it would be all guess work.

Altars H′ and I′ are the first monuments on which Copan used the uniform series of moon number. Consequently before that date we know neither their moon formula nor their year formula, positively. We can only indicate some places where there probably is information if we could read it clearly. For example, Stela I has date 9.12.3–14–0, 5 Ahau 8 Uo. This is exactly 16 vague years before Katun 13 which ends in 8 Ahau 8 Uo. On this monument we have a date which apparently reads 10 Ahau 13 Chen. Stela 19 gives a date 9.10.19–15–0, 4 Ahau 8 Chen which we know is the 3765th anniversary of 4 Ahau 8 Cumhu. But did the Maya know it? That is the point that is not clear to us.

Stela 10, 9.10.19–13–0, 3 Ahau 8 Yaxkin, may intend to relate 8 Yaxkin to 8 Cumhu. Stela 23 certainly shows a relation between 1 Yaxkin and 8 Cumhu, and Stela 2, whose date is probably 9.10.0–10–0, shows a relation between its date and 8 Cumhu, but we are not too sure of its date. It is probable from other evidence at Palenque that Stelas 2, 19, 1, and Altar H′ at Copan all show the progress from 8 Cumhu as 910, 915, 920 and 921 days respectively, 8 Cumhu-3 Chen, 8 Cumhu-8 Chen, 8 Cumhu-13 Chen, and 17 Mol-8 Cumhu.

The above summary is simply given to indicate that we can draw no clear picture of the Copan belief before Katun 15 such as we have after Katun 15. There are plenty of computations during Katuns 11, 12 and 13 that certainly have to do with the subject of length of lunar year and length of tropical year. There may even have been two or three different factions at Copan with different ideas, and it may be that further study of some of these inscriptions may lead to more definite readings, but at present we must not project the accurate knowledge of Katun 15 and later back into the period of Katuns 11, 12 and 13. If we do we shall only confuse ourselves in looking for relationships where none was intended to exist. After we have discussed the situation at Palenque we will revert to this early Copan period.

AT PALENQUE

In the preceding pages we were able to show with a fair degree of certainty how the tropical year was computed after Katun 14 at Copan and what the results were. Their habit was to select the current or preceding katun ending for one date and match it with some position of the vague year, such that one of these two dates now was the real anniversary of the other at Baktun 13. We may call this second date the determinant for the katun. Their formula was 19 years = 235 moons, the moons being computed from 149 moons = 12–4–0 = 4400 days. Their results were just as accurate as we achieve in our Gregorian calendar.

Before Katun 14 at Copan, what little evidence there is indicates a different habit, in that instead of selecting a determinant for the katun they selected one for 8 Cumhu, such that the determinant now was the anniversary of 8 Cumhu at Baktun 13, or 8 Cumhu now was the anniversary of the determinant at Baktun 13. Their formula for this period is unknown to us, but their results were nearly as good as those obtained after Katun 14. Their year seems slightly longer than the Gregorian, instead of slightly shorter as it was from Stela A onward.

In making a similar study of the Palenque inscriptions, great care must be used. There are so many dates in each inscription that one is quite likely somewhere to find the relationship he is looking for, whether it was the one intended by the composer or not. After very considerable study and with a good deal of hesitation, I suggest the following as the probable situation at Palenque:

First, they had both of the practices we found at Copan—selecting determinants not only for the katuns but also for 8 Cumhu.

Second, I do not know their formula. It was not the 19-year moon formula of Copan, either with the Copan moon or with the Palenque moon, since the former would have given results identical with Copan and the latter would have given the Julian year, neither of which is found. There are indications twice that they used something close to the equation 29 Calendar Rounds progresses 365 days, or one round of the vague calendar, and several times in their computation they apparently make use of 73 tuns, 3.13–0–0 = 72 vague years, and various multiples of this, but just how it was used is not apparent. My belief is that their later formula was: "to 7.6–0–0 add 35 days to give 144 years = 7.6–1–15," but I can not prove it. This would add 700 days for 7.6.0–0–0. From Baktun 2, 3 Uayeb to Katun 6, 3 Uayeb would represent an advance of 700 days or 30 days less than 2 rounds.

Third, their results were good, not so good as late Copan, but fairly comparable with contemporary Copan. Their earlier determinations seem a little shorter than the Gregorian year and their latest ones a little longer.

Now let us examine the evidence. On the tablet in the Temple of the Cross at Palenque the initial date is before Baktun 13 at 12.19.13.–4–0, 8 Ahau 18 Tzec, and the emphasized date is 9.10.10–0–0, 13 Ahau 18 Kankin. These dates are just 3762 years apart by Copan calculation, and if it were at Copan we could see why the computation was taken back nearly 7 years before Baktun 13 in order to have a distance number that was divisible by 19. But it is not at Copan and I do not know just why the 9.10.16–14–0 distance was computed. In any case the intention seems to be clear that 18 Tzec some 7 years before Baktun 13 is the determinant for 18 Kankin end of the tenth tun after Katun 10. Being the first one we have observed at Palenque, we should probably suspend judgment on whether the intent is 18 Tzec to 18 Kankin 910 days, or 18 Kankin to 18 Tzec 915 days. Later we shall see that it is computed from 7.6–0–0 + 35 days = 144 years.

This gives 915 days for 3762 years. The Gregorian Calendar would give about 912. Now 18 Kankin is also the determinant of Baktun 7, both of which are featured prominently on the tablet in the Temple of the Sun and 7.0.0–0–0, 10 Ahau 18 Zac, 18 Kankin at Baktun 13 = 18 Zac now, 670 days advance. Then from Baktun 7 to 9.10.10–0–0, 13 Ahau 18 Kankin we have, 18 Zac at Baktun 7 = 18 Tzec now 245 days, making the total from Baktun 13 equal to 915 days. So you have the combination which includes 18 Zac, 18 Kankin, 18 Tzec, 7.0.0–0–0, 13.0.0–0–0, and 9.10.10–0–0. I really believe this is just the sort of figure juggling that they revelled in. Only one thing would seem to be lacking to make the combination complete, and that is to bring in Katun 5, 9.5.0–0–0, 11 Ahau 18 Tzec, and sure enough this is found on the same tablet. The central shield which has Baktun 7 just at its left, has Katun 5 in the short inscription just above it seemingly associated with 8 Oc 3 Kayab, and here I get lost. But suppose we proceed: 13 Mac is the determinant for Katun 5; 18 Tzec at Baktun 13, 13 Mac now 885 days advance. But in the year of the initial date of this inscription, 1.18.5–3–6 here and 1.18.5–4–0, 1 Ahau 13 Mac in the Temple of the Foliated Cross, 18 Kankin occupies the same place in the year that 13 Mac does at Katun 5, and 8 Cumhu has the same place that 8 Oc 3 Kayab has at Katun 5. Now if your mind is not entirely confused we will proceed to the other determinants.

In the Temple of the Cross Baktun 9 is emphasized. In leading up to its determinant we find first two determinants for 8 Cumhu, 8.19.6–8–8, 11 Lamat 6 Xul, which is the 3535th anniversary of Baktun 13, and 8.19.19–11–17, 2 Caban 10 Xul, 13 years later, the 3548th anniversary. These indicate 8 Cumhu–6 Xul, 853 days for 3535 years, and 8 Cumhu–10 Xul, 857 days for 3548 years. The 2 Caban 10 Xul is almost at Baktun 9 so the determinant for Baktun 9, 9.0.0–0–0, 8 Ahau 13 Ceh, may be found by subtracting 857 days which gives 8.19.17–11–3, 9 Akbal 6 Xul, the determinant of Baktun 9. I had often wondered what this 9 Akbal 6 Xul could be. It is repeated over and over, but the only place where it occurs in the inscriptions with a Long Count date that can be determined is at 9.10.8–9–3, 9 Akbal 6 Xul, which apparently is mentioned only as the Fourth Calendar Round recurrence of its real position. It is only a coincidence that the anniversary of both Baktun 13 at 8.19.6–8–8 and the determinant of Baktun 9 at 8.19.17–11–3 occur on 6 Xul.

In the inscription we are discussing, the human figure on the left is standing on Baktun 9, while immediately over his head is recorded the determinant 9 Akbal 6 Xul. At Baktun 9 then the Palenque determination showed progress of the tropical year through the vague year as 6 Xul–13 Ceh = 127 days, plus 2 rounds of the calendar, 730 days, total 857 days. We do not know when this computation was really made, as these inscriptions are probably in the main a summary of older records.

Again 9.12.18–5–16, 2 Cib 14 Mol is a determinant for 8 Cumhu; in the tablet in the Temple of the Sun they are directly connected by a Long

Count number. Frequently the next day, 3 Caban 15 Mol, is also quoted as though there were doubt as to which is correct, and 14 Mol at Baktun 13 is 8 Cumhu now, 924 days advance. I think there is also a statement in the Temple of the Foliated Cross that 2 Cib 14 Mol at Baktun 2 is the same as now, or possibly, it is still more complicated. The date 14 Mol was the determinant for Katun 6, but I am not sure whether it was 9.5.0–2–16, 2 Cib 14 Mol, or 9.5.12–5–16, 1 Cib 14 Mol.; 3 Uayeb–14 Mol, 886 days; Gregorian for the earlier date would be 885 and for the latter 888. Both Baktun 2 and Katun 6 end on 3 Uayeb. The date 14 Mol could well have been the determinant for Katun 6 at 9.5.0–2–16, or for 8 Cumhu 3 Calendar Rounds later *i.e.*, at the Long Count date usually given it. It is difficult to say surely which was intended by the Maya, or whether both were. The date 14 Mol could also have been the determinant for Katun 3, 9.3.0–0–0, 2 Ahau 18 Muan, at 9.2.7–7–16, 2 Cib 14 Mol *i.e.*, 14 Mol at Baktun 13 = 18 Muan now 3595 years, 874 days. The continual recurrence of all sorts of cycles in the calendar makes such things possible, and a date like 2 Cib 14 Mol—which could have been the determinant of Katun 3, then 1 Calendar Round later the determinant of Katun 6, then 3 Calendar Rounds still later the determinant of 8 Cumhu—would naturally be a date to remember, even if one of the results was a day or so in error. Likewise 9.12.11–12–10, 8 Oc 3 Kayab, together with its use at Katun 5, may also be the determinant for Katun 12, 19.12.–0–0, 10 Ahau 8 Yaxkin *i.e.*, 8 Yaxkin at Baktun 13–3 Kayab now, 925 days progress. Again 9.9.2–4–8, 5 Lamat 1 Mol is the determinant for Katun 10, 9.10.0–0–0, 1 Ahau 8 Kayab; 8 Kayab at Baktun 13–1 Mol now, 908 days advance. The date 10 Zip is the determinant for Katun 4, probably indicated in the first Secondary Series of the tablet in the Temple of Inscriptions as 9.3.8–7–17, 10 Caban 10 Zip; 10 Zip at Baktun 13–18 Yax now, 878 days. This same inscription shows the determinant for 9.12.10–0–0, 9 Ahau 18 Zotz as 9.12.0–6–18, 5 Eznab 6 Kankin; 18 Zotz at Baktun 13–6 Kankin now, 918 days. Stela 1 at Palenque shows the date 9.12.6–5–8, 3 Lamat 6 Zac, which is probably intended for the determinant of Katun 13; 6 Zac at Baktun 13–8 Uo now, 917 days; but I give this last with considerable hesitation. On the part of the stela left to us there is no mention of Katun 13 or of 8 Uo. In general before we accept a date as the determinant for a katun we demand that it be within a few years of the katun ending; that it be in the same inscription with the katun ending and be closely associated with it either by adjacent position or connection by secondary series; and finally that the katun ending and determinant dates together show the progress of the real year through the vague year since Baktun 13. These limitations greatly reduce our chance of error, but I can not hope to have escaped citing some that were not intended. I have omitted a number that looked probable, because our purpose here is not to make an exhaustive study but rather to present a suggestive list of those that look fairly certain, with the conviction that this will indicate a correct interpretation of the ancient Maya practice.

TABLE 7—*Determinants for 8 Cumhu and the Katuns.*

Inscription	Date for which determinant is given	Determinant	Month position at Baktun 13 and current equivalent	Maya days	Gregorian days	Years
1 Palenque T. C.	8 Cumhu	8.19.6–8–8, 11 Lamat 6 Xul	8 Cumhu ≎ 6 Xul	853	856	3535
2 Palenque T. C.	8 Cumhu	8.19.19–11–17, 2 Caban 10 Xul	8 Cumhu ≎ 10 Xul	857	860	3548
3 Palenque T. C.	Baktun 9, 13 Ceh	8.19.17–11–3, 9 Akbal 6 Xul	6 Xul ≎ 13 Ceh	857	860	3548
4	Katun 1, 13 Yaxkin	3 Uayeb	3 Uayeb ≎ 13 Yaxkin	865	865	3568
5	Katun 3, 18 Muan	9.2.7–7–16, 2 Cib 14 Mol	14 Mol ≎ 18 Muan	874	872	3595
6 Palenque T. Insc.	Katun 4, 18 Yax	9.3.8–7–17, 10 Caban 10 Zip	10 Zip ≎ 18 Yax	878	877	3616
7 Palenque T. F. C.	Katun 5, 18 Tzec	13 Mac	18 Tzec ≎ 13 Mac	885	885	3647
8 Palenque T. F. C.	Katun 6, 3 Uayeb	9.5.0–2–16, 2 Cib 14 Mol	3 Uayeb ≎ 14 Mol	886	885	3647
9 Palenque T. Insc.	Katun 10, 8 Kayab	9.9.2–4–8, 5 Lamat 1 Mol	8 Kayab ≎ 1 Mol	908	904	3728
10 Copan St. 2	8 Cumhu	9.10.0–10–0, 6 Ahau 3 Chen	8 Cumhu ≎ 3 Chen	910	908	3746
11 P. N. St. 36	Katun 11, 8 Ceh	9.10.6–5–9, 8 Muluc 2 Zip	8 Ceh ≎ 2 Zip	909	910	3752
12 Palenque T. C.	Katun 10½, 18 Kankin	12.19.13–4–0, 8 Ahau 18 Tzec	18 Kankin ≎ 18 Tzec	915	912	3762
13 Copan St. 19	8 Cumhu	9.10.19–15–0, 4 Ahau 8 Chen	8 Cumhu ≎ 8 Chen	915	913	3765
14 Palenque T. Insc.	Katun 12½, 18 Zotz	9.12.0–6–18, 5 Eznab 6 Kankin	18 Zotz ≎ 6 Kankin	918	918	3785
15 Palenque St. 1	Katun 13, 8 Uo	9.12.6–5–8, 3 Lamat 6 Zac	6 Zac ≎ 8 Uo	917	919	3791
16 Copan St. I	8 Cumhu	9.12.7–4–0, Ahau 13 Chen	8 Cumhu ≎ 13 Chen	920	920	3792
17 Copan Altar H′	8 Cumhu	9.12.8–3–9, 8 Muluc 17 Mol	17 Mol ≎ 8 Cumhu	921	920	3793
18 Palenque	Katun 12, 8 Yaxkin	9.12.11–12–10, 8 Oc 3 Kayab	8 Yaxkin ≎ 3 Kayab	925	921	3796
19 Palenque T. S.	8 Cumhu	9.12.18–5–16, 2 Cib 14 Mol	14 Mol ≎ 8 Cumhu	924	922	3803
20 Copan St. A	Katun 15, 13 Yax	9.14.19–8–0, 12 Ahau 18 Cumhu	18 Cumhu ≎ 13 Yax	930	932	3844
21 Copan Temp. 11	Katun 17, 18 Cumhu	9.16.12–5–17, 6 Caban 10 Mol	10 Mol ≎ 18 Cumhu	938	940	3876
22 Copan Altar Z	Katun 17, 18 Cumhu	9.16.18–9–19, 12 Cauac 2 Zac	18 Cumhu ≎ 2 Zac	939	941	3882
23 Copan Altar Q	8 Cumhu		18 Yaxkin ≎ 8 Cumhu	940	942	3884
24 Copan Altar R		9.18.2–5–17, 3 Caban 0 Pop	10 Mol ≎ 0 Pop	945	946	3906
25 Copan Altar U	Katun 18, 18 Mac	9.18.2–8–0, 7 Ahau 3 Zip	3 Zip ≎ 18 Mac	945	946	3906
26 Palenque T. S.	Baktun 7, 18 Zac	18 Kankin	18 Kankin ≎ 18 Zac	670	669	2760

Table 7 gives a list of those determinants of katuns and of Baktun 13 which we have discussed, together with a few others. There are discrepancies of a few days in the determinations, probably from the use of several different methods of computation, and probably from varying skill in the observers and computers. The ones listed cover easily 350 years; most and probably all of the determinations were contemporary ones, and so were the work of many men, or rather many groups of men. That such a determination was not a one man job is shown by the group photograph of the Copan Academy of Sciences taken just after the sessions in which they decided that 6 Caban 10 Mol was the determinant for Katun 17. We still have their likenesses on Temple 11, but I did not look to see whether the ones on Altar Q were the same faces, or whether that was a group picture taken at a meeting some years later when they were bringing the count up to date. There was really no occasion for making a determination more often than once in 50 or 75 years, unless they thought the one in current use was not very exact. For casual purposes one could say 9.16.12–5–17 is the determinant for Katun 17, so 9.17.12–5–12 will be a determinant for Katun 18, or could change the 938 day number by 1 day each 4 years.

In Table 7 I have listed for comparison the leap year days which would have been added in the same period by our Gregorian calendar. These are not exact. They take no account of our deviations from uniformity. For example, 7 years from the first of 1897 include no leap year day added. 7 years from the first of 1903 contain 2 leap year days; 7 from the first of 1905 contain 1 leap year day, etc. Table 7 is computed on a uniform basis of 97 days for 400 years; 24 for each of the first three hundred and 25 for the fourth one. I have also assumed that the relation between determinant and katun, 908 days for example, shows the progress up to the year in which the determinant lies and not to the one in which the katun lies. This may not always be so and may depend on the direction of the reading or some other unknown mark in the inscription.

OTHER DATES AND OTHER CITIES

I feel reasonably certain of the interpretation we have given of the tropical year at Copan. At Palenque, however, there are so few inscriptions and so many dates in each one, that an investigator does not have sufficient checks to his imagination. If we say that the results at Palenque are suggestive, and that their comparative agreement with the results at Copan indicates that they may also be true, we are probably claiming all that is warranted now. The interpretation given does at least one thing; it supplies a uniform meaning to those odd dates that were used over and over again almost as slogans: 6 Caban 10 Mol, 9 Akbal 6 Xul, 8 Oc 3 Kayab, 2 Cib 14 Mol, 5 Lamat 1 Mol, all fall into the common class of determinants. We shall try later to put 12 Caban 5 Kayab into the same class.

In the previous pages (70-78) we confined ourselves to katuns and baktuns, with only a couple of tun dates. Many other odd dates are coupled in a way to indicate attempts at integral years, such as 1.19.5–0–17, 1 Caban 10 Tzec to 9.10.2–6–6, 2 Cimi 19 Zotz in the Temple of the Sun, 2974 years with 719 day advance. Remember too that 18 Kankin is the important date in this inscription and note that 10 Tzec at Baktun 13 is 18 Kankin at 1.19.5–0–17, 1 Caban 10 Tzec. You will be able to find many others but they will not add much to our argument until we can read the accompanying glyphs.

It may seem strange that the Maya spent so much time and effort in determining how far the tropical year had progressed, but an illustration may help: Since July 4, 1776, we have added 36 leap year days to our calendar. Suppose none had been added. Suppose we had only our usual 365 day vague year as the Maya had. When should we celebrate the Fourth of July now? The answer is, of course, on August 9. And if we held our celebration on July Fourth according to the calendar, that would really be the anniversary of May 29, 1776. In such a calendar, since the time of Christ, Christmas would have been celebrated on every day in the year and would have advanced over 100 days on its second round, being now somewhere in April. Try finding where to celebrate Easter, and Lincoln's Birthday, and Columbus Day, and Bastille Day, and Washington's Birthday, and Bunker Hill Day this year in such a calendar, and you will see the importance of such records to the Mayas.

We will conclude this Palenque performance with an interpretative reading from the right-hand tablet in the Temple of Inscriptions—that part illustrated both by Goodman and Thomas.[1] This has been rehearsed for presentation many times but I fear it still lacks much of the expression that a Maya priest could have put into it. In his computations, please remember we do not know which points he is deriving for the first time and which have long been matters of common knowledge. The preceding part of the inscription started with Katun 4, whose determinant you remember is 10 Zip, then proceeded through the katuns to Katun 13, then jumped to Baktun 10, then to Pictun 1 at 10 Ahau 13 Yaxkin, where our extract begins (fig. 17). The apparent purpose of the present part seems to be to find a date near Pictun 1 which will be the anniversary of Katun 4, and so also the anniversary of 10 Zip at Baktun 13, thus covering a total of 7885 years.

The first three glyphs (A1, B1, A2) end a preceding sentence, 10 Ahau 13 Yaxkin end of Pictun 1 (1.0.0.0–0–0). To determine the anniversary (B2) add 12–9–8 (A3, B3) to a —— moon day (A4) and a —— (B4) at 8 Ahau 13 Pop (A5, B5, 9.8.9–13–0); this gives (A6) a —— (B6) and a determinant (A7) of a katun (B7) at 5 Lamat 1 Mol (C1, D1, 9.9.2–4–8), which is 2–4–8 (C2, D2) from 3 Ahau 3 Zotz (C3, D3, 9.0.0–0–0) the end of a katun

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[1] J. T. Goodman, *The Archaic Maya Inscriptions*, Biologia Centrali-Americana, Vol. IV, plates 59 and 62.
Cyrus Thomas, *Mayan Calendar Systems*, 19th Annual Report, Bureau American Ethnology, page 771, Part 2, 1898.

(snake over C3) and the end of a tun (D4). The number 2.9.1–1–12 (D4–C6) added to the end of Baktun 7 (7.0.0–0–0, 10 Ahau 18 Zac) (C7) gives a bundle of years (D7) (just 967 years with a 237 day advance). The distance in the calendar (E1) (from the 18 Zac of Baktun 7) to 1 Manik 10 Tzec (F1, E2, 237 days) is the same as the distance from the determinant (5 Lamat 1 Mol) (E3) to the —— (F3) (8 Ahau 13 Pop, 1 Mol to 13 Pop, 237 days). The number 10.11.10–5–8 (E4-F5) added to the last date (9.8.9–13–0, 8 Ahau 13 Pop) ends the year (E6) at 5 Lamat 1 Mol (F6, E7) at Pictun 1 and 8 days (F8, G1). The tun ends (H1) at 10 Ahau 13 Yaxkin (G2, H2), but the year (G3) ends at 5 Lamat 1 Mol (H3, 1.0.0.0–0–8), and 4 Manik 10 Zip (G4, H4) is now (at 19.19.5–10–7, 4 Manik 10 Zip) the anniversary of it (*i.e.*, of the original 5 Lamat 1 Mol at 9.9.2–4–8, and of course 5 Lamat 1 Mol at 1.0.0.0–0–8 is the anniversary of 10 Zip at Baktun 13 just 7885 years before).

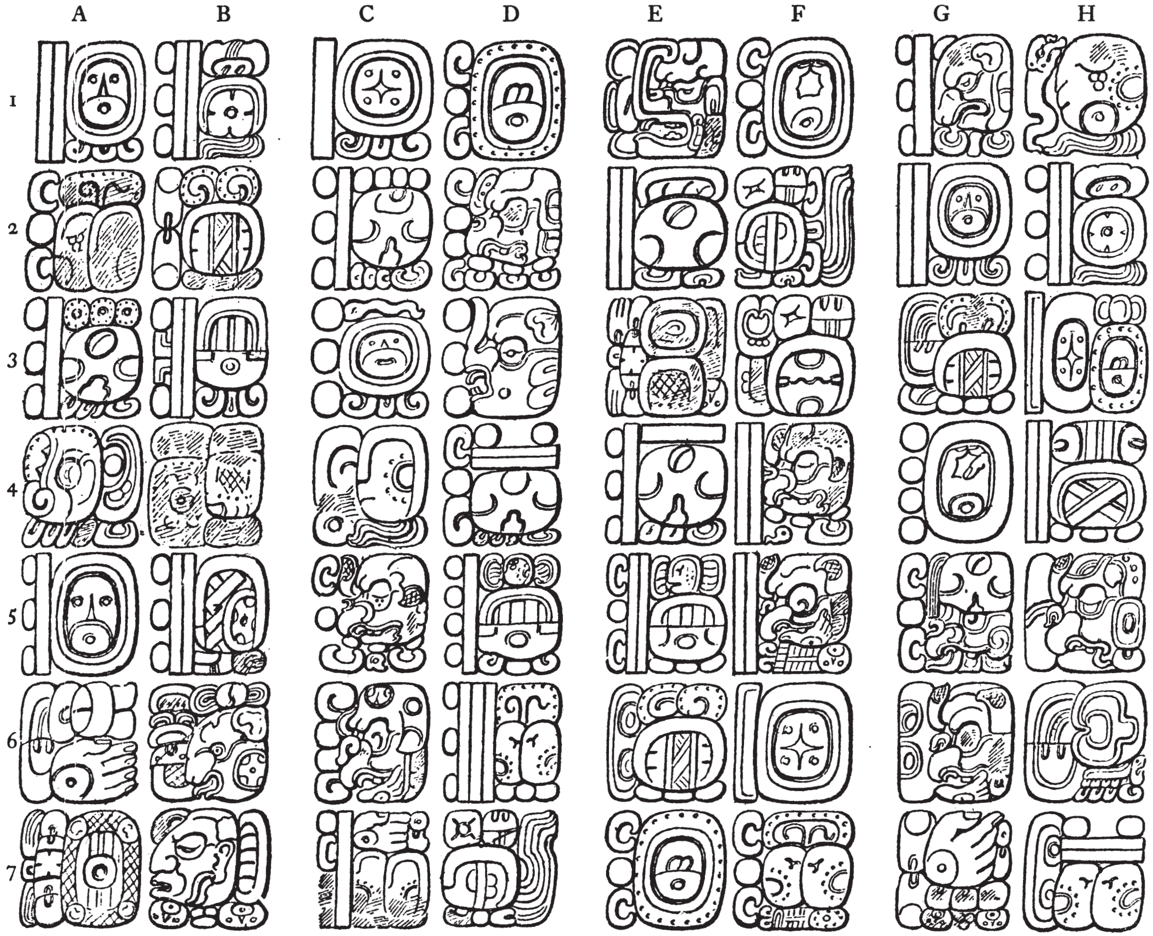

FIG. 17. Part of the inscription from the Temple of the Inscriptions at Palenque.

There are quite a number of gaps here. We do not know just what kind of a moon day A4 is, although we do know that 8 Ahau 13 Pop is about the same moon day as our extremes 10 Zip at 13.0.0–3–7 and 1 Mol at 1.0.0.0–0–8, and this is probably what is intended. The sign at B4 is unknown;

B6 is used with too many dates to yield its significance; D6 is certainly 18 pictuns or Pictun 18. It may mean Pictun 18 ending at Baktun 7, in which case 4 Ahau 8 Cumhu would be the thirteenth and Baktun 7 the twentieth of this pictun; or it may be Pictun 18 and Baktun 7, in which case Pictun 18 ended at 4 Ahau 8 Cumhu; in either case the 10 Ahau 13 Yaxkin must be 1 pictun from 4 Ahau 8 Cumhu, a distance number, and not Pictun 1, a pictun number. The sign at F3 occurs frequently, so that its meaning should not long evade us.

We wanted to know the anniversary of the 18 Yax of Katun 4, either in the year of Katun 4 or in the year of its determinant 10 Zip. The difference would be only 2 or 3 days. Having learned this, we would also have the anniversary of 10 Zip at the beginning. Now at the determinant of Katun 4 we had advanced 2 rounds and 148 days, and by Katun 4 itself it would have been about 2 rounds and 151 days; still 3.16.0–0–0 later, by Baktun 13, it would have been 3 rounds and about 151 days (149 days figured exactly). So that in 13 baktuns the advance is 3 rounds and 151 days, and there are only 7 baktuns more to go to make 1 pictun. So if we start at 4 Ahau 8 Cumhu with a date 151 days after 10 Zip and see what that will give at Baktun 7, the answer to that problem will be the answer to the anniversary at 1 pictun. From 10 Zip to 1 Zac is 151 days; 1 Zac at 4 Ahau 8 Cumhu = 1 Mol at Baktun 7, 670 day advance, and this 1 Mol is our answer. Again 18 Zac of Baktun 7 = 10 Tzec of Katun 9, 237 day advance; so 1 Mol of Baktun 7 = 13 Pop of Katun 9, but I do not know why it was the particular 8 Ahau 13 Pop 9.8.9–13–0, instead of any other 13 Pop near Katun 9. Now we find the nearest 1 Mol to 1 pictun is 5 Lamat 1 Mol at 1.0.0.0–0–8. So we need only add to 8 Ahau 13 Pop the 12.9.8 to reach the nearest 5 Lamat 1 Mol, and then the 80 calendar rounds necessary to reach the desired 5 Lamat 1 Mol at 1.0.0.0–0–8, which is the anniversary of 18 Yax at Katun 4 and also of 10 Zip at 4 Ahau 8 Cumhu. The total advance from 13.0.0–3–7, 10 Zip to 1.0.0.0–0–8, 1 Mol is 1916 days for 7885 years, or 5 rounds and 91 days. The advance from Katun 9 is 1916–908 = 1008 days = 3 rounds–87 days, so if we go back from 1 pictun about 15 years to take care of the 4-day difference between 91 and 87 days we will have a date 19.19.5–10–7, 4 Manik 10 Zip, which is the anniversary of 9.9.2–4–8, 5 Lamat 1 Mol. I do not imagine that this long tale reproduces exactly the Maya thought, but I think it does reproduce the general tenor of Maya computations and may give someone a lead to follow their thought more accurately. The date 8 Ahau 13 Pop quite surely has some meaning of its own that I have not developed, and I have made no use of the fact, which must be more than a coincidence, that the determinant of Katun 10, eighty Calendar Rounds later becomes the anniversary of Katun 4. I believe the Maya were always hunting for complicated relationships of this type.

An advance of 1916 days in 7885 years gives a year of 365.2430 days, a little longer than the Gregorian year and still longer than the Copan year.

This would give one round of the vague year in about 1502 years = 1503 vague years = 3.16.3–15–15, which is too short by 5 years. Consequently the day's advance at Palenque would be computed a little higher than the Gregorian calls for, which we actually find to be the case except in the very early ones around Baktun 9. The late Palenque formula approximates 107 years = 107 vague years + 26 days, but I do not know exactly what it is. It does not seem to be based on moons. I think it is 7.6–0–0 + 35 days = 144 years.

There are occasional indications at Palenque of the existence of a year, or a method of computation which is essentially the Julian year. In the Temple of the Cross, 4 Ahau 8 Cumhu is closely connected with a date 13 Ik 0 Chen near it, followed by an addition of about 752 years. We should normally interpret this as 0 Chen now = 8 Cumhu 752 years hence, 188 day advance, which is correct for Julian, but it should be about 182 days for Gregorian. Again, in the Temple of the Foliated Cross we reach 1.18.5–4–0, adding 14.19 gives 1.18.6–0–19, 1 Cauac 7 Yax, followed by 1.14–14–0 which leads from the first date to 2.0.0–0–0, 2 Ahau 3 Uayeb. We should expect to interpret this as 7 Yax determinant of Baktun 2, *i.e.*, 3 Uayeb at Baktun 13 = 7 Yax now, 189 day advance. This is just right for Julian, but it should not be over 183 for Gregorian. There are several others of this type, but they may easily be susceptible to some other explanation.

I have not devoted much time to study of the tropical year except at Copan and Palenque. Table 7 (page 79) includes one date from Piedras Negras, and when Dr. Morley's Peten book is available I hope to find more there. At Quirigua there is possibly a little evidence. Copan abandoned the uniform moon numbering in 9.16.5–0–0, and Quirigua followed almost immediately but reverted to the Palenque numbering for 20 years or more. Quirigua must have known the Copan formula 19 years = 235 moons, and on reversion to the Palenque moon numbering it would have been natural to assume also the Palenque moon formula 81 moons = 6–11–12. If this were done, the result would be essentially a Julian year. In 9.16.5–0–0 there first appears at Quirigua the slogan 12 Caban 5 Kayab as 9.14.13–4–17, 12 Caban 5 Kayab. It recurs repeatedly on monuments during the period when Palenque numbering was in use, and I am going to suggest that during this period Quirigua used essentially a Julian year. In 916.5–0–0, so far as we know, the last calculation made at Copan had been for the Katun 15 determinant 12 Ahau 18 Cumhu, 930 day advance. Quirigua now recalculated this and found 9.14.13–4–17, 12 Caban 5 Kayab for the determinant, 963 days for 3838 years; Julian would be 959. I find a number of dates at Palenque that show about this same excess over a Julian year, as though that were an alternative calculation discussed in connection with their real year.

In the Hieroglyphic Stairway at Copan Date 23, 9.15.6–14–6, 6 Cimi 4 Tzec is associated with 9.14.15–0–0, 11 Ahau 18 Zac. They had begun to look toward Baktun 10, 10.0.0–0–0, 7 Ahau 18 Zip, and at 9.14.15–0–0. 18 Zip is equivalent to 4 Tzec at Baktun 10, 26 day advance for 104 years. Quirigua apparently used the same figure. I think we can follow the Quirigua argument on Stela E at that city. The first date is 9.14.13–4–17, 12 Caban Glyph F, 7 days and 3 moons, Glyphs X and B, a 30-day moon, 5 Kayab, determinant for the katun. (The hand with peculiar figure above seems to be used sometimes at Quirigua to mean determinant.) The year ends with 7 Imix, but I do not know what year or what 7 Imix; 9.14.13–0–1 is 7 Imix 9 Ceh. To get the baktun year (note the baktun sign below the Zotz figure) add 6–13–3 gives 4 Ahau 13 Yax (Katun 15)—the next glyph block carries you through 5 tuns more, some way to 9.15.5–0–0—then add 1–14–6 gives 6 Cimi 4 Tzec (9.15.6–14–6 explained before in relation to Baktun 10). Adding now 1.1–16–15 (and 3 tuns more somewhere) we get the determinant of Baktun 10 in the usual form at 11 Imix 19 Muan (9.16.11–13–1); 18 Zip at Baktun 13 = 19 Muan now, 971 day advance computed Julian 969. (Note the large figure to indicate same sun day in the next glyph block.) Then follows 8–4–19 to arrive at the current Katun 17. The last 5 glyph blocks on this side I think recapitulate all the things he has recorded in this inscription, beginning with the determinant for the katun in the first, the unknown horned year ending at 7 Imix and the Zotz year over the baktun for 4 Tzec in the second, the Zotz year over the baktun for 19 Muan in the fourth, and the Zotz year connected with Katun 17 in the fifth.

After Quirigua had returned to the uniform moon numbering, there was an apparent attempt at statement of a determinant in 9.18.15–0–0, 3 Ahau 3 Yax, Stela K. The equation, if it is meant for one, is 18 Kayab at Baktun 13 equals 3 Yax now 940 days; Gregorian would be 3918 years, 949 days.

At other cities than Copan we have indicated what is to be looked for regarding the tropical year, and perhaps have found some data. At Copan we probably know what the system was. Essentially Gregorian at Copan; essentially Gregorian at Palenque, with probably considerable argument about it, and essentially Julian at Quirigua from 9.16.5–0–0 to 9.17.15–0–0.

ECLIPSES

In the previous pages we have developed from the inscriptions two formulas for long-distance moon computations, one at Palenque and one at Copan, the latter probably being also common to other cities while they were using the uniform system of moon numbering. We have also developed three formulas for computing the tropical year, one at Palenque, one at Copan and one for a time at Quirigua. This probably does not exhaust the possibilities but it will do for the present.

We turn now to the *Dresden Codex*, a manuscript which from internal evidence is probably somewhat later than the inscriptions and earlier than the arrival of the Spaniards. If we date it about 1100 A.D. or a little later we shall not be far wrong. This manuscript contains astronomical material, among which is a table on pages 51 to 58 which has been studied carefully by Forstemann, Thomas, Bowditch, Meinshausen, Willson and Guthe. They have shown that it is an arrangement of 405 consecutive moons covering a period of nearly 33 years, and arranged in 69 groups of 5 or 6 moons each. Of the 69 groups, 53 are of 6 moons = 177 days; 7 groups are of 6 moons = 178 days; and 9 groups, each followed by a picture, are of 5 moons = 148 days. These total 11,959 days, but apparently the length of the group for computation was intended to be 1.13–4–0 = 11,960 days, since the 2, 3, 4, 5, 6, 16, 17, 18, 31 and 39 multiples of 1.13–4–0 are found in the context. It will be noticed that 405 moons = 1.13–4–0 is exactly the same as the Palenque moon formula already discussed (on pages 64 to 66), 81 moons = 6–11–12.

The last three authors noted above show further that the arrangement of 5 moon and 6 moon groups is such as to give a possible table of eclipse syzygies. The distances are such that under certain conditions every one of the 69 moon groups ends on a day when an eclipse could occur somewhere on earth. The coincidences are so many and so remarkable that it must surely be intended for a table of eclipse syzygies, the only possible alternative being an intention to correlate the moon groups with the tzolkin days.

Table 8 gives a summary of the information contained in this arrangement. Column 1 of this table gives the consecutive numbers of the groups from 1 to 69; Column 2 shows the number of days in the current moon group, 148, 177 or 178; Column 3 the total number of days that have elapsed from the Zero date to the end of the current group; and Column 4 the tzolkin day on which the current group ends. The reading in the original of Group 16, for example, is simply "7–12–16, 5 Akbal, 6 Kan, 7 Chiccan, 7–17," that is 2776 days for the total of Column 3, three consecutive days for the tzolkin day of Column 4, of which I have recorded only the middle one in the table, believing the ones before and after it are used to take care of possible moon vagaries and possible difficulty encountered by the Maya in handling fractions, and finally 177 days for the current moon group in Column 2. In Column 5 of the table, I have added a number for our convenience which

TABLE 8—*Summary of pages 51 to 58 inclusive of the Dresden Codex.*

No.	Days added	Total	Day	Tzolkin Day	Real Eclipses
0	0	0	12 Lamat	168	168*
1	177	177	7 Chicchan	345	345
2	177	354	2 Ik	2	2*
3	148	502	7 Oc	150	180
		PICTURE			
4	177	679	2 Manik	327	327
5	177	856	10 Kan	504	504
6	177	1033	5 Imix	161	161
7	178	1211	1 Cauac	339	339
8	177	1388	9 Cib	516	516*
9	177	1565	4 Ben	173	173
10	177	1742	12 Oc	350	350
11	177	1919	7 Manik	7	7
12	177	2096	2 Kan	184	185
13	148	2244	7 Eb	332	332
		PICTURE			
14	178	2422	3 Oc	510	509
15	177	2599	11 Manik	167	167*
16	177	2776	6 Kan	344	343
17	177	2953	1 Imix	1	1
18	177	3130	9 Eznab	178	178
19	148	3278	1 Cimi	326	326
		PICTURE			
20	177	3455	9 Akbal	503	503
21	177	3632	4 Ahau	160	160*
22	177	3809	12 Caban	337	338
23	177 (178)	3986	8 Men	515	514*
24	177	4163	3 Eb	172	172*
25	177	4340	11 Muluc	349	349
26	148	4488	3 Caban	497	6
		PICTURE			
27	177	4665	11 Ix	154	154
28	177	4842	6 Chuen	331	331
29	178	5020	2 Muluc	509	509
30	177	5197	10 Cimi	166	165*
31	177	5374	5 Akbal	343	343
32	177	5551	13 Ahau	520	520*
33	177	5728	8 Caban	177	177
34	177	5905	3 Ix	354	354
35	177	6082	11 Chuen	11	11
36	148	6230	3 Cauac	159	159
		PICTURE			
37	178	6408	12 Caban	337	336*
38	177	6585	7 Ix	514	514
39	177	6762	2 Chuen	171	171
40	177	6939	10 Lamat	348	348
41	177	7116	5 Chicchan	5	5
42	148	7264	10 Ben	153	152

Table 8 (Continued)

No.	Days added	Total	Day	Tzolkin Day	Real Eclipses
		PICTURE			
43	177	7441	5 Oc	330	330
44	177	7618	13 Manik	507	507
45	177	7795	8 Kan	164	164*
46	177	7972	3 Imix	341	341
47	177	8149	11 Eznab	518	518*
48	177	8326	6 Men	175	176*
49	148	8474	11 Akbal	323	323
		PICTURE			
50	177	8651	6 Ahau	500	500
51	177	8828	1 Caban	157	158*
52	178	9006	10 Men	335	334
53	177	9183	5 Eb	512	512
54	177	9360	13 Muluc	169	169
55	177	9537	8 Cimi	346	347
56	177	9714	3 Akbal	3	3*
57	177	9891	11 Ahau	180	151
58	148	10039	3 Lamat	328	328
		PICTURE			
59	177	10216	11 Chiccan	505	505*
60	178	10394	7 Akbal	163	163*
61	177	10571	2 Ahau	340	340
62	177	10748	10 Caban	517	517
63	177	10925	5 Ix	174	174
64	177	11102	13 Chuen	351	351
65	148	11250	5 Cauac	499	499
		PICTURE			
66	177	11427	13 Cib	156	156
67	177	11604	8 Ben	333	334
68	177	11781	3 Oc	510	510
69	177	11958	11 Manik	167	168*

is not in the Maya text; there are 46 tzolkins in the whole eclipse table or 23 pairs of tzolkins. If we number the days of each pair from 1 to 520 consecutively, beginning with 1 Imix of the first and ending with 13 Ahau of the second we develop some interesting relationships, and so these numbers are given in Column 5. Day 12 Lamat, the Zero date for example, is the one hundred sixty-eighth day of the first tzolkin; day 7 Chicchan of the first group is the eighty-fifth day of the second tzolkin so we give it the number 85 + 260 = 345; day 2 Ik of the second group is the second day of the third tzolkin, so its number is 2, and so on through each pair of tzolkins. If one now runs his eye down the figures in Column 5 such a striking regularity is observed that one immediately plots them on the tzolkin wheel (fig. 18). The result is rather startling; the Zero date and the end of Groups 3, 6, 9, 12, etc. (in fact all groups exactly divisible by 3) are found collected in a

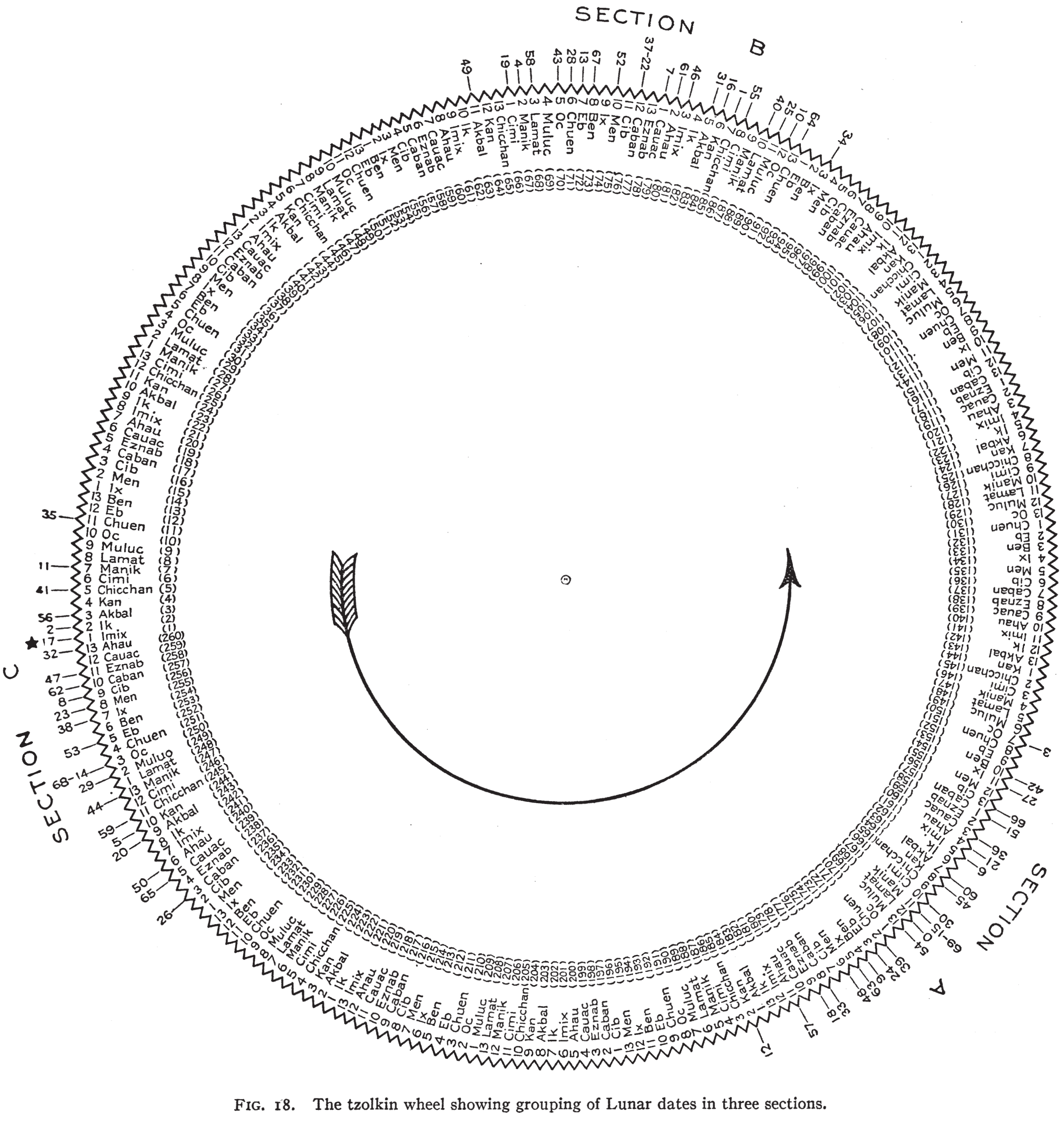

FIG. 18. The tzolkin wheel showing grouping of Lunar dates in three sections.

small arc (A) between day 150 and day 184 of the first tzolkin, a spread of 34 days; Groups 1, 4, 7 and all groups divisible by 3 with a remainder of 1 are in arc (B) between days 63 and 94 of the second tzolkin, to which we add 260 days to get our numbers 323 to 354, a spread of 31 days; and all groups divisible by 3 with a remainder of 2 are in arc (C) between days 497 of the second tzolkin and 11 of the first tzolkin, a spread of 34 days. Three small arcs of the two tzolkins with a total of 102 days out of the whole 520 days contain all the group endings or eclipse syzygies for 33 years.

Perhaps a short explanation here regarding eclipses would be in order. The sun has its path in the sky which we call the ecliptic; the moon also has a path which is inclined about 5° to the ecliptic, hence twice a year the sun is in both the ecliptic and the moon's path where they cross, at a point which we may call the node. If a new moon occurs while the sun is at that point, or in fact within about 18 days either side of the node, then the moon will obscure some part of the sun and there will be an eclipse of the sun visible somewhere on earth. If the nodes were stationary, the sun would reach one every half year, but there is a regression of the nodes, such that the sun crosses the moon's orbit on the average once in 173.31 days, the eclipse half year. Three of these eclipse half years, 519.93 days, so nearly coincide with two tzolkins, 520 days, that if the sun were at the node of the moon's orbit on days 167, 340 and 514 of the first pair of tzolkins, we should expect it to be at the same places during the second pair and third pair, etc., with a variation of not more than about 1 day in 20 years.

If we are really dealing with a table of eclipse syzygies, the node days are easily found; Group 3 ends on day 150, and this must be within about 18 days of the node day, so the node day at that time can not be later than day 168; Group 12 ends on day 184 so the node day at that time can not be earlier than day 166. Carrying the analysis to completion, we find that at the beginning of the table the Zero new moon at 12 Lamat was probably about day 168.5 and the node day was somewhat less than a day before it—at about 167.5. The three node days were 167, 340 and 514; by the end of the table they had each receded about 1.61 days in the tzolkin to days 166 (or 165), 339 and 512. The reason then for the concentration of group endings in small arcs of the tzolkin is clear; the node days are nearly stationary in the tzolkins and an ecliptic conjunction can only occur within about 18 days of a node day.

Column 6 of the table shows a list of eclipses from Oppolzer's *Canon der Finsternisse*. I selected for Zero date an eclipse January 16, 1116, which closely duplicates the conditions we have deduced for the beginning of the *Dresden Codex* table, *i.e.*, eclipse occurring within a day or less after conjunction of the sun with the moon's node. Calling January 16, 1116, 12 Lamat or day 168, the next eclipse occurred at day 345, etc., through the whole list. Compare Column 5 of Table 8 from the *Dresden Codex* with Column 6, a list of eclipses that actually occurred; the only real discrepancy is in Group 3, where Oppolzer gives the one occurring on day 180 but does not give the one on day 150; probably because it was not total anywhere. All the others agree with not more than a full day discrepancy in any group. The starred ones in Column 6 represent those that were possibly visible somewhere in Maya territory; there are 18 of them, 10 being in the part of the tzolkin we have called Section A, 7 in Section C, and only 1 in Section B. I do not know whether this distribution has any significance, but the fact that 10 of the 18 eclipses could fall on days 158, 160, 163, 164, 165, 167, 168, 172, 176 of one tzolkin—that is within a total of 19 days out of a possible 520 days—would early lead the Maya to connect eclipses with certain parts of the tzolkin, and this coincidence and the observation of it had been going on for centuries. It is not so surprising, then, that the Maya were able to construct a table of eclipse syzygies.

There is a certain symmetry to the table. Group 3 contains 148 days and is followed by a picture; then Groups 13, 19 and 26 are similar, that is the tenth, sixth and seventh following. In Groups 36, 42 and 49 we have the same tenth, sixth and seventh; but in the next series it is 58, 65, 3, that is the ninth, seventh and seventh. Why did they not make the fifty-eighth a long group and not bring in the short one till the fifty-ninth in order to maintain the symmetry? If the fifty-eighth had been a 6-moon group it would have ended on day 358, but by this time the node day had receded over 1⅓ days and was day 339, so the distance from the node would have been greater than they were accustomed to allow, although an eclipse was still barely possible on that day. Such deviations from symmetry are rather sure indications that we are dealing with natural phenomena. One other indication, however, proves that we are probably dealing with a forecast and not a record of occurrences. It would be practically impossible to have such a record of actual new moons without an occasional 147-day, or 176-day interval, neither of which occurs, all being smoothed off to 148, 177 and 178, as would be done in a forecast. Neither is it a general formal calendar for repeated use; every successive use would demand a revision on account of the retrogression of the node day. It is not a table for moon eclipses because, while every date is possible for sun eclipses, many would of necessity have been chosen differently for moon eclipses. It can not be used for both solar and lunar eclipses to any advantage, and anyone competent to draw so accurate a table as this for solar eclipses would surely have drawn a second and proper one for moon eclipses, which we fail to have. This is surely a table of new moons in groups, so arranged that a group will end on a possible date for a solar eclipse. The only alternative is to suppose it a grouping of moons to correlate the moon groups with definite days in the tzolkin, 4 Ahau, 2 Ahau and 13 Ahau, for example. This must be admitted as a possibility, and no doubt some such thing once preceded a true knowledge of eclipses, but considering the astronomical knowledge shown by the Maya as indicated in previous chapters, I feel sure we have to do here with a real table of eclipse syzygies covering a definite period of time.

Can we date the table? I formerly supposed, with others, that its Zero date was 9.16.4–10–8, 12 Lamat 1 Muan, but now I am doubtful. We mentioned (pages 59ff) that Copan abandoned the uniform moon numbering in 9.16.5–0–0 and changed to some method which might be the eclipse syzygy grouping mentioned above. We have only four group endings from Copan to consider: Stela M, 9.16.4–10–8, 12 Lamat day 168; Stela N 9.16.9–16–9, 9 Muluc day 9 (contemporary dates say 7 Manik day 7); and two from Temple 11: 9.16.11–14–7, 11 Manik day 167 and 9.16.12–5–4, 6 Kan day 344. These four could be fitted into our table and would correspond to Groups 0, 11, 15 and 16, but they are all so situated that they likewise could have been in any proper eclipse table for over 350 years before our *Dresden Codex* table. The date 9.16.4–10–8, 12 Lamat in the context of our table shows its importance in this connection and is probably sufficient to assure us that Copan did actually start the eclipse arrangement on that date with Stela M, but it does not necessarily give us the date of the present eclipse table, since 10 or 11 such tables may have been used through and discarded between Stela M and this one in the *Dresden Codex*. The only other 12 Lamat in the context that might be meant for the date of the table is apparently 10.19.6–0–8, 12 Lamat in the first column of page 51, but unfortunately 10.19.6–0–8 is not 12 Lamat, so some correction must be made. In such cases we usually find the error in the Long Count and not in the tzolkin date, so we must correct the 10, or 19, or 6, or 0. Let us try correcting them all separately and we have

No. 1 10.19. 6– 1–8, 12 Lamat 6 Cumhu
No. 2 10.19. 6–14–8, 12 Lamat 1 Mac
No. 3 10.19. 1– 0–8, 12 Lamat 11 Cumhu
No. 4 10.19.14– 0–8, 12 Lamat 6 Muan
No. 5 10. 9. 6– 0–8, 12 Lamat 11 Ceh
No. 6 3.19. 6– 0–8, 12 Lamat 11 Tzec

These are the only possible ones after making a single correction. We discard No. 6 at once as being impossible, and discard Nos. 2, 3, 4 and 5 because they are not new moon dates if there has been an unbroken count from the time of the inscriptions. If there has not been an unbroken count we are wasting our time anyway and can deduce nothing. Finally, No. 1 is a new moon day at 12 Lamat, but we discard it because it is in the wrong tzolkin; it is day 428 and not 168 if we have been right regarding the 4 dates at Copan being eclipse syzygy dates. This leaves us with nothing. If we change two of the numbers it would be easy to write beautiful dates such as 10.14.10–0–8, or 9.19.11–0–8, but this is too indefinite. There is one other date over 12 Lamat in the first column which looks like 8.16.4–11–8, but that date is not 12 Lamat either without a correction. Unless, then, 9.16.4–10–8 is the date of the table we have no date surely given for it.

The Supplementary Series of the last three dates at Naranjo give the following group endings:

Stela 13 9.17. 9–10–15, day 335
Stela 14 9.17.12–17– 5, day 505
Stela 8 9.18. 9–14– 0, day 320

These all fit well into the table as Groups Nos. 52 and 59 of the table and No. 25 of its first repetition; but unlike those at Copan the last one in particular could not fit into a table of late date. If it was intended for an eclipse syzygy in 9.18.9–14–0, then the date of the eclipse table in the *Dresden Codex* must be 9.16.4–10–8 and not later.

We must mention just one other possibility. The table in *Dresden Codex* may be the one drawn up for the 33 years beginning in 9.16.4–10–8. Copan fell, possibly its intelligentsia fell with it, but the table was preserved by descendents no longer skilled in its use and unable to make the changes necessary to keep it in order. The table would still predict some eclipses as they occurred for several hundred years, although far deteriorated from its original accuracy. We have developed, then, only the following conclusions:

1. Pages 51 to 58 of the *Dresden Codex* in all probability represent a table of eclipse syzygies.
2. The eclipse table is closely connected with Stela M at Copan, where and when the uniform system of moon numbering was first abandoned in favor probably of this eclipse system.
3. When the table was accurate the sun crossed the moon's nodes on Maya days 167, 340 and 514 at the beginning of the table.
4. If the last 4 moon groups shown on monuments at Copan represent ecliptic conjunctions, then the date of the table was 9.16.4–10–8, or some time within the next 375 years.
5. If the last three Supplementary Series at Naranjo also represent ecliptic conjunctions, then the date of the table was 9.16.4–10–8 and no later. But we must consider these three at Naranjo doubtful, because at least two of the three also agree with the uniform system of moon numbering which had been in use there, and the other might be simply an error.
6. If on 12 Lamat, for example, in an odd-numbered tzolkin there should be an eclipse near node day, then the 12 Lamat in even-numbered tzolkins can have no near relation to eclipses or node days for over 1000 years before or afterwards, hence the day numbering in pairs of tzolkins to avoid confusion.
7. There is no evidence that the Maya realized any inaccuracy in the 405 moons = 1.13–4–0, and I do know what they thought about the recession of the node day in the tzolkin, if they noticed that there was any recession, or if the node day represented any astronomical fact to their minds.
8. If the four dates at Copan were ecliptic conjunctions, then the 12 Lamat that begins the *Dresden Codex* table and the 12 Lamat of 9.16.4–10–8 at Copan must have been in corresponding tzolkins; one could not have been day 168 of our numbering and the other day 428 unless they are some 1400 years apart. In our numbering I have called the 13 Ahau that ends Katun 4 or Katun 17 day 520.

VENUS

Venus as seen from the earth is morning star for about eight months after inferior conjunction, then disappears for three months at superior conjunction, then is evening star for eight months, disappears two weeks during inferior conjunction and resumes position as morning star. The total time of this synodic revolution from one heliacal rising as morning star to its recurrence, or from inferior conjunction to inferior conjunction, averages about 584 days—583.92 days more exactly. The individual revolutions run in a series of five, approximately 580, 587, 583, 583 and 587 days, but an average of any successive five is very close to 583.92.

The Maya division of the Venus revolution as shown on pages 46 to 50 of the *Dresden Codex*[1] is 236 days morning star, 90 days disappearance at superior conjunction, 250 days evening star, and 8 days disappearance at inferior conjunction, total 584 days. The divisions are probably meant to represent in general 8 moons, 3 moons, 8½ moons, and 8 days. They are shown identically for 195 Venus revolutions, so no account is taken here of 580-day and 587-day variations, but all are smoothed out to 584 days. The first one, for example, starts the revolution with heliacal rising at 1 Ahau 18 Kayab, morning star 236 days to 3 Cib 9 Zac, disappearance 90 days to 2 Cimi 19 Muan, evening star 250 days to 5 Cib 4 Yax, and heliacal rising again, completing the revolution 8 days later at 13 Kan 12 Yax.

If we select only the part of the table which gives heliacal risings, the end of their synodic revolutions, it takes the following form, the Zero date being always 1 Ahau:

13 Kan	12 Lamat	11 Eb	10 Cib	9 Ahau
8 Kan	7 Lamat	6 Eb	5 Cib	4 Ahau
3 Kan	2 Lamat	1 Eb	13 Cib	12 Ahau
11 Kan	10 Lamat	9 Eb	8 Cib	7 Ahau
6 Kan	5 Lamat	4 Eb	3 Cib	2 Ahau
1 Kan	13 Lamat	12 Eb	11 Cib	10 Ahau
9 Kan	8 Lamat	7 Eb	6 Cib	5 Ahau
4 Kan	3 Lamat	2 Eb	1 Cib	13 Ahau
12 Kan	11 Lamat	10 Eb	9 Cib	8 Ahau
7 Kan	6 Lamat	5 Eb	4 Cib	3 Ahau
2 Kan	1 Lamat	13 Eb	12 Cib	11 Ahau
10 Kan	9 Lamat	8 Eb	7 Cib	6 Ahau
5 Kan	4 Lamat	3 Eb	2 Cib	1 Ahau
7 Xul	6 Kayab	0 Yax	14 Uo	13 Mac
12 Yax	6 Zip	5 Kankin	19 Xul	18 Kayab
2 Kayab	16 Chen	10 Uo	9 Mac	3 Xul

There are here 65 positions of the tzolkin and 3 rows of positions in the year. Taking the middle row, the heliacal rising of Venus occurred at approximately the following dates:

Zero date.........	1 Ahau 18 Kayab	4th revolution...	10 Cib 19 Xul
1st revolution......	13 Kan 12 Yax	5th revolution...	9 Ahau 18 Kayab
2d revolution......	12 Lamat 6 Zip	6th revolution...	8 Kan 12 Yax
3d revolution......	11 Eb 5 Kankin	7th revolution...	7 Lamat 6 Zip, etc.

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[1] Dr. Ernst Forstemann, *Commentary on the Dresden Codex*, page 183, Archaeology and Ethnology Papers, Peabody Museum, vol. IV.

Five synodic revolutions of Venus return to exactly the same month position, both the zero and fifth above being 18 Kayab; the first and sixth 12 Yax. We should expect this for five synodic periods of 584 days = 8 vague years of 365 days = 2920 days.

On page 24 of the *Dresden Codex* this period of 5 revolutions = 8–2–0 is recorded with its multiples up to 13, the last being 5.5–8–0 = two Calendar Rounds = 104 vague years = 37960 days = 65 synodic Venus revolutions, just the number obtained by combining the 65 tzolkin positions in our table with a single row of the month positions. On the same page of the manuscript the number 5.5–8–0 is taken as a unit and its second, third and fourth multiples given, reaching 1.1.1–14–0, 8 Calendar Rounds = 416 vague years = 4 complete Venus cycles.

Returning now to our table, we see that if the Maya regarded five Venus revolutions as exactly equal to eight Maya vague years, they would never have use for more than five positions in the year, and heliacal risings of Venus would occur only on 18 Kayab, 12 Yax, 6 Zip, 5 Kankin and 19 Xul forever. We must explain the other two rows. Rearranging them beneath each other in order of middle row, top row, bottom row, we have—

18 Kayab,	12 Yax,	6 Zip,	5 Kankin,	19 Xul	Middle Row
6 Kayab,	0 Yax,	14 Uo,	13 Mac,	7 Xul	Top Row
2 Kayab,	16 Chen,	10 Uo,	9 Mac,	3 Xul	Bottom Row

We have to do with three distinct Venus tables. The Maya were aware that the Venus revolution averaged a little less than 584 days and so receded slightly in the vague year. At some time the heliacal rising was at 1 Ahau 18 Kayab; some even number of Calendar Rounds later it had receded 12 days to 2 Lamat 6 Kayab, and 2 Calendar Rounds still later it was at 11 Kan 2 Kayab. The recession is really 5.2 days per 2 Calendar Round cycle of 65 Venus revolutions, but these tables are constructed on a basis of fours, so the usual correction would be 4 days with an occasional one of 8 days. The method of correction is also clear. The Maya were apparently insistent on a 1 Ahau as the Zero day for their Venus tables. In the 1 Ahau 18 Kayab table let us say Venus had receded considerably, owing to previous corrections of only 4 days each, so that an 8-day correction was now desirable. The 57th revolution of Venus in this table should end on day 9 Lamat 6 Zip; making the 8-day correction gives 1 Ahau 18 Uo, the Zero date of the next table. We find authority for this on page 24 of the *Codex* in the number given there, which is 57 revolutions less an 8-day correction, 4.12–8–0. 4.12–8–0 added to 1 Ahau 18 Kayab gives 1 Ahau 18 Uo, and we find both these dates at the bottom of page 24. For the next correction, which will be a 4-day one, we take the 61st revolution of a 1 Ahau 18 Uo table which is 5 Kan 17 Mac, deduct 4 days and it gives 1 Ahau 13 Mac—the Zero date for the top row of year positions. Here, too, we find authority on page 24 of the *Codex*. We have used 57 revolutions with an 8-day correction and 61 with a 4-day one, reaching a total of 118 revolutions of 584 days less 12 days. This is the number 9.11–7–0 on page 24, 4.12–8–0 for the 57, and 4.18–17–0 for the 61, total 9.11–7–0. It will be found that this number added to 1 Ahau 18 Kayab reaches 1 Ahau 13 Mac. Correcting the 1 Ahau 13 Mac table in the same manner by subtracting 4 days from the 61st date, 5 Kan 7 Xul, gives 1 Ahau 3 Xul the Zero date of the table for the bottom row.

1 Ahau 18 Kayab
        add 4.12– 8–0
1 Ahau 18 Uo
        add 4.18–17–0
1 Ahau 13 Mac
        add 4.18–17–0
1 Ahau 3 Xul
        add 4.18–17–0
1 Ahau 18 Pax, etc.

From the beginning of the 1 Ahau 18 Kayab to the end of the 1 Ahau 3 Xul tables given on pages 46 to 50 of the manuscript is then 19.9–5–0 for 240 Venus revolutions, nearly 384 years. We do not know whether the Maya had been using tables like this long enough to know how often an 8-day correction should be made. We know that one group of 57 to four groups of 61 would be about right, but that does not tell us that the Maya knew it. It is evident, however, that they knew an average synodic revolution of Venus was less than 583.935 days, while our present figure for the same thing is 583.920. Since they knew the recession of Venus revolutions in the annual calendar, it is very probable that they also knew the recession of the nodes in the tzolkin discussed on pages 90 and 91. Both are of the same order of magnitude, the former being 5.2 days per pair of Calendar Rounds or per 104 years, while the latter is about 5.1 days for the same period. They recede in almost identical amounts, and we shall make use of this fact later.

Just as the tzolkins must be taken in pairs for the eclipses, so must the Calendar Rounds be paired for Venus. If there has been a heliacal rising at 1 Ahau 18 Kayab in one Calendar Round, then at 1 Ahau 18 Kayab of the second Calendar Round Venus will be just about as far away from inferior conjunction as possible; in the third Calendar Round, however, a heliacal rising will occur about 5 days before 1 Ahau 18 Kayab at 9 Men 13 Kayab (we are discussing here the planet itself and not the Venus table), the fourth would be blank again at that point so far as Venus is concerned; in the fifth, Venus would be at 4 Oc 8 Kayab; in the seventh, perhaps at 11 Kan 2 Kayab, etc. The date 1 Ahau 18 Kayab, in what we may call the odd Calendar Rounds, would see only one heliacal rising in about 6000 years, and the 1 Ahau 18 Kayab of even Calendar Rounds would alternate with it, so that only once in about 3000 years would any 1 Ahau 18 Kayab be associated with the end of a Venus synodic revolution. Even as the Zero date of a Venus table it would be in use only 91 years, being preceded by the 1 Ahau 3 Yaxkin table and followed by the 1 Ahau 18 Uo table. This is emphasized here to indicate that 1 Ahau 18 Kayab, or even 18 Kayab in general, is no more associated with Venus than is any other month position on which a heliacal rising occurred, and one occurs every 1.6 years.

The general idea of the table seems to be that the synodic revolution ends, for example, at 1 Ahau 18 Kayab—4 days after inferior conjunction; this probably applies to the average Venus revolution. For the short and long ones the distances would be about 8 days and 1 day, respectively. Further, if the average conjunction is 4 days before 18 Kayab at the beginning of a table it must be at least 8 days near the end of it, and the short ones would then be 12 days distant. It would seem natural to construct the table in this way, so that it was approximately correct for the average ones at the beginning, but we are only guessing when we say the Maya did so.

Having discussed the construction and use of the tables and their distance relations to each other, it remains to see whether we can give a Long Count date to one of them. On page 24 of the *Dresden Codex* we find the date 9.9.9–16–0, 1 Ahau 18 Kayab, and this may be the Zero date of the first table. On the other hand, alongside the two numbers we have already used from that page, we find a third number, 1.5.14–4–0. Now this number consists of 8 Calendar Rounds plus 4.12–8–0, the length of the 1 Ahau 18 Kayab table. If that is the intention, then the Zero date would be 10.10.11–12–0, 1 Ahau 18 Kayab. One of the two dates is probably correct, and whether we use the one or the other will only vary the end of the Venus revolution by about 20 days in its position in the annual calendar. If the first date is correct then at the second date there would be a heliacal rising of Venus about 20 days before 1 Ahau 18 Kayab.

All of the above statements are from the *Dresden Codex*. We get little help from the inscriptions. We find three or four different Venus glyphs from the manuscript, but they seem to be used indiscriminately for the various divisions of morning star, evening star, and the disappearances before conjunctions. There are several Venus glyphs in the inscriptions, but very few of them can possibly be the end of synodic revolution 4 days after conjunction; they may refer to any or all of the above divisions, or some may be points of greatest brilliancy or greatest elongation. I once thought the Venus sign in the introducing glyph of the date 9.12.16–7–8, 3 Lamat 16 Yax on Altar K at Copan surely gave us a definite point for end of a Venus revolution, and it may, for it would fit somewhat with either position of 1 Ahau 18 Kayab as given above, but the evidence is probably not sufficient. It would probably be fruitful for some one to collect data on every Venus glyph in the inscriptions and determine whether their dates could be arranged to give an intelligible meaning.

In the case of the eclipse table (page 91), we were left in doubt whether it began on 9.16.4–10–8 or some time within the next 375 years. So here with the 1 Ahau 18 Kayab Venus table we have the possibility that it began in 9.9.9–16–0 or 416 years later at 10.10.11–12–0. We are, however, able to make one deduction from the recession of the nodes in the tzolkin and of Venus in the year, provided we can assume an unbroken calendar up to the present. The two tables were both early or both late. The eclipse table as given was valid beginning within 50 years before or after the beginning of the 1 Ahau 18 Uo Venus table. If the eclipse table is dated 9.16.4–10–8, then the 1 Ahau 18 Kayab was 9.9.9–16–0. If the latter was 10.10.11–12–0, then the eclipse table must date somewhere between 10.12.0–0–0 and 10.17.0–0–0. In the former case the Zero dates of the Venus tables are—

9. 9. 9–16–0, 1 Ahau 18 Kayab
9.14. 2– 6–0, 1 Ahau 18 Uo
9.19. 1– 5–0, 1 Ahau 13 Mac
10. 4. 0– 4–0, 1 Ahau 3 Xul
10. 8.19– 3–0, end of 1 Ahau 3 Xul table at 1 Ahau 18 Pax.

In the latter case the Zero dates of the Venus tables are—

10.10.11–12–0, 1 Ahau 18 Kayab
10.15. 4– 2–0, 1 Ahau 18 Uo
11. 0. 3– 1–0, 1 Ahau 13 Mac
11. 5. 2– 0–0, 1 Ahau 3 Xul
11.10. 0–17–0, 1 Ahau 18 Pax end of 1 Ahau 3 Xul table.

It is unfortunate that we must leave the Venus tables with such a lapse between the possible dates, and the eclipse table with only the limits of possible dates determined, but we have made some progress in reaching the above conclusions, and there is a clear possibility that other workers may narrow the limits to a satisfactory point.

SIXTEENTH CENTURY CALENDAR

We have had a glimpse of Maya astronomy at the time of the inscriptions and another at the time of the *Dresden Codex*. From the former we know new moon days in the Long Count, and within certain limits we know eclipse syzygies. We know from the Copan monuments that 9.16.4–10–8 was an ecliptic conjunction (not necessarily an eclipse visible in Central America), and the node day was either 9.16.4–10–7, 11 Manik, or some time within the next 19 days.

From the *Dresden Codex* we learned the method of handling eclipse and Venus tables, and if we can assume no calendar break between the inscriptions and the codices we know that a Venus revolution ended at heliacal rising about 9.9.9–16–0 or 10.10.11–12–0, 1 Ahau 18 Kayab. In the former case we can compute another revolution ending on 9.16.4–9–4 and inferior conjunction about 9.16.4–9–0 or a little earlier—at least 27 days before node conjunction. Using the later date for 1 Ahau 18 Kayab, we get inferior conjunction at about 9.16.4–10–0 or a little earlier, and again this must be about 27 days before node conjunction, which might in this case be as late as day 184 or 186. In either case we have an inferior conjunction of Venus somewhere in the neighborhood of 9.16.4–9–0, 10 Ahau 13 Mac, or 9.16.4–10–0, 4 Ahau 13 Kankin, about 27 days before a node day; and every two Calendar Rounds, less about 5 days, this Venus conjunction will recur, and is recurring today once every 104 years. In 1040 years it will recede only about 52 days from 10 Ahau 13 Mac or 4 Ahau 13 Kankin, whichever we start from, and will still be about 27 days from the node day.

These deductions seem reliable but they are not sufficient of themselves to establish a correlation, although very satisfactory for picking flaws in proposed ones. The Venus conjunction is not defined with sufficient accuracy; the spread of 19 days in the possible date of node conjunction is too great. If we had two such dates definitely fixed as I once thought I had, we could arrive at a correlation. Some day we may recover the missing data; then the whole correlation can be deduced from the inscriptions, which is the only satisfactory way. As soon as we bring into account the codices, or the Sixteenth Century calendar which the Spaniards found in operation, we are at once faced with the important question whether the calendar had undergone any adjustment since the time of the inscriptions. No one can answer this in the negative with any certainty. There was no adjustment during the time of the inscriptions, unless it was on the last few monuments at Quirigua, which we have not used for that reason. A gain or loss of a few days in the whole calendar between the inscriptions and the codices or between the codices and Spanish times need not trouble us seriously, but any change such as Pope Gregory made in our calendar when Thursday, October 4, was followed by Friday, October 15, would leave us at sea. It is well for us to bear this in mind continually. Any correlation based on data of early Spanish times presupposes an unbroken calendar from the time of the inscriptions—a premise that is quite doubtful and for which very little evidence could be furnished.

With these precautionary warnings, since we can not derive a correlation from the inscriptions alone at present, we will assume an unbroken calendar up to Spanish times and see whether the application of the Sixteenth Century calendar to our deductions from the inscriptions and codices may not at least limit the number of proposed correlations. I do not feel competent to offer any critical analysis of the Sixteenth Century data, but simply accept what has been gathered by Dr. Morley, Mr. Martinez and other workers. There are many conflicting statements, but there seems to be fairly general agreement on the following points:

1. The year bearers were known. These are the tzolkin days that introduce the month Pop in the Maya year. During the inscriptions the year bearer was probably unknown, but 0 Pop was the day emphasized, whether for ending the old year or beginning the new one, and only days Ik, Manik, Eb and Caban could fall on 0 Pop. In the time of the codices there may have been year bearers, but the monthly position selected was 1 Pop, and

only days Akbal, Lamat, Ben and Eznab could fall on that day. In the sixteenth century there were surely year bearers and they were Kan, Muluc, Ix and Cauac—days that would fall on 2 Pop in the inscriptions but now are said to be on first of Pop. If we are told that 8 Cauac was the year bearer in 1536, it means that 8 Cauac 2 Pop occurred some time during that year and began a new Maya year. From one of these we can practically deduce all the others, and the many year bearer statements for different years are in excellent agreement, with only 4 or 5 exceptions.

(2) The position of the year bearer is known in the Christian year. We have only two statements on this point, but they almost agree. In one case Bishop Landa, in a double calendar, places 12 Kan first of Pop opposite July 16; since 12 Kan was the year bearer for 1553, this must have been 12 Kan 2 Pop = July 16, 1553. In the other case recorded in the Chilan Balam books, Maya sages gathered at Bacalar determined that 11 Chuen 18 (19) Zac was February 15, 1544; in a critical examination Martinez has shown that this was probably February 18, 1544. Computed from the Landa date it should have been February 21, 1544, only a 3-day discrepancy. Incidentally this 11 Chuen 19 Zac was probably a determinant or anniversary of something, but we are left to guess what relation is intended. With these two dates in such near agreement, we can use either as a starting point and spread out the whole Maya calendar past and future, so far as giving a Calendar Round date to any Christian date; but any Calendar Round date recurs every 52 years, so we are unable to give the positions in the Long Count. We can list every Christian date on which 13 Ahau 18 Cumhu fell, but we have no means of knowing which was 9.17.0-0-0, 13 Ahau 18 Cumhu.

(3) A Katun 13 Ahau ended in 1536 according to some statements, 1539 according to another, and about 1542 or 1543 according to others.

Add to these our deductions from the inscriptions and the codices.

(4) We know new moon days; for example, 9.16.4-10-8 12 Lamat 1 Muan was a new moon day.

(5) We know something of eclipses from the last four moon groups recorded at Copan. The date 9.16.4-10-8, day 168, was an ecliptic conjunction and the node day was not earlier than day 167 nor later than day 186 of that tzolkin, which is equivalent to saying that the *Dresden Codex* table is not more than 375 years later than Stela M at Copan.

(6) A Venus revolution ended at 1 Ahau 18 Kayab, which was either 9.9.9-16-0 or 10.10.11-12-0. In either case a Venus inferior conjunction occurred on or just before 9.16.4-9-0, or 9.16.4-10-0, that is about day 140 or day 160 of the same tzolkin as the ecliptic conjunction mentioned in No. 5 above.

(7) We are assuming that no shift or serious interruption of the calendar had occurred between the inscriptions and Spanish times.

Let us consider these seven points, starting with No. 3 as the simplest: that a Katun 13 Ahau ended somewhere between 1536 and 1543.

(*A*) There is a list of tuns given in the Chronicle of Oxkutzkab and month positions are also given. Among them is the statement that a tun ended in 1539 on a day 13 Ahau 8 Xul. If we accept this statement there is little more to be done. A tun ending on a given day *and* month position only recurs once in 936 years, so we need consider only three here:

9. 8.11–0–0, 13 Ahau 8 Xul
11.16. 0–0–0, 13 Ahau 8 Xul
14. 3. 9–0–0, 13 Ahau 8 Xul

The first is much too early for Spanish times, being in the very middle of the inscriptions; and the last is much too late as it would end all inscriptions before the year 1 A.D. This leaves only 11.16.0–0–0, 13 Ahau 8 Xul, which also ended a katun in 1539 as No. 3 requires, and satisfies all the 7 points as well if we place it at November 3, 1539, which is in accord with the Landa position in No. 2. Yet some do not accept the statement of this chronicle as final, so we will proceed.

(*B*) Suppose we do not know the month position but simply have the general statement that a Katun 13 Ahau ended about 1536 to 1543. 13 Ahau occurs only once in 260 days and it is easy to enumerate the 10 or 12 that occurred during these years, with their month positions, and select the katuns that they could end. This is easy because a given day *and* month position only recurs as a katun ending about once in 18,000 years. The only ones we need consider are—

No. 1	10.10.0–0–0,	13 Ahau 13 Mol	1546
No. 2	11. 3.0–0–0,	13 Ahau 13 Pax	1543
No. 3	11.16.0–0–0,	13 Ahau 8 Xul	1539
No. 4	12. 9.0–0–0,	13 Ahau 8 Kankin	1536
No. 5	13. 2.0–0–0,	13 Ahau 3 Zotz	1532

Even the first and last of these are beyond our 1536 to 1543 limits, so there is no occasion to discuss them. Numbers 2 and 4, if given their proper dates according to our point No. 2, February 10, 1543, and April 12, 1536, respectively, do not agree with the new moon days in our point No. 4, nor with the node days in point No. 5, nor with the Venus dates in point No. 6. In fact, they are in the wrong Calendar Round entirely to have any relation to our 1 Ahau 18 Kayab Venus dates. This leaves the middle one, No. 3 11.16.0–0–0, 13 Ahau 8 Xul, November 3, 1539, as the only possibility. It is the same date we found under (*A*) and agrees with all the other points.

(*C*) This seems to exhaust the Katun 13 Ahau possibilities for the moment, so let us turn to point No. 2 and accept a date 12 Kan 2 Pop as July 16, 1553. This leads to a date 12 Lamat 1 Muan on April 26, 1535 Julian, and again on April 23, 1587 Gregorian. But the 12 Lamat 1 Muan of Stela M Copan, day 168, had a node conjunction on day 167 to 185, which has been receding in the tzolkin at the rate of about 5 days per hundred years. Now we find that our 1535 date has a node conjunction about 108 days before it, consequently this can not be the lineal successor of the Stela

M date, unless Stela M is well over 2000 years before 1535. We are in the wrong tzolkin; the 12 Lamat of 1535 is day 428 and not 168; so we take the 1587 date one Calendar Round later and find that there is a node conjunction about 24 days before it—at day 144 of the tzolkin. From this we deduce that the *Dresden Codex* table is approximately 480 years before 1587, that is a little after 1100 A.D. and that the 9.16.4–10–8 of Stela M is April 23, 1587 Gregorian, minus some even number of Calendar Rounds, not less than 4 double Calendar Rounds nor more than 8. From this we have the following possible dates for 9.16.4–10–8, 12 Lamat 1 Muan:

July 26, 1171
August 21, 1067
September 16, 963
October 12, 859
November 7, 755

But 9.16.4–10–8 must be both a new moon and ecliptic conjunction. All the above are near enough to node day to satisfy ecliptic conjunctions, but only one is near enough to new moon day, and this is the last one, November 7, 755, which is within one day of the new moon on November 8, 755. If we accept this as the date of 9.16.4–10–8 it leads again to 11.16.0–0–0, 13 Ahau 8 Xul for November 3, 1539, the same value reached in (*A*) and (*B*). One other date in the above list must be considered, that is September 16, 963, which is only 4 days from new moon at September 20, 963. Accepting this latter date would place 12 Kan 2 Pop in 1553 on July 20 instead of July 16, and would make 11.5.9–2–0, 13 Ahau 8 Xul fall on November 7, 1539, with no katun ending of any kind between 1530 and 1550.

(*D*) If we use the 11 Chuen 19 Zac date of point No. 2 as February 18, 1544, it moves the possible date of the *Dresden* table about 60 years as it stands, but it makes no change in our list of 5 dates given under (*C*), except to move each one 3 days earlier. This leaves November 4, 755, the nearest to a new moon date again, and that must be moved 4 days to November 8, 755, to coincide with new moon, which brings us again to 11.16.0–0–0, 13 Ahau 8 Xul for November 3, 1539.

(*E*) Suppose we now disregard both points Nos. 2 and 3 and adhere only to point No. 1 in Spanish times, *i.e.*, that the year bearers as given are correct, that there has been no real shift in the calendar but it may have gained or lost 20 or 30 days since the time of the inscriptions. By combining points Nos. 1, 5 and 6 and assuming that the *Dresden Codex* table was valid somewhere between 200 and 1400 A.D., it can be shown by a simple but very tedious analysis that the 12 Kan 2 Pop of July 16, 1553, could not have been earlier than June 29 nor later than August 17 and still have the year bearers given from 1392 onward correct. Table 9 gives, I think, the only reasonable dates for 9.16.4–10–8, 12 Lamat 1 Muan which would make it an ecliptic conjunction falling not more than 1 day after a node day, nor more than 18 days before one, and so situated that 12 Kan 2 Pop would fall between June 29 and August 17, 1553. The second column gives the date for 9.16.4–10–8, the third column the node day on that date which must lie between 167 and 186. Column 4 gives the approximate day on which 12 Kan 2 Pop would fall in 1553, and Column 5 the tun of the Long Count which would fall in 1539. Dates before 340 A.D. make 12 Kan 2 Pop fall after August 17 in 1553.

TABLE 9—*Several equivalents in Christian chronology for the date 9.16.4–10–8.*

No.	Date of 9.16.4–10–8	Node day 9.16.4–10–8	12 Kan 2 Pop 1553	Date Dresden Eclipse Table	Tun ending in 1539
1	Mar. 14, 340	182	Aug. 11	640	12.17.1–0–0
2	Jan. 26, 548	168	Aug. 11	570	12.6.11–0–0
3	Dec. 18, 651	175	July 31	810	12.1.5–0–0
4	Nov. 8, 755	185	July 16	1110	11.16.0–0–0
5	Sept. 20, 963	171	July 20	1040	11.5.9–0–0
6	Aug. 12, 1067	179	July 7	1300	11.0.3–0–0
7	June 24, 1275	166	July 10	1275	10.9.13–0–0

These seven are the only dates falling within our limits, but we can reduce the number still further. It will be noticed that all the dates are in a series of multiples of 65 Venus revolutions, or nearly 104 years. This series continued would reach a Venus conjunction on December 1, 1898, nearly 28 days before node conjunction on December 29, 1898. You remember that Venus and node conjunction both recede, the former in the vague year, the latter in the tzolkin at about the same rate. In 1275 the Venus conjunction was also a Venus transit and is recorded by La Lande as occurring May 25, also 28 days before node conjunction. The same 28 days holds for all the above seven dates. But from our point, No. 6, a Venus conjunction occurred either on or just before 9.16.4–9–0, day 140, or 9.16.4–10–0, day 160, consequently the node days were 168 or just before, or 188 or just before. This eliminates Nos. 1, 3, 5 and 6, leaving only Nos. 2, 4 and 7.

No. 2 would date Stela M at Copan in 548 and would give the *Dresden* eclipse table the same date; it would make the Zero date of the 1 Ahau 18 Kayab Venus table in 9.9.9–16–0; it would make Landa's calendar in error 26 days, and the nearest katuns in early Spanish times would be 12.6.0–0–0, 6 Ahau 3 Zac in 1529, and 12.7.0–0–0, 4 Ahau 3 Xul in 1548.

No. 7 dates Stela M in 1275, giving *Dresden* eclipse table the same date; makes the Venus table 9.9.9–16–0, 1 Ahau 18 Kayab; makes Landa's calendar 6 days in error, and gives a katun 13 Ahau, 10.10.0–0–0, 13 Ahau 13 Mol in 1546—a date which we rejected under (*B*).

No. 4 dates Stela M in 755 and the *Dresden* table about 1120. The Zero date of 1 Ahau 18 Kayab table becomes 10.10.11–12–0, the *Dresden* table about 10.15.0–0–0 plus or minus a katun, and Landa's calendar is exact or not more than 1 day in error, and a Katun 13 Ahau, 11.16.0–0–0, 13 Ahau 8 Xul ends in 1539.

These three seem to be the only dates we need to consider if there is an almost unbroken calendar sequence between the inscriptions and the Sixteenth Century. Of these three dates No. 4 meets all our conditions, while No. 2 and No. 7 do not satisfy our points Nos. 2 or 3, and only partly satisfy point No. 7, having a break of 6 and 26 days respectively in the sequence.

In every experiment we have made in this section the 11.16.0–0–0 date appears either as the best or as the only answer. If there was only one Maya calendar in use in the Sixteenth Century, and if there was an unbroken sequence or nearly so, and if our fugitive data regarding the calendar in Spanish times is correct, then this is our correlation; 11.16.0–0–0 = November 3, 1539. Hence I have used it for purposes of comparison of different dates. But was there only one Maya calendar in use in the Maya chronicles, and was there an unbroken sequence, and how accurate were Landa's figures and those of the Indians at Bacalar? I do not think any one of these three questions can be answered with certainty now, hence I shall not be entirely satisfied with any correlation until we can derive one from the inscriptions alone.

CORRELATIONS

We have developed in preceding pages a large amount of Maya astronomy, and we are now in a position to organize it for use in examining correlations. From the inscriptions alone we have only two points that are usable:

(1) We can give the moon position rather accurately for any Long Count date in the inscriptions, and of course can compute it correctly from them to more recent periods.

(2) We know, from the beginning of the moon-eclipse system of moon numbering at Copan on Stela M and its continuation on Stela N and Temple 11, that the sun was in conjunction with the moon's node between day 164 and day 186 of the tzolkin in which 9.16.4–10–8, day 168, was an eclipse syzygy.

I formerly thought we had a third point in a definite Venus heliacal date, but as I see it now there is not sufficient evidence in the inscriptions alone to prove it. There are too many other Venus symbols of unknown meaning which still await elucidation. The two points alone mentioned above are far from sufficient to give a correlation.

From the *Dresden Codex* we get two more points on the assumption that the codex is later than the inscriptions and that there is no break or shift between them.

(3) The Codex eclipse table has node day 167 at the start, and since this table is not earlier than Stela M, the node day at 9.16.4–10–8 must lie between 167 and 186.

(4) There was a Venus heliacal rising about 9.9.9–16–0 or 10.10.11–12–0, and consequently a Venus inferior conjunction about 9.16.4–9–0, or 9.16.4–

10–0, depending on which of the two dates for 1 Ahau 18 Kayab is correct. That is, the Venus conjunction was about 8 or 28 days before the eclipse syzygy at 12 Lamat 1 Muan and about 7 to 26 , or 27 to 46 days, before node conjunction. At every two Calendar Rounds there will be a Venus conjunction near 12 Lamat 1 Muan, about 5 days earlier in the calendar than the preceding one and keeping a nearly uniform distance from the node day.

So much we get from the inscriptions and codices; these are still insufficient data for a definite correlation. If the spread between Venus conjunction and node conjunction were not so indefinite it would be worth a trial such as I attempted in the *American Anthropologist* (page 283, 1927). We must either have more data or call on the Sixteenth Century evidence for a suggestion as to where 12 Lamat 1 Muan is now.

(5) If the year bearers of 1392 to 1800 are correct and there has been no shift or change in the calendar, then 12 Kan 2 Pop was July 16, 1553, as given by Landa, or let us say within 20 or 30 days of that date.

Point No. 5 enables us to place a 12 Lamat 1 Muan at February 6, 1899, plus or minus about 20 days. There was a Venus conjunction December 1, 1898, 67 plus or minus 20 days before it, and a node conjunction on December 29, 1898, nearly 28 days after the Venus conjunction. Of course there was another 12 Lamat 1 Muan, one Calendar Round earlier in 1847, and there will be still another one Calendar Round later in 1951; but since no Venus conjunction occurred within 200 days of either one they are an odd number of Calendar Rounds from 9.16.4–10–8 and do not concern us here.

The 28 days between Venus and node conjunction in 1898 will be about 27 days at 9.16.4–10–8, consequently we know that the node day at Stela M was either very close to day 167 or very close to day 185, but was not for example anywhere between day 170 and day 180.

We come now to a comparison of some correlations, taking first those that agree essentially with the Landa date.

(*A*) The equation 11.16.0–0–0, 13 Ahau 8 Xul = November 3, 1539. This is the correlation which emerges from every test made in the preceding pages. It was first announced by Goodman, I think in 1905, later revived by Juan Martinez Hernandez in 1926, and supported by J. Eric Thompson in 1927. Whether we use Landa's 12 Kan 2 Pop = July 16, 1553, or the Bacalar Indians 11 Chuan 19 Zac = February 15, 1544, or Martinez's correction of this to February 18, 1544, is immaterial because all must lead to 9.16.4–10–8, 12 Lamat 1 Muan = November 8, 755, as an eclipse syzygy at day 168, node day being about day 185, Venus conjunction about day 158 at 9.16.4–9–18. This satisfies all the conditions of this section.

(*B*) Two other dates for 9.16.4–10–8 mentioned in the previous pages would satisfy all our present conditions; they are January 26, 548 and June 24, 1275; they have little connection with Spanish times, except that they bring the annual calendar nearly into line with Landa's date. The 548 date was also worked out among others from the inscriptions alone. Since no one has seriously proposed either of these as being the right correlation they need not detain us now. The September 20, 963, date for 9.16.4–10–8 is nearly as good.

(*C*) The equation 12.9.0–0–0, 13 Ahau 8 Kankin = April 12, 1536. This correlation proposed by Spinden has been rather widely used, but so far as I know no one has submitted it to a critical examination. This correlation places 9.16.4–10–8 on January 11, 496. The date is not a new moon day but is 10 or 11 days after new moon, consequently it disagrees with our point No. 1—in fact it disagrees with the Supplementary Series of the inscriptions throughout. The date is not an eclipse syzygy as called for by point No. 2; the nearest eclipse syzygy given by Oppolzer is 69 or 70 days before it. Instead of having node conjunction not over one day before 12 Lamat as called for in our point No. 3, it appears by this correlation to be about 56 days before 12 Lamat. Finally, instead of having Venus conjunction some 8 or 28 days before 12 Lamat as called for by our point No. 4, we find no Venus conjunction within about 280 days in either direction—just about as far away as possible. The 12.9.0–0–0 correlation gives a 12 Lamat 1 Muan in the wrong Calendar Round and consequently in the wrong tzolkin to correspond with 9.16.4–10–8. This correlation does not furnish a single agreement with anything that we have found from the inscriptions alone, or from the inscriptions and codices combined.

We should not be surprised to find such a condition, as this correlation was deduced by Dr. Morley solely from Sixteenth Century chronicles, and not until several years later did Dr. Spinden in *The Reduction of Mayan Dates* attempt to relate 12.9.0–0–0, 13 Ahau 8 Kankin to the inscriptions. It is not quite clear whether the author of this book intended to furnish evidence of the correctness of the correlation, or whether the latter was admittedly correct to begin with and he simply gives lists of dates reached by the inscriptions. If the latter is the case, we should have no argument with the book, provided only we could admit the postulate of correctness at the outset. If, however, it purports to give evidence from the inscriptions in favor of the particular correlation then we should examine the evidence.

The author apparently relies on the incidence of certain Mayan dates, by his correlation, in the neighborhood of ten points in the Christian year; these are, first, the three anniversaries of Baktun 13, Baktun 7 and Baktun 9; second, the four equinoxes and solstices; and third, three points in the "Farmers Year." Now the Mayan anniversaries of Baktun 13, 7 and 9 will of necessity still be anniversaries regardless of what correlation is used. They of course can not be used as evidence either for or against any correlation whatever. Next, the four equinoxes and solstices—if there are 1500 or 2000 known Mayan dates, every one of them must fall on some one of the 365 days of our vague year, say an average of 4 every day, or 16 for the four equinoxes and solstices. If we allow only 1 day leeway on each side, we may expect about 50 equinoctial and solstitial dates for any correlation you care to suggest, and if we list "approximations" and permit Calendar Round shifts as the author does, we see at once the unreliability of such data as evidence of any correlation.[1] Finally, consider the "Farmers Year" dates; so far as I can learn, the idea of a farmer's year with two important dates equivalent to April 5 and September 6, which were later shifted to April 9 and September 2, did not exist until it was invented by the author to fit the supposed Christian dates. Now that the "Great Sun Dial of Copan" has been read as April 12 and August 30, instead of the above dates with no physical possibility of a shift having been made, any connection between the "Farmers Year" and the "Sun Dial" seems vague. In any case the "approximations" to the "Farmers Year stations" used by the author have such a spread that, like the equinoxes and soltices, they can scarcely be used as evidence for any correlation. It is just as convincing to accept Thompson's suggestion that August 30 was the only date used on the sundial, and that it was the anniversary of the original 0 Pop near Baktun 13, as called for by the 11.16.0-0-0 correlation, but I am not inclined to stress this either. Except in pages 101(C)ff, I have avoided any deduction that was dependent on a particular correlation, or on a special position in our Gregorian year.

I have never been particularly impressed by the reasons given for assuming that Stelæ 10 and 12 at Copan were intended as a sun dial or astronomical base line. Any two objects whatever, in space, give a line of sight if one is visible from the other. If this line of sight cuts the horizon or any part of the sky it might be astronomical, and an intersection at the western or eastern eighths of the horizon, anywhere over one-fourth of the whole 360°, would be just as much a sun dial as this one at Copan. Moreover, anyone who has read the report of the last party at the sun dial, their struggle to reach Stela 12, and their inability to see Stela 10 five miles away until another party had lighted a fire behind it, will realize at once its inconvenience and general deficiencies as a sun dial. A line of sight 250 feet long would have served every purpose in determining the day that this five-mile one could possibly have served, and the Maya have shown themselves good enough astronomers to know it.

The above rather long discussion of the Spinden correlation has been given simply because this is the one most frequently used, especially by writers of popular articles. If our deductions are correct, however, this correlation can not possibly be correct, and the users who quote it as one of the established facts of Maya history are fostering a belief which in all probability must be corrected later. On the other hand the Goodman correlation may not be correct either for the inscriptions, but at least it does not disagree violently with their indications at any point. These are

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[1] The same remarks apply to Dr. Spinden's *Maya Inscriptions dealing with Venus and the Moon*, Bull. Buffalo Soc. Nat. Sci., vol. XIV, 1928. If this article is meant to present evidence of his correlation, I am quite unable to follow the argument.

the only two correlations in close agreement with Landa's typical year which have attracted any serious following, and as far as the inscriptions are concerned one can say unhesitatingly that that of Goodman is possible while that of Spinden is certainly very improbable.

(*D*) There is another series of correlations which do not agree with Landa's typical year but still do make use of some information from early Spanish times. Such is Morley's, which places 12.9.0–0–0, 13 Ahau 8 Kankin around 260 days later in the year 1536 or 1537 than would agree with Landa's statement. This could be placed at a date giving general agreement with the inscriptions, except in one point; it calls for Venus conjunction near 9.16.4–10–8 several days later than the node conjunction, while the reverse is quite surely the case.

The correlation of Joyce which is derived from that of Bowditch falls in the same series. This places the year 4 Kan in 1536 instead of 1545 as agreement with Landa would demand. Joyce's correlation places 9.16.4–10–8 on March 15, 227, not a new moon day but 10 days from one, not an eclipse syzygy but 49 days from one, and too far away from node conjunction or Venus conjunction to be comparable with our 12 Lamat 1 Muan. There is no agreement at all between this correlation and our deductions from the inscriptions.

(*E*) A third series attempts to reconstruct a correlation from the inscriptions alone, or the inscriptions and codices, disregarding entirely the katuns, year bearers and annual calendar of the early Sixteenth Century. This is done by Willson, who places 9.16.4–10–8 on October 29, 357. This correlation is based on inscription and codex data for new moon, eclipse syzygy, and Venus, consequently it affords fairly close agreement within the limits of our deductions on those points; it places the node conjunction, however, about day 156 of the tzolkin, while we deduce that node day could not be earlier than day 167. Willson, of course, did not take into consideration the position of node day at all; his determining factor for choosing between the many dates on which the eclipse syzygy was the right distance from Venus was the supposed configuration of Mars. I have not used this because it seems very doubtful whether we know how to use the Mars tables, or in fact whether they are really Mars tables at all. The same remarks apply to the other two dates worked out by Willson, July 15, 223, and February 14, 492.

(*F*) We may place in the same general category of dates based on the inscriptions and the *Dresden Codex* alone those which I have suggested in previous articles as possible equivalents for 9.16.4–10–8, such as,

December 14,	46 B.C.
June 6,	327 A.D.
November 22,	504
January 26,	548
May 16,	877
January 5,	1098

All the above dates presuppose node day at day 167 near 9.16.4–10–8, instead of allowing the broader limits 167 to 186; and Venus conjunction between days 139 and 149, instead of extending the possibility as we do up to day 160. In reaching the narrower limits used for these 6 dates it was postulated that Altar K at Copan, 9.12.16–7–8, represents a heliacal rising of Venus according to the Venus table, and that the eclipse table is definitely dated at 9.16.4–10–8. Both these are possibilities, but I am compelled to think now that we are not warranted in limiting ourselves so narrowly. If we disregard the calendar of early Spanish times, as we are attempting to do here, and use the broad limits outlined under points 1 to 4 at the beginning of this section, then these dates under discussion only become a particular 6 out of many that might be named. The fourth of the dates given, January 26, 548, happens to vary from Landa's calendar statement by only 26 days, and has been mentioned under (*E*) (page 103) and (*B*) (page 105). The third date, November 22, 504, differs from Landa's by just 9 tuns.

Many other general suggestions regarding correlations have been made, such as that a certain stela was erected during the First Century A.D., or about the Tenth Century. Such statements are too indefinite for us to examine profitably on the basis of our deductions from the inscriptions and codices alone. We conclude this section, then, much as we did the preceding one. There is not yet sufficient data available from the inscriptions either alone or with the *Dresden Codex* to determine a correlation. I have hope that sufficient data will ultimately be available from these sources alone. If we assume that the statements of early Spanish times all refer to a single calendar, and that this is the same as used in the inscriptions with no interruption, then we are forced to the correlation 11.16.0–0–0 = November 3, 1539, which is the same as 9.16.4–10–8 = November 8, 755. If we waive all Sixteenth Century information except year bearers, we arrive at the same correlation, or at most vary from it only by multiples of 65 synodical Venus revolutions, or approximately 104 year periods. We are at the point where just a little more definite information may clear up the whole matter. No correlation will fit every statement in the chronicles of Spanish times and also fit the requirements of the inscriptions and the codices. Each one must select for himself such data as he deems reliable, remembering always that the dates in the inscriptions are the ones to be correlated with our Christian chronology. It would be desirable if those interested could reach some agreement regarding the validity of deductions from the inscriptions and from the *Dresden Codex* that have been made, the comparative probability of conflicting statements in the chronicles, the likelihood of an uninterrupted calendar from inscriptions to codex and from codex to Sixteenth Century, and, if interrupted, the character and probable limits of the change. In the meantime if one must use a correlation, then Goodman's 11.16.0–0–0 = November 3, 1539, seems to meet fewest objections, although I am far from being convinced yet that it is the correct one.

CONCLUSIONS

The foregoing sketchy and incomplete statement of Maya astronomical knowledge still gives an outline of their attainments, so far as we now know them. For 522 years, from 8.16.0-0-0 to 10.2.10-0-0, they recorded the age of the moon at a great many intervening dates. These records show both contemporaneous agreements between cities and chronological agreements between early and late dates, so that for any newly discovered dated monument from Mexico, Honduras, British Honduras or Guatemala, we are prepared to predict the moon age recorded, with an error of not over a couple of days. The only real exception is the city of Quirigua for the last twenty years of its existence. Apparently all Maya peoples who erected monuments used an identical calendar, and it suffered no interruption during these 522 years, except possibly temporary ones due to human frailty, such as we make when we can't remember whether today is Friday the 30th or Saturday the 31st. For about 110 years of the whole period we can also predict the moon numbering in the lunar year. From 9.12.15-0-0 to 9.16.5-0-0, 70 years, it was uniform everywhere; then Copan adopted a moon eclipse system which we can closely predict, and Quirigua reverted to a previous Palenque system beginning the lunar year one moon later than the other cities, which we can also predict.

We know their idea regarding average length of a moon for purposes of computation at three different periods. First, at Palenque when the Initial Series were written probably not long before 9.13.0-0-0, it was 29.53086 days, the formula being 81 moons = 2392 days. Second, at Copan at least after 9.13.0-0-0, and probably at all cities using the uniform system of moon numbering it was 29.53020 days, from the formula 149 moons = 4400 days. Finally, later at the time of the *Dresden Codex* the Palenque formula had been resumed.

We know something of their ideas regarding the length of the tropical year. At Copan after 9.14.0-0-0 it was 365.2420 days computed by the formulæ 19 years = 235 moons and 149 moons = 4400 days. This is just a little shorter than our present-day computation, and still shorter than the Gregorian year of 365.2425 days. At Palenque, in the later years before 9.13.0-0-0, it was about 365.2430 days, probably from the formula 144 years = 146 tuns or 144 vague years, plus 35 days. This is a little longer than the Gregorian year, and seems to be about identical with the one used at Copan about the same time. The earliest determinations at Palenque seem to show a year a little shorter than the Gregorian. One gathers the impression at Palenque that they were weighing the comparative merits of a number of successive formulæ, among them being one that nearly corresponds to our Julian year. Isolated examples from Yaxchilan, Piedras Negras, El Cayo, etc., indicate that all the cities probably knew a tropical year of the approximate accuracy of our Gregorian year. Finally, for a period of about 25 years after 9.16.5–0–0, Quirigua seems to have used approximately the Julian year computed from the formulas 19 years = 235 moons and 81 moons = 2392 days.

In the matter of eclipses very little has as yet been identified in the inscriptions. In the *Dresden Codex*, however, we find a fully developed lunar eclipse table giving a series of eclipse syzygies over a period of 33 years, and grouping the moons in sixes and fives so that the ends of the groups always reach these syzygies. We also find a prominent date in the context, 9.16.4–10–8, 12 Lamat 1 Muan. When we find this same date reached by the moon grouping on Stela M at Copan, and when we find the succeeding dates at Copan with moon groupings which would fit such a system of eclipse syzygies, we feel warranted in saying that the Maya, of the later inscriptions at least, were familiar with the general method of eclipse occurrence, and that Stela M at Copan, 9.16.5–0–0, is the place where they first adopted a lunar eclipse year to replace their former 12-moon lunar year arrangement of moons.

Our information regarding Venus likewise comes largely from the *Dresden Codex*. We find there reference to four tables of the movements of Venus, the first, third and fourth given in full, but of the second only the zero date is given. From the beginning of the first to the end of the last table covers a period of 384 years. We learn here their method of constructing the tables, of making necessary corrections in them, and their probable connection with the Long Count of the inscriptions. The average length of a Venus synodic revolution is now computed at 583.920 days; the Maya computation was a little shorter than 583.935 days, but we do not know just how much more accurate it was. The inscriptions contain numerous Venus glyphs, but comparatively few of them could have represented heliacal risings of the planet, and our knowledge of the glyph variations is insufficient for us to positively select the proper ones without the aid of the *Dresden Codex*.

Both Förstemann and Willson recognize Mars, Jupiter and Saturn tables in the *Dresden Codex*, but I have not been able to convince myself fully that they exist; if they do exist I do not know how to use them.

This is rather a startling array of astronomical information to be possessed by barbarous Indians 1000 to 1500 years ago, completely isolated from the Old World civilizations; in fact it is probably somewhat in advance of that possessed by our own noble ancestors at that time. But there still is no doubt much more to be obtained from the inscriptions: For example,

(1) We have shown the remarkable accuracy in computing the advance of the tropical year through the vague year. But this accuracy and the computation itself can be the result only of long series of recorded observations. How did the Maya determine the passage of a year? Was it by observation of equinox, solstice, sun overhead, or line of sight to the rising

or setting sun, and are there glyphs in the inscriptions recording such observations? I think there must be.

(2) The Venus tables must also be the result of observations recorded over long periods of time, and these records are no doubt in the inscriptions. Someone must isolate all the Venus glyphs and dates and study them.

(3) Likewise the eclipse tables. There are no doubt many eclipse records before us, but no one has yet surely identified an eclipse hieroglyph or a certain reference to an eclipse. None of the supposed eclipse syzygies at Copan are necessarily visible eclipses. See Addendum, page 115.

(4) Before the time of uniform moon numbering there was no agreement between cities, but it may be possible to take all the dates from a single city and determine the system used. Do they show a relation to the tzolkin, to the vague year, to the tropical year, or to something else?

(5) I have given some evidence of a relation between Glyph X of the Supplementary Series and the moon number. Can we determine this relation in full and does it throw any light on the meaning of Glyph X?

(6) The significance of the faces in Glyph C of the Supplementary Series still evades us.

(7) The legged kin signs and other symbols sometimes with coefficients, found in the Supplementary Series at Yaxchilan frequently and a few times at other cities, are intriguing. I haven't the vaguest idea of their meaning, but since they are numerical a solution would likely be very helpful.

(8) All forms of Glyph G, except the kin maize form, should be carefully searched out and redrawn from the originals, so that their essential characteristics may be more fully determined than Thompson was able to do with the few examples available. These are not only of value in deciding between possible dates for an Initial Series that is partly illegible, but their use may have persisted after the Long Count ceased, in which case they would be of aid in determining tun endings. If they really represent Lords of the Night, we may find some of them almost up to Spanish times.

(9) I have pointed out a few glyphs which seem to refer to determinants and to end of computed years. If my general idea of determinants should be accepted, it would be helpful to segregate and classify all these glyphs. If their general meaning is once ascertained, it will at least reduce the number of unknowns still to be studied.

(10) To my untrained eye the inscriptions at Yaxchilan seem to stand apart from those of all other cities of the central zone, with the exception of a few glyphs at Piedras Negras, possibly borrowed from Yaxchilan. Likewise the inscriptions at Quirigua seem to me much more reminiscent of Palenque than of Copan. Possibly a keen eye could trace such likenesses and determine what cities are daughter colonies or successors of other cities.

All these and many other problems demand the laborious collection and tabulation of glyphs and dates, and then their careful analysis. They require, too, a greater accessibility of more Maya inscriptions; further, compilation like Maudslay's drawings and Morley's *Inscriptions at Copan* are probably the greatest need at the moment.

(11) The matter of correlation I regard as quite unsettled, and much work needs to be done on the inscriptions before we may reach a conclusion. If we could postulate an unbroken calendar from the inscriptions, and that 12 Kan 2 Pop was July 16, 1553, then I should consider the matter closed with the equation 11.16.0–0–0, 13 Ahau 8 Xul = November 3, 1539. I feel sure that no real progress can be made by assuming a correlation and then trying to force agreements out of the inscriptions. By that method almost any correlation can be made to look plausible, provided no one examines it too closely. The work must proceed from the other direction, assuming that we do not know equivalent Christian dates unless and until our accumulated knowledge from the inscriptions forces them on us. Tedious search for all glyphs and Mayan dates of a given form in the inscriptions, tabulation and analysis of the results—this is the only method, aside from direct revelation, which will ultimately produce a correlation inspiring general confidence.

It will be seen from the foregoing pages what a field for work we have and how little has as yet been done. Some things we may say that we know; some look very probable; some are very suggestive, and finally others can only be regarded as indicative of places where work would likely prove productive. The ground has only been touched here and there, and I hope this review of Maya astronomical knowledge may, first, produce critical comment and, second, be an incentive to further investigation.

We are attempting to recover from the hieroglyphic records and reconstruct for ourselves one phase of a civilization that vanished only recently. There is probably enough material in existence to make the reconstruction fairly complete if we work it out. Such an effort has a peculiar fascination for me, as it probably has for others. It has given me many hours of most pleasant recreation during the five or six years since I first started with Morley's *Introduction to the Study of the Maya Hieroglyphs*. Goodman in his *Archaic Maya Inscriptions* furnished my first problem by his remarks on the exasperating and irritating character of the Supplementary Series glyphs, and a reading of Morley's summary in the Appendix to *Inscriptions at Copan* indicated that they were still exasperating. Guthe's discussion of pages 51 to 58 of the *Dresden Codex* induced another line of attack, for if we really had an eclipse table, then the node days must be identifiable and must be almost fixed in the tzolkin. Förstemann's commentary on the *Dresden Codex* indicated at least three different Venus tables, and if so they must have a discoverable relation to each other, which of course gave me another problem. Bowditch's *Maya Numeration, Calendar and Astronomy* and especially Willson's astronomical notes on the Maya codices opened my eyes to the possibility of an eventual definite correlation based on the inscriptions alone. To all these writings I am much indebted for suggestions and for material starting points, while in Willson's case I am also indebted to some extent for method.

It has been a most interesting occupation, but there is one apparent danger. Both Goodman and Förstemann seem to have fallen so completely under the influence of the mysticism of numbers that as a consequence some parts of their work are far below their level of attainment, and some parts are completely invalidated. I fully expect to escape this pit of mysticism, this habit of reading into their simplest statements more absurd ideas than the Maya themselves were capable of formulating. But one never can tell; perhaps I am part way in already. If you think I am not, then you might say a little prayer to keep me out of it.

ADDENDUM

A glyph has recently come to my attention which might represent an eclipse. In 1926 Senor Enrique Juan Palacios of the Ministry of Public Education of Mexico discovered, photographed and made a drawing of Stela 3 at Santa Elena Poco Uinic in Chiapas. Two years later Frans Blom also drew it. The monument is clearly dated 9.18.0–0–0, 11 Ahau 18 Mac. Near the end of the inscription is a date 5 Cib 14 Chen which must be 9.17.19–13–16, 5 Cib 14 Chen as it is followed by a distance number 4–4 to connect it to the Initial Series.

We know from the inscriptions and the *Dresden Codex* alone that this day 5 Cib 14 Chen was a new moon day, and either this new moon or the one immediately before it must have been an eclipse syzygy according to our analysis, because it is day 356 of the double tzolkin. We suggested previously that Glyph B of the Supplementary Series might represent the idea of the moon entering its house, *i.e.*, disappearing at conjunction. Now, in the monument under discussion, immediately following the date 5 Cib 14 Chen is a glyph (fig. 19) which would represent the sun entering its house, in fact a double house. By analogy this would mean disappearance of the sun which could scarcely be anything but solar eclipse. This is the only glyph that I have found which tempts me to regard it as an eclipse glyph.

I do not know that it adds anything to the strength of the above suggestion, but we might note that according to the Goodman correlation, which we have been using, this 5 Cib 14 Chen fell on July 16, 790, and on that day shortly after noon a total eclipse of the sun was visible from the spot where this monument was soon afterward erected.

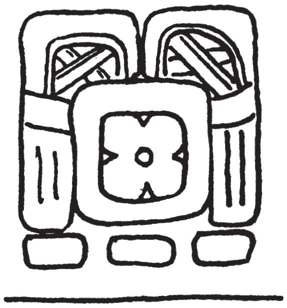

FIG. 19. Possible Eclipse Glyph.