Archaeoastronomy of Altar de los Reyes In Campeche, Mexico



Satoko Asahi

A Senior Comprehensive Project
Allegheny College
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Submitted to the Allegheny College Department of Physics in partial fulfillment of the requirements for the degree of Bachelor of Science

Committee Members:

Dr. Jamie Lombardi
Dr. D. Willey

I hereby recognize and pledge to fulfill my responsibilities, as defined by the Honor Code, and to maintain the integrity of both myself and the college community as a whole.

Pledge:_____

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2. ABSTRACT

Following the steps of the research previously done by Anthony Aveni, I was able to examine the archaeoastronomy of the newly found archeological site, Altar de los Reyes in Campeche, Mexico. There is clear evidence the Maya designed the west acropolis to observe astronomical events to track the time of year. This result confirms that the Maya had accurate observations of planetary objects.

3. INTRODUCTION

Today we use a watch to check the time, and a calendar to plan. When we see the sun rising, we say it is morning. After the sun sets, we say it is night. We appreciate sunshine so that we can produce food and survive, but celestial objects are longer the tools we use for tracking time. The celestial objects were the only tools to know the time of the year for Maya. From the records of their calendar and the design of their buildings we can catch a glimpse of their impressive knowledge of celestial bodies. Some of their writings which are still preserved record important dates of their history. Their style of culture changed as time progressed; this allows to us to distinguish the time period of archeological sites (Aveni 2001). I investigated and demonstrated the archaeoastronomy on a newly found archeological site, Altar de los Reyes in the modern state of Campeche, Mexico. I was able to prove that the people of Altar de los Reyes used celestial objects, specifically the Sun and Venus, to track yearly events on their calendar by studying the orientation of buildings and stone markers called stelae.

4. BACKGROUND

Archaeoastronomy is the study of how people in the past have understood the phenomena in the sky, how they used phenomena in the sky, and what role the sky played in their culture. The term**,** archaeoastronomy, was first used by Elizabeth Chesley

Baityat at the suggestion of Euan MacKie in1973 (“Archaeoastronomy”). Anthony Aveni, a Physics professor at Colgate University, characterized archaeoastronomy in two different categories: green archaeoastronomy and brown archaeoastronomy. Green archaeoastronomy is focused upon the relationship between the alignments of buildings and astronomical events. Brown archaeoastronomy is primarily focused upon the broad range of cultural evidences such as written documents and pictures on the walls and examines how they are related to the astronomical events (Aveni 2003). In my senior project, I am focusing on green archaeoastronomy. In particular, I have been focused on the connection with the design of the buildings from the previously studies archeological sites in Campeche.

4.1. RESEARCH OBJECT

From 1996 to 2005, the research group led by Slovenian archeologist, Ivan Šprajc, did surveys in the southeastern part of Mexican federal state of Campeche, the southern part of the Yucatan peninsula. It is on the border between Mexico and Guatemala as well as between Mexico and Belize. The red square in Figure 1 shows the area surveyed by Ivan Šprajc**.** The group has found more than 80 unknown archeological sites including complex buildings, caves and some hieroglyphs. All of the sites are Mayan. Most of settlements were built during the Classic period (A.D. 250-A.D. 900) but some of the settlements were built during the late pre-Classic period (300 B.C.-A.D. 250) (Moshier 2000). According to the report by the group, the standing architecture is rarely preserved. Still, it is possible to characterize them by the size and the style of the buildings and to rank them according to their social importance (Moshier 2000)**.**



Figure 1
The red square shows the location of the research objects.
http://mayaruins.com/yucmap.gif

The Mayan area is often divided into three different groups: the northern lowlands, the southern lowlands, and the highlands/Pacific piedmont based upon geology, soil, climate, anthropology, climate and vegetation. The research objects belong to the southern lowlands located within the Belize section, and northern part of Guatemala (“Maya”). Unlike the northern part of the Yucatan Peninsula, there are small rivers, seasonal streams, lakes and the ancient presence of low-lying swamps called bajos in the area has been established (“Maya”). Bajos allowed the Maya to retain water during the four dry months. They had a rainy season and sustained about 2,000 millimeters of annual rainfall (“Maya”). Due to the rainy season, the humid tropical forest sustained there. Although the soils in the southern lowlands are notoriously deficient and not suitable for agriculture, the people found the places where the soil is rich and did horticulture.

Altar de los Reyes locates at latitude of N17º59’ and longitude of W89º24’. It consists of two major groups, the main complex and the Southeast group. I have picked the west acroplis in the main complex as my research object. Four altars and one stela have been reported by the team directed by Ivan Šprajc. An altar is a circular stone

monument and a stela is a stone marker which has four faces. Because of the poor condition of stelae, only one date on Stela1 was legible. Figure 2 shows that the location of Altar de los Reyesand 2-D picture of the west acropolis.

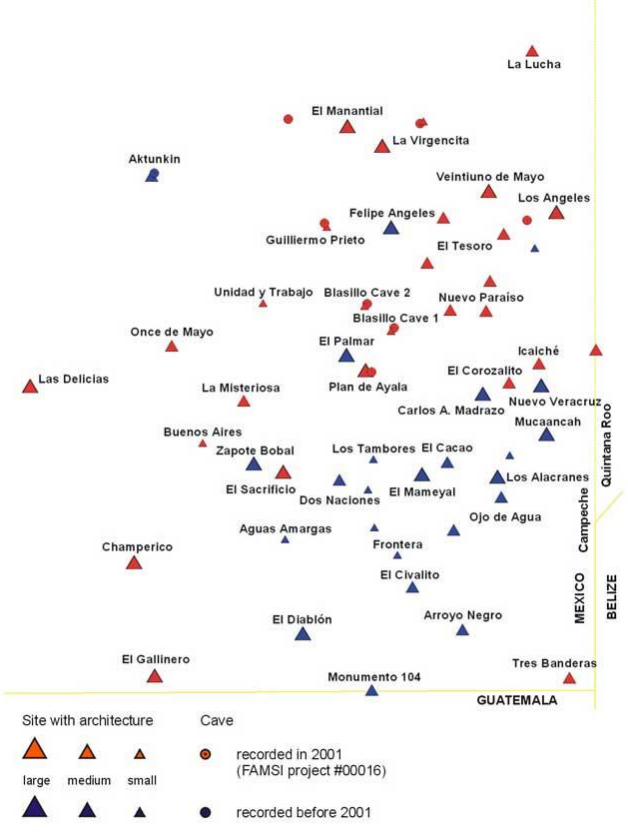


Figure 1. Location of archaeological sites in southeastern Campeche, México.

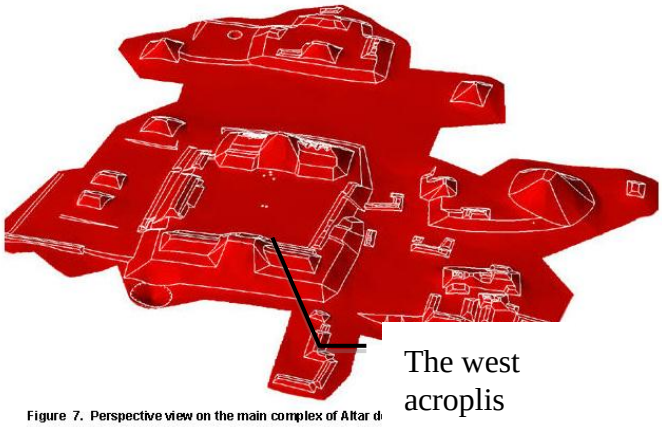


Figure 7. Perspective view on the main complex of Altar d
(digital model by Tomaž Podobnikar).

The west acroplis

Figure 2
Left: Enlarged map of Campeche, Guatemala, and Belize area (From Dos Naciones to Los Alacranes is about 25km)
Right: 2-D map of Altar De Los Reyes.
http://www.famsi.org/

4.2. MAYAN CALENDAR AND FOUR SURVIVING CODICES

The main goal of my project is to understand the relationship between the settlement patterns and astronomical events. It is necessary to understand what data of astronomy the Maya had and the Mayan world-view. It is well known that the Maya had their own calendar system which differs from the Christian Calendar system we use today. The idea of their calendar system is very rational and fits the astronomical events such as the cycle of Venus and lunar eclipses (“Paris”). Similar to the Mayan calendar, the four surviving codices are an important source in understanding the Mayan worldview. The Mayan calendar system and codices are linked together in the following way: the Maya recorded the astronomical events and the calendar along with their history and beliefs in the codices (Vali 2003).

4.2.1. Mayan Codices

Most of codices were destroyed during the Spanish Conquest which happened during 16th century, but the four surviving Codices: Madrid, Paris, Dresden, and Grolier codices reside in different places today (Moshier 2000). The name of Codices except

Grolier Codex refers to the place where they have been recovered and where they were most likely delivered by the conquistadors. Even though they are not completely decoded, they have been a primarily source to understanding Mayan culture and their view of astronomy ("Maya").

The Dresden Codex is the best preserved codex and is known as the most sophisticated codex as well. It contains two important astronomical tables. One is the table for the planet Venus showing the 584-day Venus cycle. The other is an eclipse table and shows the calculation of lunar and solar eclipses. Scholars agree that they are not a record from observation since the information in the eclipse table does not match the theoretical eclipse station in the Mayan area. Thus, they were intended to predict significant stations in the astronomical cycle described.

The Paris Codex consists of eleven double-sided pages and its origin is unknown and the exact time period this codex was produced is not known either. The codex contains the same hieroglyphic form as the Dresden codex.

The Madrid Codex was originally believed to be two different codices, the Troano and Cortesiunuus codices. In 1881, these two codices were recognized as one codex. The Madrid codex is the longest codex of the four surviving codices and consists of 112 pages. Unlike the Dresden and the Paris codices, it does not contain any astronomical tables, but contains much information about their ritual events and daily life. It contains the almanacs which are believed to have guided the Maya in the timing of specific events and their ritual activities.

4.2.2. Mayan Counting

First, we need to be familiar with Mayan mathematics so that we can be acquainted with their calendar system. The two major differences from the number system we use are that the Mayan numbers were written vertically, with the place increasing value from bottom to top, and that the base of number system is 20 instead of 10; therefore, the higher counting goes 20, 400, 8000, 16,000 and so on (Aveni 2001). This counting system is called the vigesimal system. It is believed that the root of this system is the Maya merchant counting numbers with his hands and feet (Vali 2003).

For example, the number 562,677 can be express as shown below. The value increases from bottom to top and the increments are all power of 20. Figure 3 shows that the expression for the numbers 0 to 19 and an example of the Mayan counting system for 562,677.

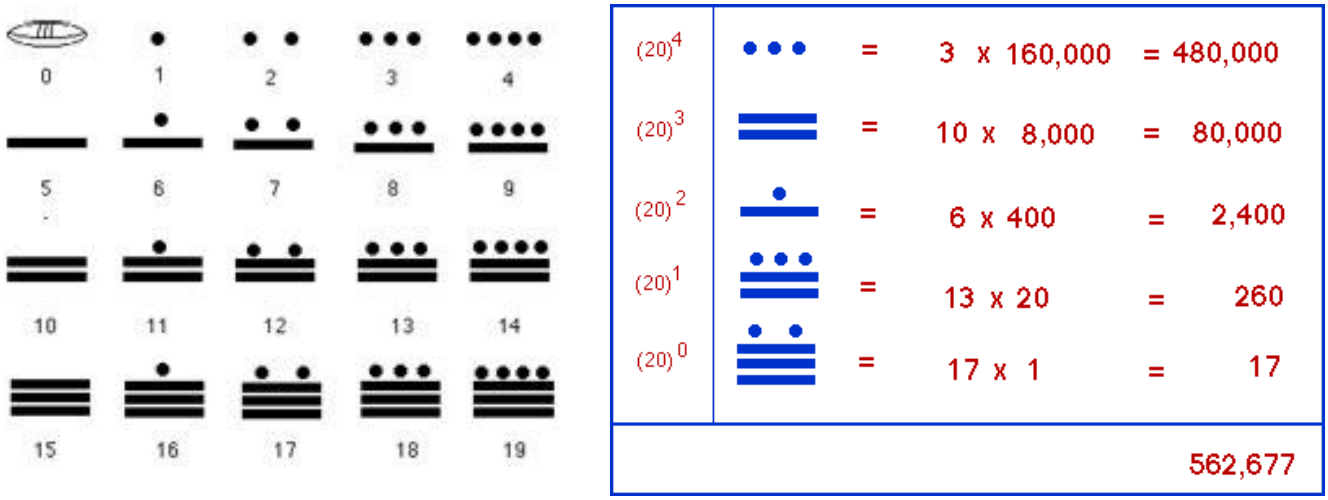


Figure 3
Left)Number 0 to 20 of Maya counting system.
Right) The example of Maya counting system. You start counting from the bottom to top.
http://history-of-mathematics.org.ru/maya.html

4.2.3. The Long Count

It is impossible to comprehend the Mayan calendar system without understanding the concept of the Long Count**.** This system was primarily used to record the date on a stone marker stela ("The Long Count"). The people who marked the date on the stela know the day zero which is the starting day of the Long Count. They used five major units to record the date ("The Long Count").

1day = 1kin
1 unial = 20 kins
1 tun = 18 unials = 360 kins
1 katun =20 tuns =7,200 kins
1 baktun =20 katuns =144,000kins

We can consider unial as a month and tun as a 360-day year. There are certain hieroglyphs to represent each unit. It is known that they used the hieroglyphs to keep the calendar on a stela to record astronomical events. The most recent zero point of the Long Count is believed to be August 12, 3114 B.C (Aveni 2001). They used the Long Count to express the date in the past as well as in the future.

4.2.4. The Mayan Calendar

The Mayan calendar consists of the Long count, a 260-day cycle called tzol'kin, and a 365-day cycle called Haab ("Maya").

The 260-day cycle calendar is found to be the most important tool to keeping the date in Mayan culture. This calendar is independent of the Long Count. The Maya used a system consisting of twenty named days which continuously repeated. Running concurrently with the named days are the numerals 1 through 13 which also repeat

continuously. Therefore, it takes 13 cycles of the twenty named days to complete a full calendar (Aveni 2001**).** Figure 4 shows the possible combinations of tzol'kin. The left wheel is numbered from 1 to 13 and the right wheel has the 20 named days.

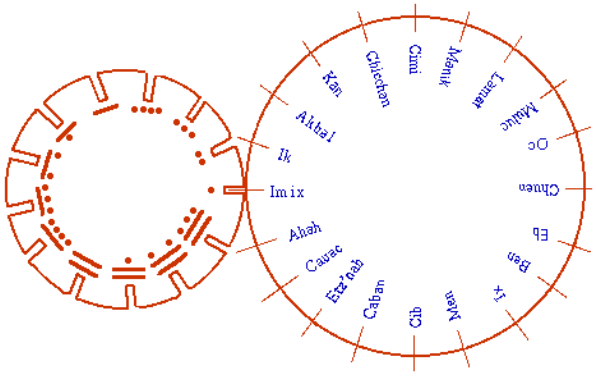


Figure 4
The left gear shows the number from 1 through 13 and the named days are on the right gear. You can find 260 different combination of the number and named day.
http://www.astronomy.pomona.edu/archeo/yucatan/karenstrom.maya.calendar.gif

The Maya is the only civilization which used 260-day cycle. Even now a small number of areas in Mesoamerica use the 260-day cycle when they make a life decision such as marriage and divines used it to advice about clients' illness, land disputes and so on. Other astronomical events are linked to the 260-day count (Aveni 2001). For example, Mars' synodic period is exactly three cycles of 260 days (Von Hagen 1960).

5. APPROACHES

Based upon my background research in Fall 2008, I have identified four similar sites to Altar De Los Reyes. These four sites were chosen because of their similarities of structure and time period to Altar De Los Reyes. The archeological sites of Zapote Bobal, Copan, Teotihuacan and Tenochtitlan which have been studied by archeologists led me to pursue four approaches similar to the ones used at these sites.

5.1. THE CASE OF TEMPLO MAYOR IN TENOCHITITLAN

The design of the Templo Mayor of Tenochititlan shows that the Maya had a deep understanding of the sun's trajectory. At the equinox, you will be able to observe the sun rising between the twin temples of Templo Mayor (Aveni 2001). The design of the twin temples carefully takes into consideration the azimuth angle and their altitude. The building 13 and 12 seems the main buildings in Altar de los Reyes and may be designed to observe the sun rising or setting at the equinox (See Appendix). The right hand side picture of Figure 5 is the twin temples at Tenochititlan.

5.2. THE CASE OF TEOTIHUACAN

The study of the orientation of the city of Teotihuacan by Rene Millon and his coworkers has contributed a lot to reveal its meaning. They have found a curious marker pecked into the plaster floor in one of the buildings. The marker was there to track the agricultural calendar. The marker on the floor consists of two lines: one is oriented 15º28' north of east and the other line is 16º30' south of east. The sun set along the alignment

occurs on April 29 and August 12. These two dates are meaningful because they are separated by 260 days which is one cycle of tzol'kin (Aveni2001).
April 29 is 40 days after vernal equinox and is 20 days before the first zenith passage. The report by Ivan Šprajc does not provide information about the markers on the ground; however, it appears that the Mayas tried to determine the agricultural season by looking at the sunset from their observation point.

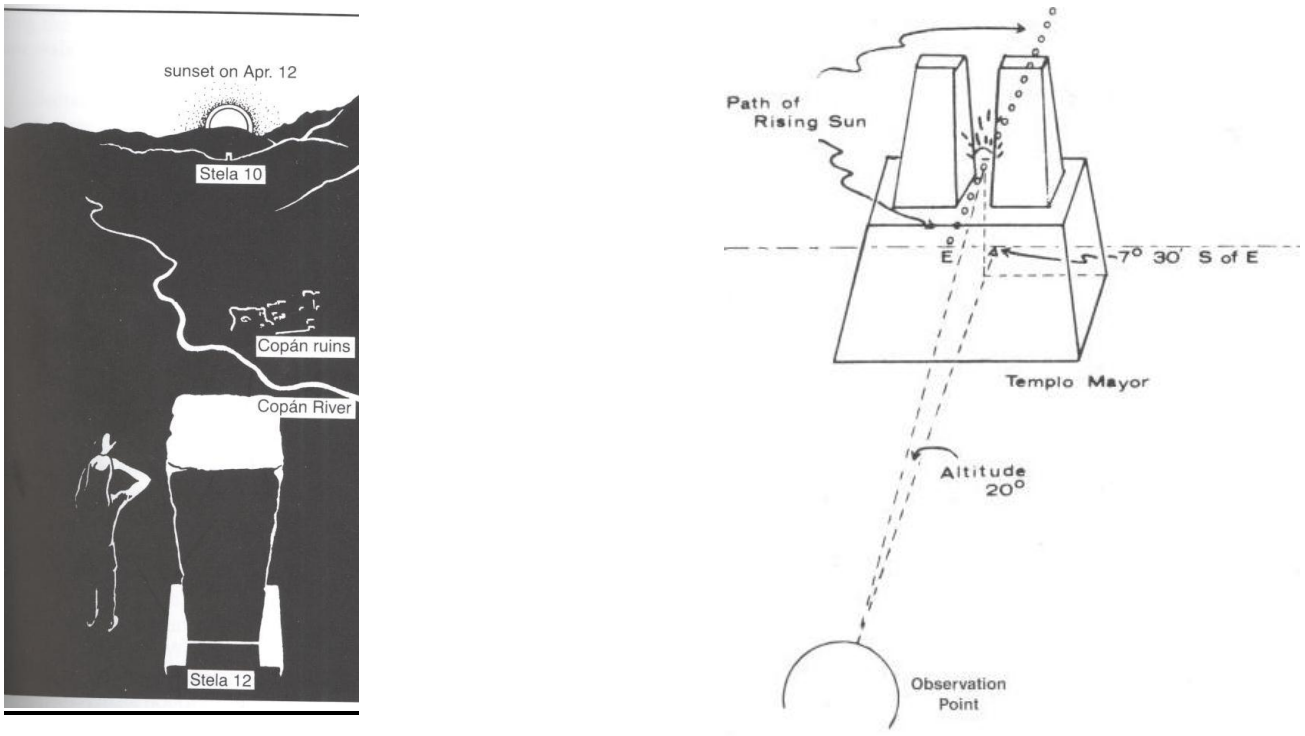


Figure 5
Left: the example of Copan (Diagram by P. Dunham)
Right: The picture of twin temples at Templo Mayor

5.3. THE CASE OF COPAN

In the archeological study of Copan, Sylvanus Morley pointed out that, as viewed from Stela 12, the sun sets over Stela 10 on April 12th and again in September. He connects the first date with initiation of the milpa agricultural season practiced by the ancient Mayas. The sunset on April 12 can be observed along the baseline of Stela 12-10 (Figure 5). It announces the start of the rainy season in the annual calendar (Aveni 2001). Charles Wisdom, an anthropologist who studied the Mayan people in nearby Guatemala, notes that they prepare for the annual rain-making ceremony and festival which is held on April 25 and continues for eight days until May 2. The twenty days from April 12 and May 5th agree with one cycle of the Mayan calendar, the tzol'kin (Aveni 2001). On the third of May, the sun crosses the zenith which is the official start of the agricultural season in Copan. The baseline of stelae in Altar de los Reyesmay match with the sunset or the sunrise points on a certain date so that people can prepare for their ritual events or some other cultural purposes.

5.4. THE DATES ON STELAE

Most of the altars in Altar de los Reyes have been severely destroyed; only one of them is well preserved. Even though it is impossible to tell much about the original features of the stela and only small part of glyphs is readable, the date, August 13, 800 on Altar in matches the date engraved on the stela in Zapote Bobal. Both the Altars in de los Reyes and Zapote Bobal were built during the late classic period (A.D. 600-A.D. 900) and their geographic location is not so far away one another. The Maya used altars to record their history. They used their codices to record their history and ritual events as well as some astronomical events such as the accurate cycle of Venus. Therefore, it would not be surprising if they also engraved an occurrence of an astronomical event which was significant or meaningful in their culture. Previous research by Ivan Šprajc has suggested that there may be some connection between Zapote Bobal and Camperico. Thus, it is worthwhile to also check the dates engraved on stelae in Camperico. They may have shared information, or may be three of the major buildings in Mexico during late classic period.

Altar de los Reyes	Altar 1	9.18.10.0.0.10. Ajaw 8 Sak (Aug 13, 800)
Zapote Bobal	Stela 1	9.18.10.0.0.10. Ajaw 8 Sak
Camperico	Stela 1 Stela 3	3 Ajaw 3 Sot'z 9.9.0.0.0 (March 7, 613) 11 Ak'b'al 6 Muwaan 9.8.0.6.3 (December 21, 593) 9.8.10.0.0.4. Ajaw 13 Xul (July 1, 603)

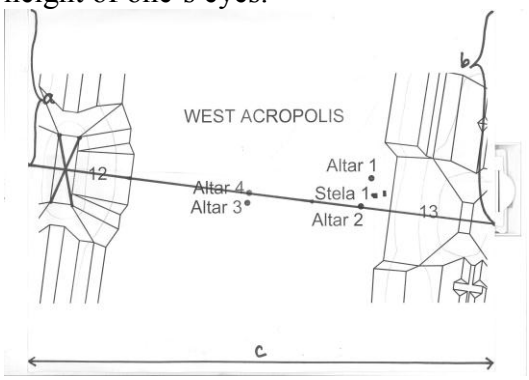
Table 1 Dates recoded on Altar and Stelae

http://images.google.com/imgres?imgurl=http://www.famsi.org/reports/00016/images/image170.jpg&imgrefurl=http://www.famsi.org/reports/00016/section13.htm&usg=__lCsYmRLEXWJ9mn0X--q3mPR0SAY=&h=1006&w=407&sz=57&hl=en&start=2&sig2=Aeg7GRE6dp1JyzDG7L5hJA&um=1&tbnid=ynfmfFzhLyJeyM:&tbnh=150&tbnw=61&ei=cZ-dSb2EKduImQeXrv3sBA&prev=/images%3Fq%3DChamperico%2BStela%26um%3D1%26hl%3Den%26client%3Dsafari%26rls%3Den-us%26sa%3DN

6. METHODS

Three major steps will be used to explore the four possibilities outlined in the Approach section. The first step is to identify the altitude and azimuth angle of observing points. Since a two dimension topological map is available on the website of Ivan Šprajc. I was able to calculate both altitude and azimuth angle. For both altitude and azimuth angle I used Pythagorean theory. For the altitude, I found the height difference of two buildings or stelae and the distance separating them. By these two measurements, I was able to obtain a triangle as shown below and by using the Pythagorean theory, the angle of altitude was derived. For example, the observing point, along the line of Stela 1 and building 12 is the line drawn in Figure 6. Then, the length of both a and b in the picture are measured. The horizontal distance of two objects will be always the same because I always use the same size of paper. Since the vertical side of paper is the azimuth angle 0 degree, I was able to obtain azimuth angle for each observing points in Altar De los Reyes. This is the most accurate way available without using any special programs.

Table 2 shows the latitude and azimuth angle of observing points for each approach. The research team directed by Ivan Šprajc has reported that the original height of all stelae is unknown since they are poorly preserved. Arbitrarily the height of stelae was set to be 1.74m. This appears to be a reasonable assumption if you imagine that the Maya used stelae for a tool to observe astronomical events. The height of 1.74m is a reasonable height of one's eyes.



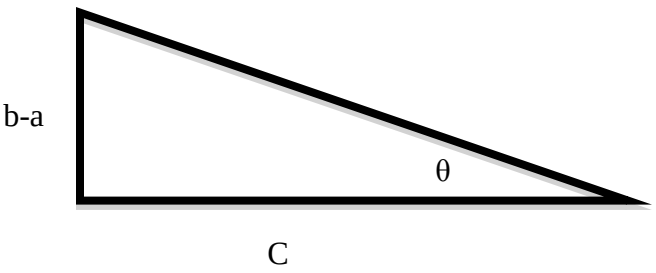


Figure 6
Left: 2-D picture of Altar de los Reyes
Right: The triangle to measure the azimuth angle of the line of sight

Altitude (Degrees)	Azimuth (Degrees)	Line of Sight		Dec.
6.56	-88.62	Altar 1to Building 12	■	3.50
34.28	112.59	Altar 1 to Building 13	●	-6.26
13.05	-79.89	Altar 3 to Building 12	*	13.71
18.30	93.48	Altar 3 to Building 13	X	2.95
13.04	-82.78	Altar 4 to Building 12	▲	11.03
18.33	96.46	Altar 4 to Building 13	○	0.31

Table 2
Altitude and Azimuth angles of observation points in Altar De Los Reyes

Also, I was able to derive objects' declinations which pass through the observation points at Altar de los Reyes

Step two is to find the declination of a celestial object on the day of interest. The program AA.ARC v5.5, it is able to find the declination and right angle of celestial object (See Appendix).

The third step is to plot the value of declination of the object using the programs called alatz2.f and archeo.smx. (See Appendix).

To test the reliability of programs, they were run to prove the temple Mayor case. The program was able to show that sun rises between the two buildings of Temple Mayor at the equinox. The trajectory line of the sun passes through the circle of the altitude and azimuth angles of the observer. This result demonstrated the reliability of these programs.

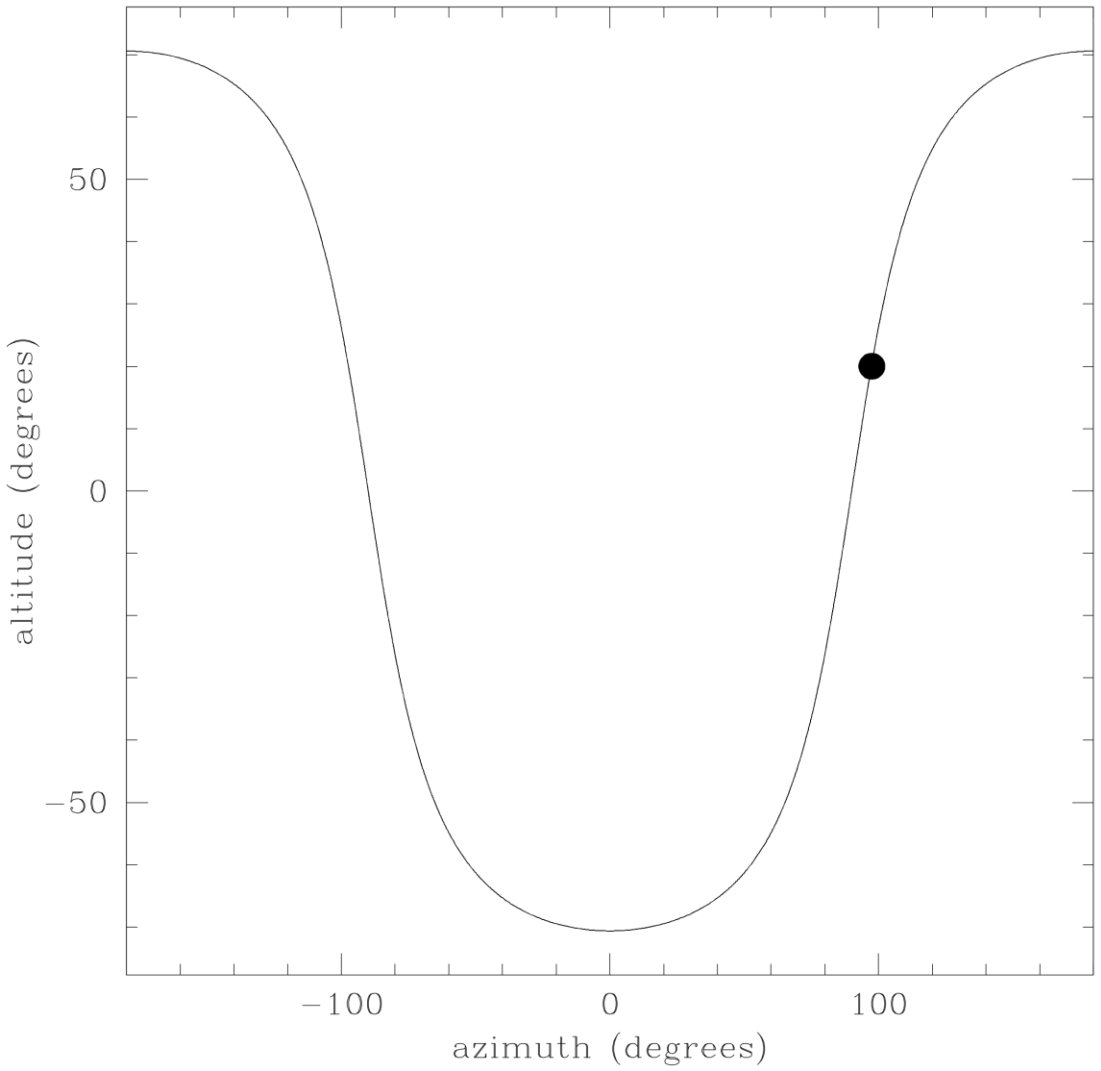


Figure 7
Diagram showing the path of rising sun at Templo Mayor of Tenochtitlan at the equinox.
Altitude of Templo Mayor: 20
Azimuth angle of Templo Mayor: 7 30’ South of East (Aveni 2001)

7. RESULTS

Altitude (Degrees)	Azimuth (Degrees)	Line of Sight		Dec.
6.56	-88.62	Altar 1to Building 12	■	3.50
34.28	112.59	Altar 1 to Building 13	●	-6.26
13.05	-79.89	Altar 3 to Building 12	*	13.71
18.30	93.48	Altar 3 to Building 13	X	2.95
13.04	-82.78	Altar 4 to Building 12	▲	11.03
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7.1. THE CASE OF TEMPLO MAYOR AT ALTAR DE LOS REYES

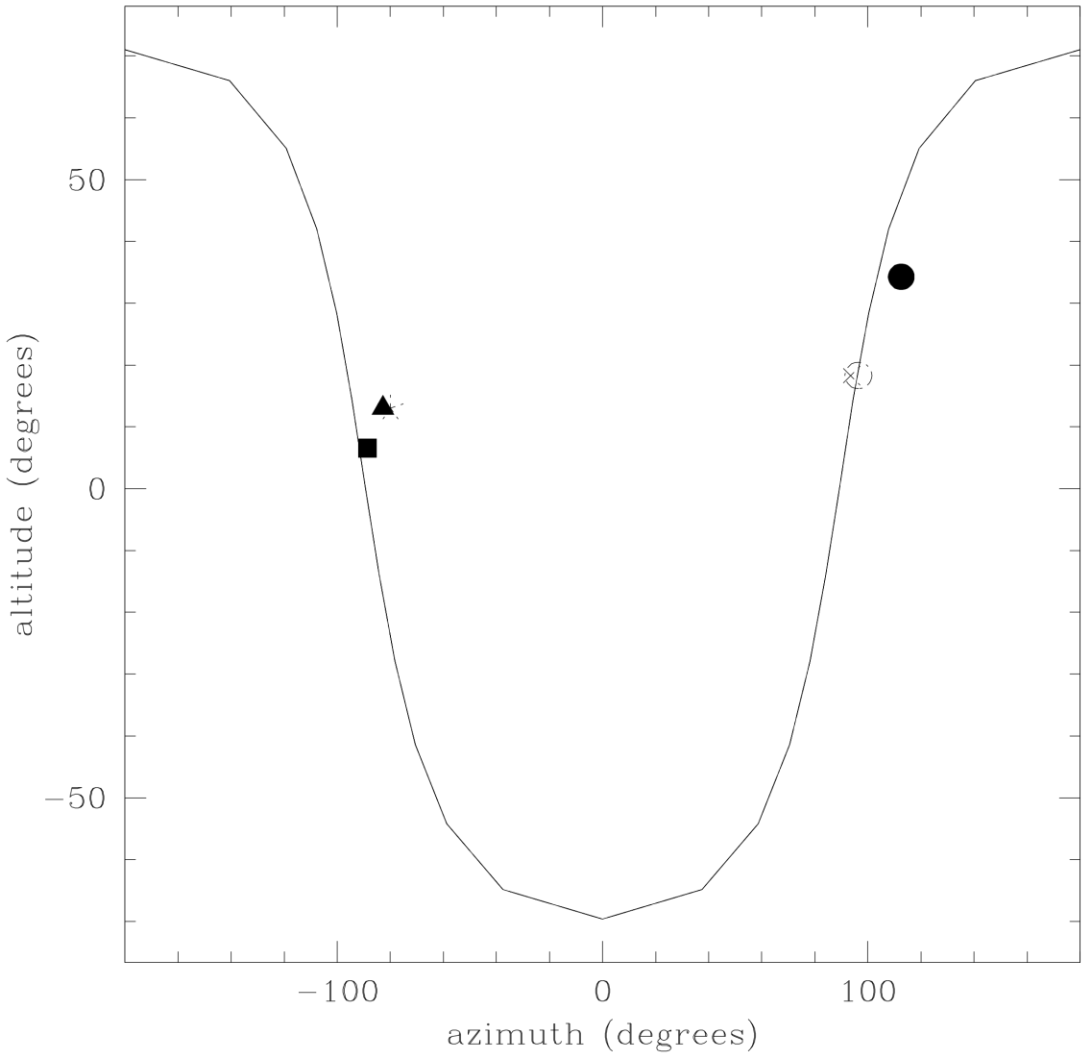


Figure 8 Sun's trajectory line at Altar de los Reyes at the equinox

You will be able to observe sun rising at the observation points along the baseline of Altar 4 to the building 13

Spring/Vernal equinox

7.2. THE CASE OF TEOTIHUACAN AT ALTAR DE LOS REYES

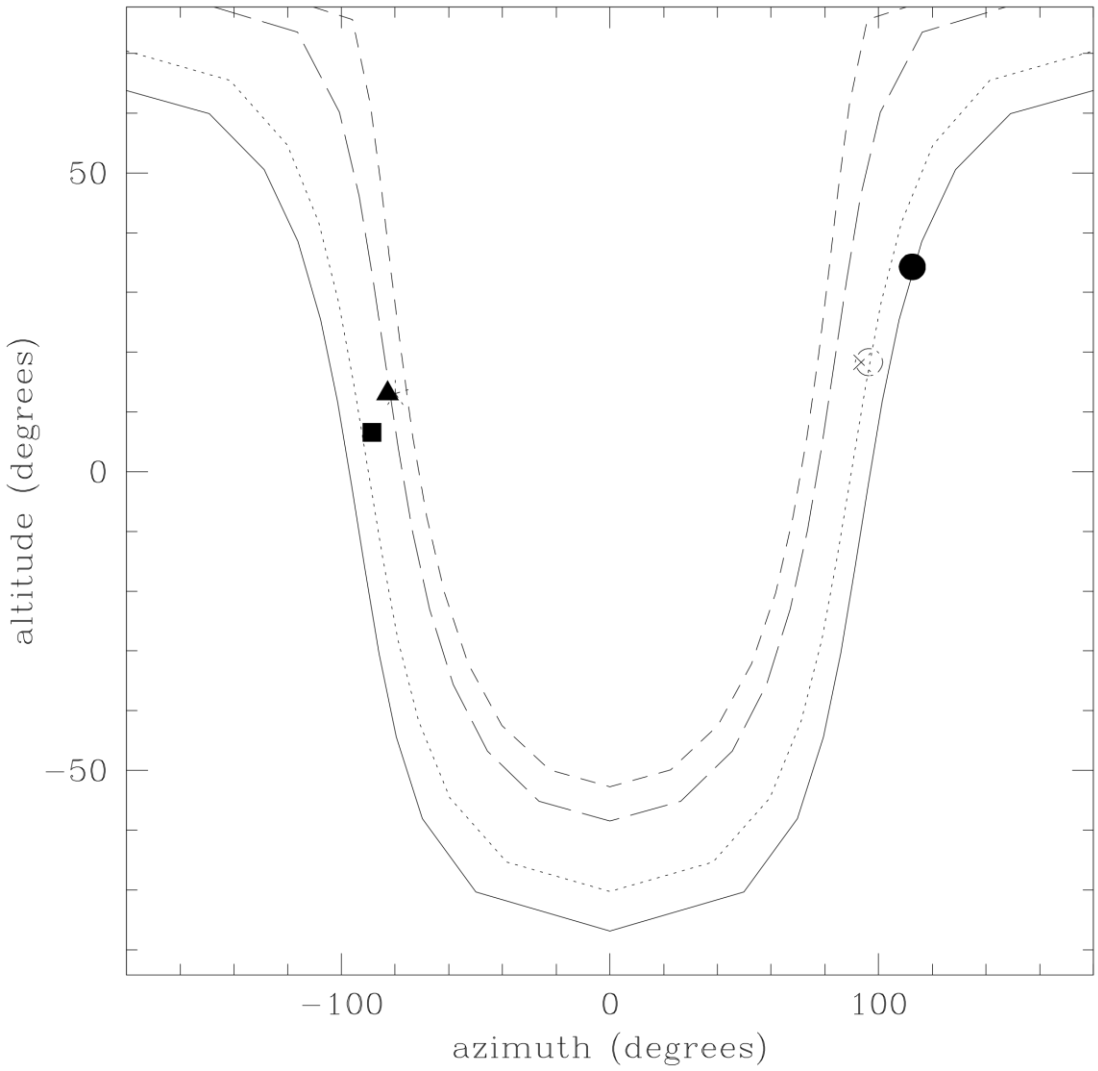


Figure 9
Trajectory line of Sun at the certain dates at Altar de los Reyes

20 days before spring/vernal equinox
Spring/vernal equinox
The sun passes the zenith
20days before the sun passes the zenith

7.3. THE CASE OF COPAN AT ALTAR DE LOS REYES

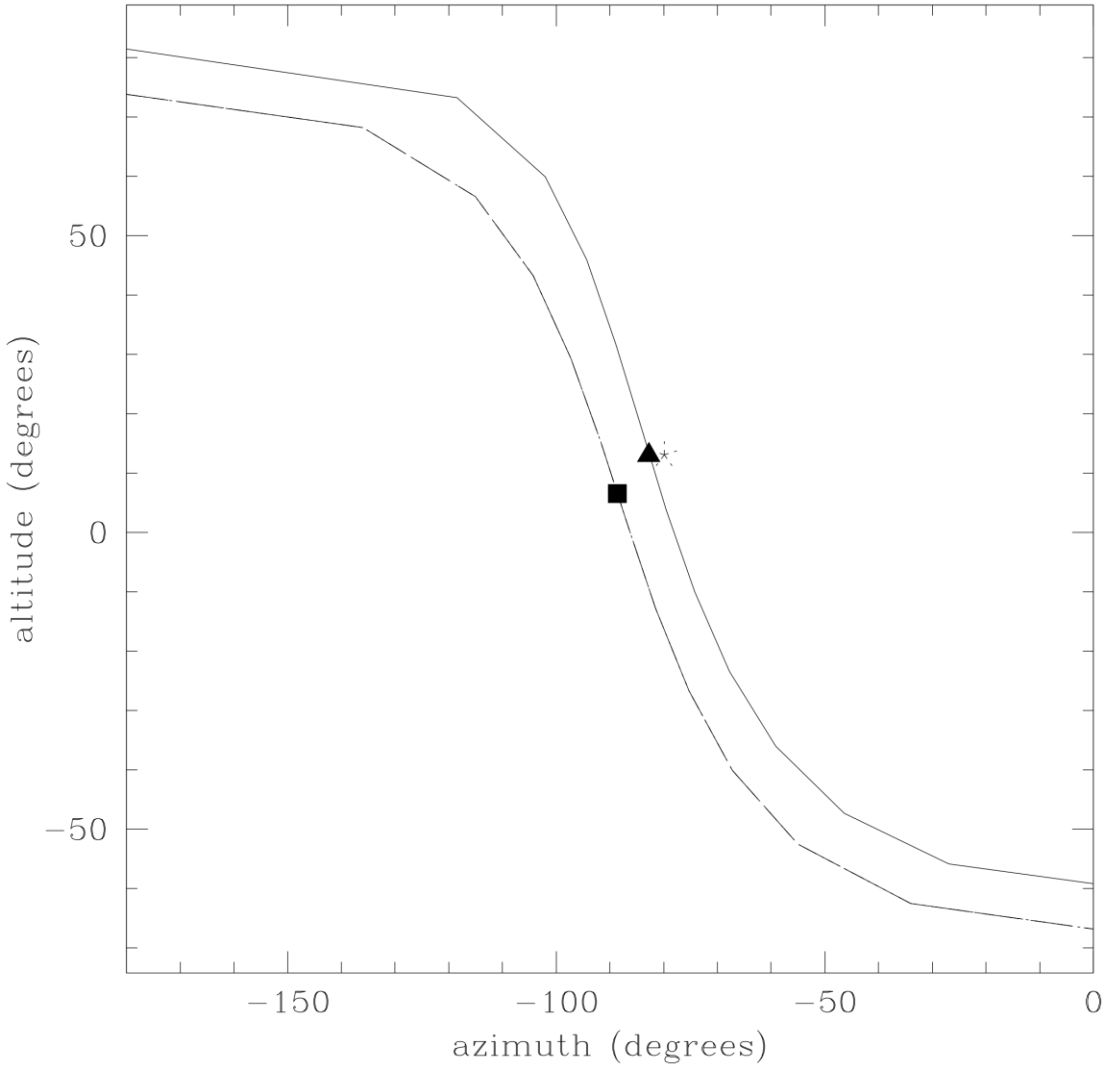


Figure 10

Trajectory line of a celestial object with the declination of 3º32'at Altar de los Reyes: In this case, I took a backward approach. I found the declination of an object which passes through the observation point along the baseline of Altar 1 and Building 12

A celestial object with the declination of 3º32'
Venus on March 7, 613

7.4. . THE DATES ON STELAE WITH VENUS

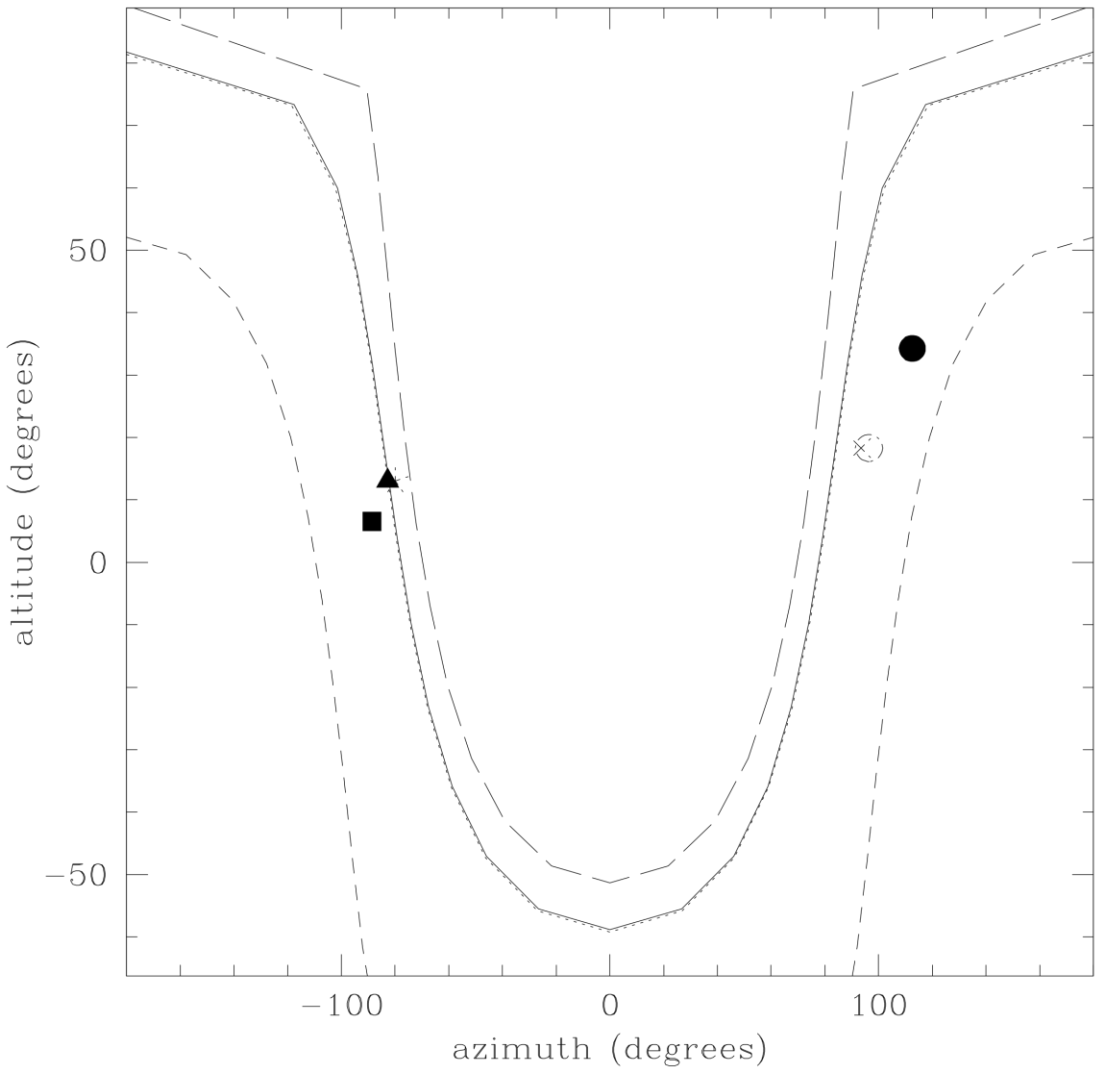


Figure 11
Trajectory line of Venus at the dates recorded on Altars at Zapote Bobal, Camperico, and Altar De los Reyes

August 13, 800
March 7, 613
December 21, 593
July 1, 603

7.5. THE DATES ON STELAE WITH SUN

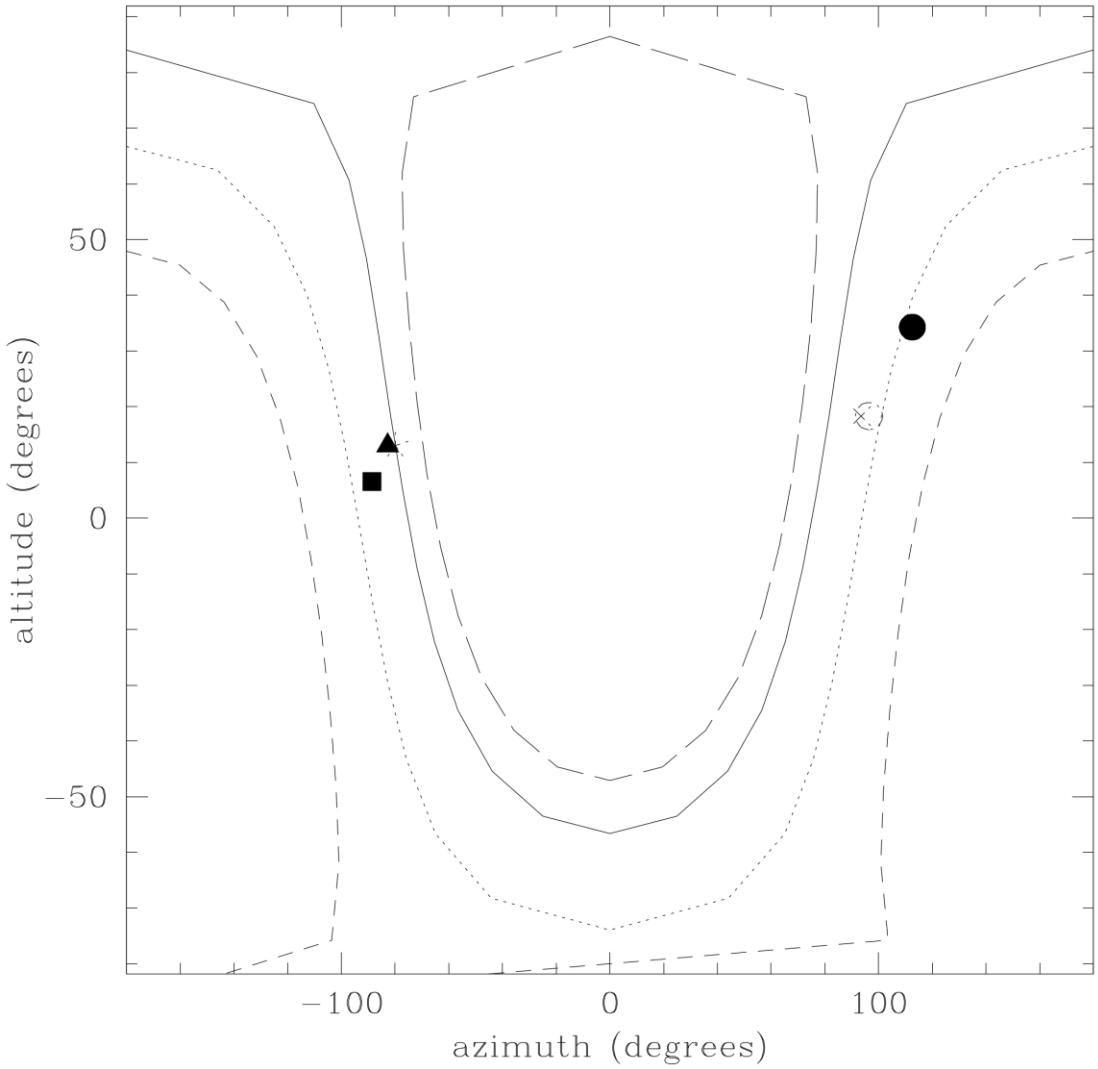


Figure 12 Trajectory line of Sun at the dates recorded on Altars at Zapote Bobal, Camperico, and Altar De los Reyes

July 1, 603
March 7, 800
December 21, 593
August 13, 800

8. DISCUSSION

8.1. THE CASE OF TEMPLO MAYOR IN TENOCHITITLAN

I was able to show that the observation point along the baseline of Altar 4 to 13 was design to determine the sun rising at the equinox. Instead of watching the sun rise between the twin temples of Templo Mayor, you will see the sun rise form the apex of building 13 at Altar De Los Reyes. This result shows that the Maya were acquainted with the annual path of the sun.

8.2. THE CASE OF TEOTIHUACAN

I was able to find the relationship between sun's motion and the orientation of altars at Altar De Los Reyes. As is the case in Teotihuacan, the alignment of altars at Altar de los Reyes matches with the key dates for their agricultural schedule. The sun passes over the observation point along the baseline of Altar 4 and building 13 on twenty days before spring equinox. From this result, it appears that they may have similar ritual events such as a rain making festival. As it is stated in the discussion of Approach 1, the sun passes over the observation point of Altar 4 and the building 13 at the equinox. Moreover, the sun setting can be seen at the point of Altar 4 and building 12 on twenty days before the sun passes its zenith. These results show that the Maya planned the orientation of buildings and altars so that they could keep the track of year.

8.3. THE CASE OF COPAN

I was unable to find any similarity with the case of Copan and the alignment of the buildings at Altar De Los Reyes. I assumed that the observation points along the baseline of Altar 1 and 12 were designed with a specific purpose. Although the celestial objects set over the observation parts, it appears to be unrelated to any know dates on the Mayan calendar. Arbitrarily the year 613 A.D was picked and it was found that the sun set over the points on September 10, 613 and Venus set on October 28, 613. I was unable to verify the intention of the observation points, Altar 1 and the building 12 and Altar 3 and the building 13.

8.4. THE DATES ON STELAE

Interestingly the declination of Venus on March 7, 613 and Aug 13, 800 is only 0.3 degrees apart. In spite of this, it is still unknown why Maya marked this date. The declination of Venus is not at its largest, nor is the elongation from Sun at either its minimum or maximum. It is possible that the two days, March 7, 613 and August 13, 800 had heliacal settings of Venus, hence, they record it on stelae. Further investigation is needed to identify the meaning of these two dates when Venus passes through one of the observation points. Result 7-5 shows that Sun setting over the observation points which is along the baseline of Altar 3 and 12. The date, August 13, 800 was recorded on the stela at Altar De Los Reyes. Thus, it must be either an important date on their calendar or in some ritual aspect of Mayan culture. From the result, it is probable that Zapote Bobal, Camperico, and Altar de los Reyes had shared information among themselves. It appears

that the alignment of buildings at Altar de los Reyes was incorporated into some kind of event that led to the recording of dates in the Altars at Camperico. The three places, Camperico, Zampote Bobal, and Altar de los Reyes may had been centers of Maya in late classic period.

9. CONCLUSION

I was able to show some celestial motion relationships between the buildings and altar at Altar De Los Reyes. It appears that the sun was the most powerful tool in Mayan culture to know the time and season of the year. It is amazing that the Maya had unrivaled knowledge of astronomy around 150 A.D. There are still unanswered questions; however, they would be more in the area of brown archaeoastronomy. Without a doubt, Altar de los Reyes was designed to observe some celestial events so that the Maya could plan their agriculture and lives.

10. BIBLIOGRAPHY

Aveny, Anthony F. Skywatchers of ancient Mexico. Texas: the University of Texas Press,1980. ---. Skywatchers. Austin: University of Texas Press, 2001.---.The Sky in Mayan Literature. New York•Oxford: Oxford Univeristy Press, 1992.--- "Archaeoastronomy in the Ancient Ameicas" Jounarl of Archeological Research. 11 (2003): 149-191

Krupp, E.C., ed. Archaeoastronomy and the Roots of Science. Colorado: Westview Press, inc.,1984.

Williamson, Ray A.Living the Sky. Boston: Houghton Mifflin company, Boston, 1984.

Heizer, Robert F., ed. THE ARCHAEOLOGIST AT WORK. New York: Harper & Brothers, 1959.

Hawkins, Gerald S. STONEHENGE DECODED. New York: DOUBLEDAY & COMPANY, INC., 1965.

Moshier, Steve. Astronomy and numerical software source codes. 28 July. 2000. 8 Oct. 2008 <http://www.moshier.net/aadoc.html>

Servin, Gregory M. "The Paris Codex: Decoding an Astronomical Ephemeris." TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY. 71 (1981): 1-101.

Bricker, Harvey M., Aveny, Anthony F. and Bricker, Victoria R. "Ancient Maya Documents concerning the Movements of Mars." National Academy of Sciences. 98, 4 (2001): 2107-2110.

Vali, G. "New perspectives on the Madrid Codex." Current Anthropology. 44 (2003): S105-S112.

"Paris, Codex." THE OXFORD ENCYCLOPEDIA OF MESOAMECAN CULTURES. 2001.

"The Long Count" THE OXFORD ENCYCLOPEDIA OF MESOAMECA CULTURES. 2001.

Von Hagen, Victor W. WORLD OF THE MAYA. New York: THE NEW AMERICAN LIBRARY, 1960.

Winzerling, E.O. ASPECTS OF THE MAYA CULTURE. New York: THE NORTH RIVER PRESS, 1956

Vaillant, Gerogi C. Atzecs of Mexico. New York: Doubleday&Company, Inc., 1962. Ashmore, Wendy. Lowland Maya Settlement Patterns. University of New Mexico Press, 1981. Šprajc, Ivan. "Reconocimiento arqueologico en el sureste del estado de Campeche, Mexico: 1996-2005." Paris Monographs in Amrican Archeology 19 Oxford: Archaeopress, 2008.

Witzgal, Al., and Shapp, Ray. ASTRONOMICAL FORMULAE. 23 Jun. 2001. 29 Jan. 2009 < http://www.asterism.org/clubact/calcfrm4.htm>

Love, Jamie. The Motion of the Planets. 2008. 5 Apr. 2009. < http://www.synapses.co.uk/astro/planets2.html>

FAMSI Foundation for the advancement of Mesoamerican Studies. <http://www.famsi.org/index.html>

Pehani, Peter. Archaeological Reconnaissance in Southeastern Campeche Mexico. 2008. 27 Mar. 2009 <http://gis.zrc-sazu.si/campeche/CmpHome.aspx>

McKenzie Barbara Yucatán Peninsula. 2009. 7 Nov. 2009

<http://mayaruins.com/yucmap.html> Šprajc
"Archaeoastronomy." WIKIPEDIA The Free Encyclopedia. 15 Nov. 2008
<http://en.wikipedia.org/wiki/Archeoastronomy>

11. APPENDIX

Program AA.ARC v5.5

The program AA.ARC v5.5 computes the orbital positions of planetary bodies and provides the information of declination, hour angle, rising and setting time, and light time. Most of the algorithms employed are from the Astronomical Almanac (AA) published by U.S. Government Printing Office. The program uses several different calculating methods for orbit calculations. In the manual, it says that orbit calculations in the interval from 1350B.C to 3000A.D have high accuracy. Position and proper motions of the 59 navigational stars are available in the file star.cat. Also, more information is available in the file messier.cat. The accuracy of the program is examined with *skyandtelescope.com*. Both sources gives the same sun rising and setting time.

Altaz2.f

This program is designed to read the planetary body's declination and right angle of a certain date and construct the chart with respect to the proper interval of hour angle. To construct the chart, these equations were used to convert declination and ascension right angle to azimuth and altitude.

$$az=\operatorname{atan}(-\sin(ha)*\cos(dec)/(\cos(lat)*\sin(dec)-\sin(lat)*\cos(dec)*\cos(ha)))$$

$$alt=\operatorname{asin}(\sin(lat)*\sin(dec)+\cos(lat)*\cos(dec)*\cos(ha))$$

where atan=arctangent, dec=declination, lat=latitude, and ha=hourangle.

It is possible to change the interval of hour angle as you like and it will give you rise and setting altitude and azimuth angles in degrees.

Xrp3

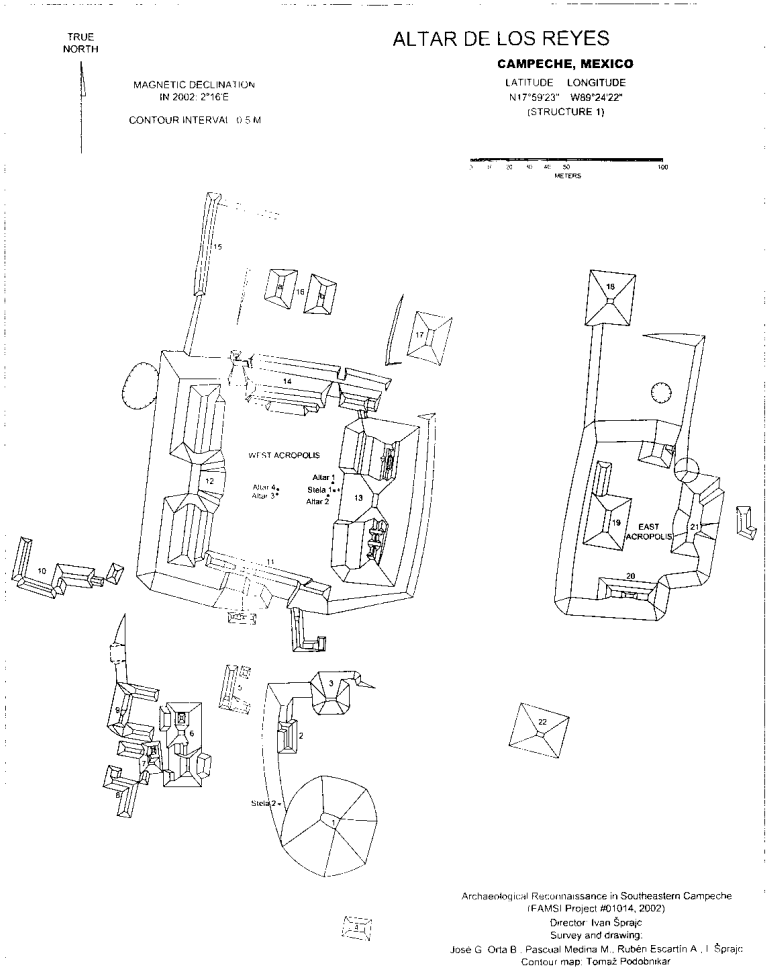
Xrp3 pictures the trajectory line of a maximum of four planetary objects with given inputs which has been obtained from Altaz2.f. If the line passes through the points of the observer's location, it indicates that people will see that astronomical occurrence along the baseline of the building and /or Altar.

program altaz2.f

```
      implicit none
      real*8 ra,dec,lat
      real*8 alt,alt2,az,az2
      real*8 hainhours,ha
      real*8 pi
      character*4 dummy4
      character*1 dummy1
      real*8 rah,ram,ras
      real*8 decd,decam,decas

      pi=4*atan(1.d0)

      read(5,*)dummy4,rah,dummy1,ram,dummy1,ras,dummy1,
     $     dummy4,decd,decam

      if(dummy4.ne.'Dec.' .or. dummy1.ne.'s') then
         print *,'unexpected input format'
         stop
      endif

      ra=(rah+ram/60+ras/3600)/24*2*pi    ! right ascension in radians
for Pleides
      dec=(decd+decam/60+decas/3600)/180*pi    ! dec in radians for
Pleides

      lat=(19+41./60+32./3600)*pi/180.

      print *,'ra,dec,latitude (in radians)=',ra,dec,lat
      print *,'ra,dec,latitude (in standard)=',
     $     ra*24/(2*pi),dec*180/pi,lat*180/pi

      print *,'alt (degrees), az (degrees), hour angle (in hours)'
      do hainhours=0,24,0.1
         ha=hainhours/12*pi

         alt=asin(sin(lat)*sin(dec)+cos(lat)*cos(dec)*cos(ha))

         az =atan(-sin(ha)*cos(dec)/
     $        (cos(lat)*sin(dec)-sin(lat)*cos(dec)*cos(ha)))
         az2=atan2(-sin(ha)*cos(dec),
     $        (cos(lat)*sin(dec)-sin(lat)*cos(dec)*cos(ha)))

c         print *,'alt,az (in radians)=',alt,az,az2,ha
         print *,alt/pi*180,az2/pi*180, hainhours
      enddo

      print *,'rise or set:'

         ha=acos(sin(lat)*sin(dec)/(-cos(lat)*cos(dec)))
         alt=asin(sin(lat)*sin(dec)+cos(lat)*cos(dec)*cos(ha))
         az =atan(-sin(ha)*cos(dec)/
     $        (cos(lat)*sin(dec)-sin(lat)*cos(dec)*cos(ha)))
         az2=atan2(-sin(ha)*cos(dec),
```

```
     $        (cos(lat)*sin(dec)-sin(lat)*cos(dec)*cos(ha)))

c         print *,'alt,az (in radians)=',alt,az,az2,ha
          print *,alt/pi*180,az2/pi*180
       end


xrp3 7      #Plot Altitude vs azimuth
       erase
       expand 1.3

       data $1
       lines 4 99999
       read {alt1 1 az1 2 ha1 3}

       data $2
       lines 4 99999
       read {alt2 1 az2 2 ha2 3}

       data $3
       lines 4 99999
       read {alt3 1 az3 2 ha3 3}

       data $4
       lines 4 99999
       read {alt4 1 az4 2 ha4 3}

       set alt=alt1 concat alt2
       limits $5 $6 alt
       box
       ltype 0
       connect az1 alt1
       ltype 1
       connect az2 alt2
       ltype 2
       connect az3 alt3
       ltype 3
       connect az4 alt4
       ltype 4

       xlabel azimuth (degrees)
       ylabel altitude (degrees)
       data $7
       read {altx 1 azx 2 pt 3}
       expand 3
       ptype 30 3
       points azx altx if (pt==1)

       ptype 4 3
       points azx altx if (pt==2)

       ptype 3 3
       points azx altx if (pt==3)

       ptype 5 1
       points azx altx if (pt==4)
```

```
      ptype 4 1
      points azx altx if (pt==5)

      ptype 30 0
      points azx altx if (pt==6)

      ptype 4 0
      points azx altx if (pt==7)

      ptype 3 0
      points azx altx if (pt==8)
      echo solid cicle=1, solid square=2, solid triangle=3, star=4,
X=5, open circle=6, open square=7, open triangle=8
```



Archaeological Reconnaissance in Southeastern Campeche
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