TOWARDS AN UNDERSTANDING OF AZTEC ARCHITECTURE AND URBAN PLANNING

by

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Abstract

There exists a vast literature examining every aspect of Aztec culture. Despite this, few studies focus specifically on Aztec architecture and its implications for understanding broader aspects of Aztec cosmology. This dissertation contributes to our knowledge of Aztec society through an exploration of architectural and urban design principles that guided the building of their cities and ceremonial precincts.

By examining ethnohistoric and archaeological sources, and drawing on evidence from several disciplines—art, astronomy, geography, geometry, mathematics and religion—I compile a body of information relevant to the study of Aztec architecture and urban planning. Cosmovision studies offer an understanding of ritual space and time; pictorial manuscripts contribute mathematical insights; analyses of monumental sculpture provide geometric knowledge; and high mountain archaeological research highlight the sacred landscape. The resulting information was then used in a set of archaeoastronomical analyses of seven pre-Aztec and Aztec architectural complexes. This approach builds on previous studies that have revealed the importance of astronomical considerations in Mesoamerican settlements.

In order to analyse Aztec ceremonial architecture and urban planning from an archaeoastronomical perspective, I developed a methodology that allowed accurate analyses of the astronomical and topographic orientations of settlements and ceremonial architecture. This methodology integrates a wide range of digital applications including Google Earth, Google Maps, solar charting, topographic analysis, open-content collaborative, geo-location-oriented photo sharing applications as well as a custom-built geometric application.

The results allow for a new understanding of: (1) the design principles of the *Huey Teocalli*, the unique Aztec double-temple architectural type found in almost all of their ceremonial centres, (2) the layout and design principles utilized in the construction of Tenochtitlan and Tlatelolco and, (3) the Aztec remodelling of Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. These analyses are also extended to the antecedent cultures of the region, revealing new aspects of the urban design principles of Teotihuacan and Tula including an additional interpretation of the Tlaloc mural in Teotihuacan.

The implications of this research extend beyond Aztec scholarship, providing a replicable methodology that can be applied to the archaeoastronomical analysis of ancient settlements and ceremonial structures anywhere in the world.

Preface

This dissertation is original, unpublished, independent work by the author, Antonieta María de la Paz García Ocampo Rivera.

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Dedication

To the memory of my Indigenous relations, for inspiring me.

To the memory of my parents Rosa y Abel, for encouraging me.

And to my family, Javier, Javier and Joel, for their immeasurable support.

Ni mitz tlazojtla ika nochi no yolotl.

Chapter 1: Introduction

> The historic present of modern Mexico is like a river fed by many streams, both recent and remote in origin, which make up the complex reality of the country today. Each of the historical periods survives in contemporary Mexicans; no matter how distant they may seem, they merge in the present.
> (López Austin and López Luján 2001:3)

This dissertation rests on a straightforward question: What are the main design principles embedded in Aztec architecture and urban planning *from an architect-builder point of view*?

I commence the introduction to this dissertation with a summary of the history of my lifelong interest in Aztec architecture and my professional and academic career in order to provide the context for the results of this research and to expose some of my personal biases as researcher and practicing architect in Mexico and Canada. I discuss concepts and ideas as to how and why Aztec cosmovision and religion were deeply embedded in Aztec architecture and urban planning. I present pictographic, written, oral, sculptural, archaeological, cultural, astronomical, mathematical, geometric and topographic notions that serve as a framework for the digital archaeoastronomical analyses of pre-Aztec and Aztec sites utilizing several applications. Based on these analyses, I reveal a set of design principles that were utilized in Aztec architecture and urban planning, and propose several innovative theories regarding the orientation of major Aztec sites in Central Mexico and the design principles embedded in the double temple teocalli, a unique Aztec building type. I also introduce a replicable methodology for archaeoastronomical analyses that can be utilized in any archeological site in the world.

Ever since I can remember, on February 5th, my family and I, together with all my paternal relatives, attended the celebrations of *Nuestra Señora del Pueblito* in Querétaro. For nine days, we danced, feasted and participated in ceremonies that went from the blessing of the sacrificial animals for the *Día del caldo* ([Beef] Stock Day) to the blessing of sugar figurines in the form of fruits that we would eat the last day of the feast. I recall the excitement when, after two hours cramped in our car full of relatives, food and clothes, we could see *El Cerrito* (Figure 1.1), a

small mountain that only the Elders were allowed to climb while the rest of us stayed in the plaza at the side of the mountain. I still remember the day when we followed them and discovered that the mountain had stairs to climb! The Elders did not see us at the time, but I will not forget the scolding we received after they found out. The following year, after the premature death of my father, Don Lucino, my grandfather asked me to go up the mountain with him. While we climbed up, sometimes on stairs, sometimes through loose pieces of rock, he told me that *El Cerrito* had been a temple for hundreds of years and had been visited by his family ever since he could remember. From that moment on, I saw *El Cerrito w*ith different eyes. As the years passed, I could distinguish portions of the temple that were still visible. I can still feel the awe of trying to understand how this temple was built.

Figure 1.1. El Cerrito (translated as "The Little Mountain") archaeological site in the state of Querétaro, Mexico. Except for some walls of the platforms and fragments of stairs, most of it remained uncovered until 1995, when excavations officially began. Only the main façade has been partially restored (Photograph by Julià Sastre - CC-BY 2.0).

This awe stayed with me every time we went to archaeological sites and their on-site museums, or visited the *Museo Nacional de Antropología (MNA),* where I spent hours contemplating the model of the ceremonial precinct of Tenochtitlan. Since that time, I have searched for books about Aztec architecture but I always found the same image from the Museo Nacional de Antropología. The discovery of the Templo Mayor (Huey Teocalli) in 1979 increased my interest in Aztec architecture as I had heard for so many years that it was buried under the cathedral.

Years later, as a practicing architect, I understood the decision of the Conquistadores to construct the Cathedral *beside* the Templo Mayor; they utilized it as the source for construction materials. Many other buildings in the ceremonial precinct of Tenochtitlan suffered the same fate and traces of them can still be found in colonial edifices.

I frequently visited the excavations during the 1980s thanks to the friendship of my family with Pedro Ramírez Vázquez (the architect who designed the *Museo Nacional de Antropología* and later, the *Museo del Templo Mayor*), and read any information as soon as it was published. A myriad of articles and studies came out about the excavations, but never a publication about Aztec architecture that explored more than the Templo Mayor. The excavations of the Templo Mayor ignited an interest in Aztec architecture, and other archaeological sites such as Tlatelolco, received funding for excavation projects.

While I was in university, I had the privilege of attending the courses about Mesoamerican architecture imparted by architect Luis Mariano Aceves. His images and verbal descriptions of Teotihuacan were so vivid, that when I subsequently visited Teotihuacan, I could feel how spaces, buildings and mountains spoke to each other: architecture was the writing and the landscape was the canvas. Even though I had previously been in Teotihuacan many times, this was the first time I saw it with the eyes of an architect. Being one of the best students in the School of Architecture, several professors granted me the freedom to explore my interest in Mesoamerican architecture in Central Mexico, allowing me to study different aspects of it according to their subjects. I visited not only the sites within Mexico City, but also in the states of Mexico, Morelos, Puebla, Tlaxcala, Hidalgo, Querétaro, and even Veracruz. During these years, even though Aztec scholarship was producing a large amount of research, there was still none conducted on Aztec architecture other than the research related to the Templo Mayor. The only sources for Mesoamerican architecture that had a reference to Aztec architecture at that time were the *Arquitectura Prehispánica* by Marquina (1964), *Ciudades precolombinas* by Hardoy (1964) an the *Pre-Columbian Architecture of Mesoamerica* by Gendrop and Heyden (1973).

During my last two years in university, my family asked architect Pedro Ramírez Vázquez if I could join his architectural practice as an apprentice. I was really excited as it was one of the

most prominent firms in Mexico; its commissions not only included the *Museo Nacional de Antropología* and the *Museo del Templo Mayor*, but also numerous projects from museums, embassies, stadiums and international pavilions to the *Basílica de Guadalupe* (the most important Catholic temple for Mexicans). The agreement was that I would work as an unpaid intern every weekday afternoon until I graduated, by which time I would decide if I would stay in the firm.

On the first day, Don Pedro called me to his office. I nervously walked through the door into a relatively small office and found him sitting behind a beautiful wooden table that served as his desk. The white wall behind him only had a couple of shelves with books and some pre-Columbian figurines, but the wall on the opposite side had built-in bookshelves protected with panels covered by black and white images of some of his oeuvre. I was mesmerized when I saw images of the *Museo Nacional de Antropología (MNA)* and the tower of the Foreign Affairs Ministry in Tlatelolco with the archaeological remains in the forefront. At that moment, I was transported to the model of Tenochtitlan in the *MNA* and forgot where I was until I heard the voice of Don Pedro pronounce my name. What followed was a lively exchange about Mesoamerican architecture that lasted all afternoon. By the end of the conversation, he stood up, opened a discrete door to his right, and invited me to enter. This small door led, to my surprise, to an immense boardroom that had, along one wall, the most amazing collection of architectural and museography magazines; along the other perpendicular wall, bookshelves overflowing with architecture and art books; and on the opposite side, a floor-to-ceiling, wall-to-wall window with floating transparent shelves that held his glass artwork. He proceeded to ask me if I would like to help him with his personal library before I started to work in his studio. I immediately accepted as I could not keep my eyes off everything! The couple of years that followed were filled with rewarding conversations about architecture and museography, especially Mesoamerican architecture as we both shared the same passion. Every afternoon he would come into the boardroom and chat with me while he was working with his glasswork. This was also the first time I saw a book of old plans of Mexico City and facsimiles of codices that were not even in the collection of the university I attended.

The space in this introduction would be too small to recount what I learned from Architect Pedro Ramírez Vázquez about Mesoamerican architecture, archaeology, conservation and museography, but our conversations were fundamental for increasing my knowledge and interest about Aztec architecture.

All my plans changed at 7:19 AM on September 19, 1985 when an earthquake measuring 8.1 on the Richter scale shook Mexico City. In a matter of seconds, several parts of the city were destroyed. Hundreds of buildings collapsed and left thousands of people dead. A second earthquake occurred at 7:40 PM the next day. More devastation and destruction ensued and left many buildings heavily damaged. Our house had only a cracked wall, however as many other Mexicans, we slept on the streets in makeshift camps for the fear of having our homes fall on us. In the days that followed, we concentrated on helping find survivors in the rubble. A reporter described the scene in Mexico as similar to Beirut, which had been ravaged back then by the civil war in Lebanon. What followed was the most intensive reconstruction program in Mexico: the *Programa de Renovación Habitacional Popular* (Popular Residential Renovation Program), which eventually built 42 090 new homes, repaired 4 210, and rebuilt another 2 500 in 150 buildings listed as historical monuments. The program gained worldwide recognition for its size, efficiency and ability to bring together of many national and international organizations.

The reconstruction of the city meant a once-in-a-lifetime opportunity for many professionals (engineers, architects, and builders, among others) to construct or repair a large number of buildings (homes, schools, hospitals, etc.) in less than four years. I was no exception, as the father of one of my friends and civil engineer, recruited me to work as the Structural Engineering[1] Coordinator of Zone 1 of the *Programa de Renovación Habitacional Popular.* The main responsibilities of my job were to determine if a building could be repaired or had to be demolished and to inspect the steel reinforcements before the concrete was poured into the structure. I spent most of my time on sites working alongside engineers and construction workers who had poured from all the surrounding areas of the Valley of Mexico. The first time I visited a

[1] Back in the eighties, the program of study of the School of Architecture at the *Universidad Iberoamericana* consisted of a set of six courses on structural engineering and six courses on construction science in addition to the regular design, geometry, theory and history of architecture courses, which resulted in a 5-year program plus a 1-year thesis.

site to determine the location of the foundations, I realized that most of the steel reinforcements were already on the ground. Concerned that it was done right, I asked for a steel measuring tape to check it. Nobody had one at that moment as the *maestro* (master builder) had left the site to buy sodas. To my surprise, I was handed over a stick with marks and a cord, and casually, one of the bricklayers asked me where I wanted to start. Fortunately, at that moment the *maestro* arrived and gave instructions to the bricklayers. When they were ready, the *maestro* took a measuring tape out of his pocket and I was able to confirm that the reinforcements were placed in the right place. When I asked the *maestro* about the stick and cord, he nonchalantly answered that those were all the tools they needed. From this moment on, I carefully observed how foundations and walls were laid with several tools complemented by sticks, cords, and mirrors. The use of the mirror took me a while to understand, until I saw its use to determine the location of a wall on a rather long lot. The coordination among the *maestro,* the construction workers and their varied tools fascinated me as they constituted a building construction entity that worked very efficiently.

When I read the descriptions of Sahagún about the skilled Aztec craftsmen, I could not help but think about the way I had seen the *maestro* work with his people, who were usually from the same family or small town. As many scholars have argued, the reconstruction, after the devastation caused by the Conquest, was only possible because the Aztecs had a building execution system that included skilled craftsmen, materials and tools.

After the *Programa de Renovación Habitacional Popular*, I started my architectural practice with another colleague. At the beginning, our commissions were mostly houses and small buildings, but in the early nineties, we landed the architectural supervision contract for the Mexican Foreign Trade Bank building in Mexico City. The architect was in Monterrey, a 1.5-hour flight from Mexico City, so he sent us the plans through long strips of paper via fax. I found the system inaccurate and time consuming, so I suggested we try sending diskettes via messenger services. This partially solved the problem, but making changes was still ineffective because we had to exchange diskettes, which also took time. Even though we finished the building before we effectively solved the matter, I became increasingly interested in Computer-Aided Design.

I searched for programs in several countries and I found the Masters of Advanced Studies in Architecture (MASA) with a specialization in Computational Tools in Design at the University of British Columbia. I traveled to Vancouver and met with Dr. Jerzy Wojtowicz. He accepted me without hesitation. He was impressed with my architectural design thesis not only for its content, but also because the text and plans had been done in a computer, which was not common at the time. It was a privilege to spend time in the studio with Dr. Wojtowicz as we had the most advanced computer systems and CAD programs in the world. Due to my interest in Mesoamerican architecture, and the expertise of Dr. Wojtowicz in geometry, he suggested I explore the geometry of the Templo Mayor. Since I already had a fair amount of material and the library had a quite complete collection of books and journal articles about the Templo Mayor, I decided to explore its regulating lines. I was intrigued by my findings, as I discovered relationships between the proportions of the building stages of the Templo Mayor as well as some key locations where offerings had been discovered. Technology enabled me to add as many layers of exploration as I needed. For my Master's thesis, I extended my findings and built the most accurate digital interpretation of the ceremonial precinct of Tenochtitlan within a multimedia application, one that allowed the user to explore different sources and display different interpretations according to the source.

Proud of my work, I traveled to Mexico to show my CD-ROM to Eduardo Matos Moctezuma, an icon in Mexican archaeology and the Director of the Templo Mayor Project and museum. To my dismay, Matos Moctezuma was unable to see me because his agenda was full for months. Sad but not defeated, I went to show my work to Architect Pedro Ramírez Vazquez whom I had also planned to visit during that trip. As always, Don Pedro received me with a lot of affection and patiently waited until I was ready to show him my work in the computer. The more I showed him, the more his small eyes opened. He was captivated with the interpretation and the technology, and kept on requesting that I show him more. At the end, he asked me, "Has Matos seen *this*?" I told him that he was unable to meet with me due to his lack of time. Don Pedro immediately activated the speakerphone and called the office of Matos at the Templo Mayor. The secretary transferred straightaway the call to Matos who was surprised to receive an unexpected call from Don Pedro. The conversation was short and to the point, and Matos agreed to see me the following morning.

Early the next day, I arrived at the Templo Mayor on time for the meeting, but was placed in a very small meeting room until Matos was able to see me. About a half an hour later, Matos finally arrived. Without much conversation, I started to show him my CD-ROM. His reaction was very similar to that of Don Pedro; the more I showed him, the more he wanted to see. However, when I showed him the plan of the ceremonial precinct he told me in a slightly louder voice, "Stop." He looked at me and asked, "How did you know that the ball court was in that location if we only discovered it in the last few weeks and have not shared our findings with anybody?" I immediately explained that I had utilized geometric and achaeoastronomical principles to determine its location. He was so astonished that he asked me to go to his office so that Dr. Leonardo López Luján could also see the CD-ROM and hear my interpretation. Again, I received a similar reaction from López Luján who asked the secretary to call the archaeologists working on-site to come to a larger meeting room to see my work. Everybody was fascinated with the media and the interpretation. Even though it was a great academic achievement for me as it validated my architectural research methodology, the results of my Master's thesis encouraged me to continue researching Aztec architecture, as it was an aspect of Aztec culture that was still not being addressed by scholars except for research directly related to the Templo Mayor.

The years that followed were so full of activity and went by so rapidly—I started both a doctorate and a family—that as I now reflect upon them they seem more dreamlike than real. During those years, I continued my research but got increasingly involved in the continuous development of digital tools and the internet in all areas of academia. My technical expertise was sought after because I could move fluidly from discipline to discipline and from paper to technology. I also became more involved with the Indigenous community, who had always been a source of encouragement and support since I came to UBC.

This relationship validated my Indigenous heritage in many ways. We not only shared cultural practices, but I was introduced to post-colonial theories. I had the opportunity of sharing discussions with Māori educators and scholars Dr. Linda Tuhiwai Smith and Dr. Graham Hingangaroa Smith, as well as spending time almost every day with Dr. Jo-ann Archibald (Q'um

Q'um Xiiem) due to my role at the First Nations House of Learning. The validity of Indigenous knowledge in my own research was strengthened when was I was invited as the visiting scholar of the James Henare Māori Research Centre at The University of Auckland by Dr. Te Tuhi Robust. I shared research with scholars and community members throughout northern New Zealand, however it was the oral history embedded in their architecture that stayed with me. After my time in New Zealand, many of the stories from my Elders came back to me. I could see *Doña Josefa* talking to my uncles while we sat down quietly in the corner of her house. It was built on a temple, or so they said. Hence, local history became an additional source in my research about Aztec architecture.

Research Methodology

In order to answer my research question I utilized what could be best described as a radial methodology where Aztec architecture and urban planning where always at the centre of all the investigations I made in the different disciplines: archaeology, art, history, astronomy, geography, geometry, mathematics and religion. This approach also resulted in my applying different architectural research methodologies in each chapter depending on the source material and the expected results.

Hence, I analyzed ethno-historical sources following an interpretative-historical research approach with the aim of defining Aztec typology, understanding the relationships between Aztec cosmology and architecture and exploring Aztec mathematics, geometry and topography. However, to analyze the topography and the movement of the Sun in each site with the precision I intended, I followed a more scientific approach in the archaeoastronomical-topographic analyses chapter that would let the archaeological sites reveal their design principles. To this end, I developed a detailed step-by-step methodology, applied it to the archaeological sites and summarized the findings by comparing the same kind of data among the sites. The results of this approach not only answered my research question but brought forth theories that contribute and enrich current Aztec and Mesoamerican scholarship.

Chapter One, the introduction, is a synthesis of how my research has come together. It begins with the research question and continues with a summary of the history of my lifelong investigation into Aztec architecture and my professional and academic careers in order to provide the context for the results of this research.

Chapter Two is an overview of the different ethno-historical, archaeological and sculptural sources where architectural representations are present either in pictorial, written or physical form. The first section presents a review of Aztec historiography after the Conquest. The subsequent sections include a description of each source and a summary of the architectural and urban depictions found within the source. These sources include: pictorial manuscripts, pictorial-administrative manuscripts, eyewitness accounts of the Conquistadores, chronicles compiled by the missionaries, archaeological evidence in pre-Aztec sites, archaeological evidence in Aztec sites, monumental sculpture, as well as architectural and urban models.

Chapter Three presents a visual sample of the inventory of Aztec architectural types that was done for this research based on the meticulous analyses of the ethno-historical sources carried out in Chapter 1 in order to investigate the common features of each architectural type, especially of the double teocalli, which is considered the most distinctive architectural type. To this end, the first section introduces the concept of typology following the ICOMOS *Principles for the Recording of Monuments, Groups of Buildings and Sites* and discusses the role of typological studies within the context of architectural research in Latin-America. The second section argues the need to define Aztec building types within their cultural context, which serves as the antechamber for the third section that consists of a representative sample of probably the most thorough inventory of Aztec building types in Aztec scholarship. Each sub-section presents a dossier of each building type following ICOMOS principles. The fourth and last section discusses the application of the urban planning principles of Tula and Teotihuacan in the design of Tenochtitlan.

Chapter Four introduces the Aztec cosmological concepts of space and time in order to understand how they were embedded in Aztec architecture and urban planning, as the research carried out in the ethnohistorical sources (Chapter 2) and the typological studies (Chapter 3)

revealed their intrinsic connections. The first section presents the concept of cosmovision and its relationship with the landscape, skyscape and religious beliefs embedded in the symbolism of the Huey Teocalli. The second section narrates two fundamental stories in Aztec religion and mythology: the creation of the world and the birth of Huitzilopochtli —god of Sun, fire, war and patron deity of the Aztec— and the relationship of these myths with the four directions, the movement of the Sun across the sky and the symbolic meaning of mountains. The third section describes the concept of space and time in the Aztec calendar. The fourth section describes how these cosmological concepts were integrated into the sacred landscape comprised of mountains, caves and bodies of water, and emphasizes the importance of Tlaloc — god of rain, water and lighting— and the rituals performed on Cerro Tlaloc. The last section introduces the research carried out in the field of high mountain archaeology and its relevance for the understanding of the sacred landscape in the Valley of Mexico.

Chapter Five provides an overview of Aztec astronomy, mathematics and geometry with the purpose of understanding how these disciplines were applied to Aztec architecture and urban planning, as this knowledge was necessary to create the horizon reference system to track the Sun at calendrically significant intervals within the solstitial points as presented in Chapter 4 and to construct their cities and buildings. To this end, the first section includes an explanation of archaeoastronomy, and its foundations and application in the study of archaeological sites; is followed by an overview of Aztec astronomy; and concludes with a technical explanation about charting the movement of the Sun. The second section introduces Aztec mathematics, including a discussion of numerical systems that included linear and angular measuring systems. The third section presents Aztec geometry and the underlying design principles within sculpture and architecture that were undoubtedly applied to architecture and urban planning. The last section presents an overview of Aztec building practice —including designers, tradesmen, materials and tools recorded in historical and linguistic sources— as a sophisticated design and construction system was required to lay out their urban centres and architectural structures.

Chapter Six has two main sections. The first is a step-by-step description of the methodology I developed to analyze each site, as a very dissimilar corpus of information had to be taken into consideration: from religious myths, to technical information distinct for each location (its Sun

path, rising and setting times of the Sun during the year, and altitude and azimuth of the Sun in a certain day), to the topographic features such as mountains, caves and springs. The second section includes the archaeoastronomical-topographic analyses of two pre-Aztec sites — Teotihuacan and Tula— and five Aztec sites —Tenochtitlan, Tlatelolco, Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. The analyses of each of these sites consists of four parts: a historical background; a summary of previous archaeoastronomical research and theories that have been proposed to explain its orientation; a discussion of the digital archaeoastronomical analyses and research findings; and a selection of images to illustrate the analyses. Each archaeoastronomical analysis involved identifying the site in the context of the Valley of Mexico, defining the major alignment of the site, calculating the visibility of major topographic features, exploring with precision each significant direction (site alignment, solstices and equinoxes), building an horizon calendar based on identified alignments, and summarizing the findings of each site. These summaries contain the same type of information that allows the comparison among sites and the identification of their similarities and differences. The chapter concludes with a set of the main design principles of Aztec architecture and urban design deduced from my research.

Chapter Six is the centre of the radial methodology where all the cultural information extracted from traditional and non-traditional ethnohistoric sources converges and overlaps in order to understand the design principles of Aztec architecture and urban planning; the research carried out in the previous chapters demonstrated that cultural aspects such as religion, astronomy, mathematics and geometry were embedded in their urban centres and architectural structures. This chapter is divided in two main sections. The purpose of the first section is to demonstrate with a case study the methodology that was applied in the archaeoastronomical analyses through a series of images and detailed explanations. This methodology is described step-by-step, as a very dissimilar corpus of information — that ranged from religious, mathematic and geometric cultural knowledge to specific topographic and solar information distinct to each location— had to be taken into consideration. The topographic and solar information included: the seasonal-and-hourly positional changes of the Sun throughout the year; the rising and setting times of the Sun during the solstices, equinoxes and alignment dates; the altitude and azimuth of the Sun these dates; and finally, the topographic features in the local horizon of each site such as mountains, caves and springs. The second section is a summary of the archaeoastronomical-topographic

analyses of two pre-Aztec sites, Teotihuacan and Tula, and five Aztec sites: Tenochtitlan, Tlatelolco, Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. The analysis of each of these sites has four parts: a historical background; a summary of previous archaeoastronomical research and theories that have been proposed to explain its orientation; a discussion of the digital archaeoastronomical analyses and research findings; and a selection of images to illustrate the analyses.

The archaeoastronomical-topographic analyses of each site consists of: identifying the site in the context of the Valley of Mexico, defining the major alignment of the site, calculating the visibility of major topographic features, exploring with precision each significant direction (site alignment, solstices and equinoxes), building an horizon calendar based on identified alignments and summarizing the findings of each site. These summaries contain the same type of information that allows the comparison among sites and the identification of their similarities and differences. The chapter concludes with a discussion of the main urban and architectural design principles deduced from the archaeoastronomical-topographic analyses and their application in main Aztec cities and their respective Huey Teocallis.

Chapter Seven, the conclusion, is structured in four parts. The first part synthesizes the contributions of each chapter and integrates them into the key architectural and urban findings of this research. The second part identifies the implications of the research findings in Mesoamerican and Aztec scholarship. The third part discusses the benefits and limitations of utilizing digital resources and applications for this type of interdisciplinary research. The last part outlines further research that can be performed utilizing this methodology in Aztec sites or other archeological sites around the world.

Chapter 2: Sources for the Study of Aztec Architecture and Urban Planning

2.1 Introduction

The aim of this chapter is to give an overview of the different ethno-historical, archaeological and sculptural sources where architectural representations are present either in pictorial, written or physical form. The first section presents a review of Aztec historiography after the Conquest. The subsequent sections include a description of each source and a summary of the architectural and urban depictions found within the source. These sources include: pictorial manuscripts, pictorial-administrative manuscripts, eyewitness accounts of the Conquistadores, chronicles compiled by the missionaries, archaeological evidence in pre-Aztec sites, archaeological evidence in Aztec sites, monumental sculpture, as well as architectural and urban models.

2.2 Overview of Aztec Historiography

The understanding of Aztec historiography is a complex endeavor, as the hybrid nature of the primary sources is as diverse in format and content as the historical context in which they were created and transmitted. Scholars such as León Portilla (1971) and Glass in collaboration with Robertson and Nicholson (1975), among others, have aided in the understanding of these sources by proposing different classifications for the vast body of historical material. However, Santamarina (2006:261) has demonstrated that a multitude of classifications[2] can be established based on the system of representation (pictorial or alphabetical), language (Nahuatl, Castilian or Latin), thematic character (historical-political, religious, ethnographic, economic), ethnic or professional origin of the author (native, mestizo, Spanish, or conquistador, clergyman, official), or origin of the primary source (native pictographs, oral tradition, accounts), to name a few. The dating of the sources (pre-Hispanic or colonial) in particular has caused real disagreements among scholars who base most of their arguments on the iconographic analysis of the drawn

[2] The intent of Santamarina is not to propose additional or more detailed classifications systems of ethno-historical sources, but to demonstrate its heterogeneous character. Even though some sources could be placed in a single category, most of their (sources) could fall into several categories, which is a reflection of the acculturation process that occurred during the early colonial period (2006: 262).

elements (Mohar 1997:56). Therefore, any classification of historical sources about the Aztecs has the potential of being controversial.

In addition, it is important to point out that Aztec historiography began with the Aztec themselves, as ethno-historical sources reveal that the rulers of Tenochtitlan performed archaeological excavations in both Teotihuacán and Tula with the purpose of legitimizing their ancestral rights to power and sources of Aztec identity (Smith 2008a:25). These cultures inhabited the Central Highlands of Mexico and its surroundings several centuries before the Aztecs arrived to the valley. Teotihuacan was established in 150 B.C. and was destroyed around A.D. 650, its hegemony lasting for more than eight centuries. The political and commercial void left by Teotihuacan was filled by Tula from 700 to 1150 A.D. For the Aztecs, Teotihuacan was the place where time began and Tula was the source of power. Since Tula had claimed for itself the role of the mythical Tollan, the Aztecs justified their right to military expansion due to their Toltec heritage (López Austin and López Luján 2001:199). The Aztecs considered the Toltecs as their ancestors and utilized Tula and Toltec practices as the basis for much of Aztec religion (Evans 2004:402).

Except for the research done by Smith in *Aztec City-State Capitals*, the few studies of Aztec architecture (Marquina 1964, Matos 1999, Pasztory 1983, Aguilar 2007) have mainly concentrated on its physical description, its archaeological characterization (such as belonging to certain cultural and temporal horizons), the exaltation of its physical characteristics, the analysis of certain features, and in some cases, proposing visual interpretations. Hence, a different approach to Aztec historiography is necessary that focuses on Aztec architecture from an *architectural* point of view rather than from a political, economic, social, cultural or religious point of view.

Consequently, I propose a classification of primary sources that utilizes the categories suggested by León Portilla[3] as a basis for the organization of material, since he has attributed the same value to ethno-historical and archaeological evidence throughout his oeuvre:

> It is necessary to insist on the importance for the historian of pre-Hispanic cultures to know, as widely and deeply as possible, the results of archaeological research. Studies of primary sources such as codices, texts by indigenous writers, and by Spanish chroniclers, take on new meaning and can be placed in its corresponding historical time when they are associated with archaeological discoveries.
>
> It is only by considering the written sources and archaeology as two forms of knowledge that must converge at one point, will it be possible to penetrate more and more into a culture where much remains to be elucidated (León Portilla 1971:40).[4]

This classification was complemented by the wide corpus of historiographical and archaeological research about the Aztecs carried out by Mexican and foreign scholars which has often gone in different directions. According to Drinot, there is awareness that:

> this divergence is a reality in Mexican historiography since much of USA-based Mexican historiography has become largely self-referential. At its most extreme, this process amounts to a form of academic colonialism. Mexico serves as a source of raw material which USA based historians mine assiduously. However, the historiography that results serves to feed academic debates within USA universities but is seldom intended to

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[3] A summary of this classification can be found in *De Teotihuacan a los Aztecas: Antología de Fuentes e Interpretaciones Históricas* (León Portilla 1971:29-50).

[4] Translated from León Portilla (1971:40):

No es necesario insistir en la importancia que tiene para el historiador de las culturas prehispánicas conocer, tan amplia y profundamente como le sea posible, los resultados de la investigación arqueológica. Los estudios acerca de las otras fuentes primarias, los códices, los textos indígenas y de los cronistas españoles, adquieren un nuevo sentido y pueden situarse mejor en su correspondiente momento, al ser relacionados con los descubrimientos arqueológicos. Tan solo así, considerando a las fuentes escritas y a la arqueología como dos formas de conocimiento que deben convergir sobre un mismo punto, será posible penetrar cada vez más en un mundo de cultura sobre el que tanto queda por esclarecer.

> influence the writing of Mexican history in Mexico, though it may unintentionally do so (Drinot 2000:72).

In spite of this divergence, I have employed the studies that best inform the architectural subject matter. This corpus included the original primary source as well as its distinct and sometimes conflicting interpretations.

This historiography was expanded to include monumental sculpture, urban and architectural models and oral tradition as categories. Paradoxically, in spite of the evident geometric characteristics in the creation of sculptural pieces, studies have concentrated on descriptions of its religious, iconographic and its epigraphic characteristics. Furthermore, urban and architectural models have barely been studied (Schávelzon 2004).

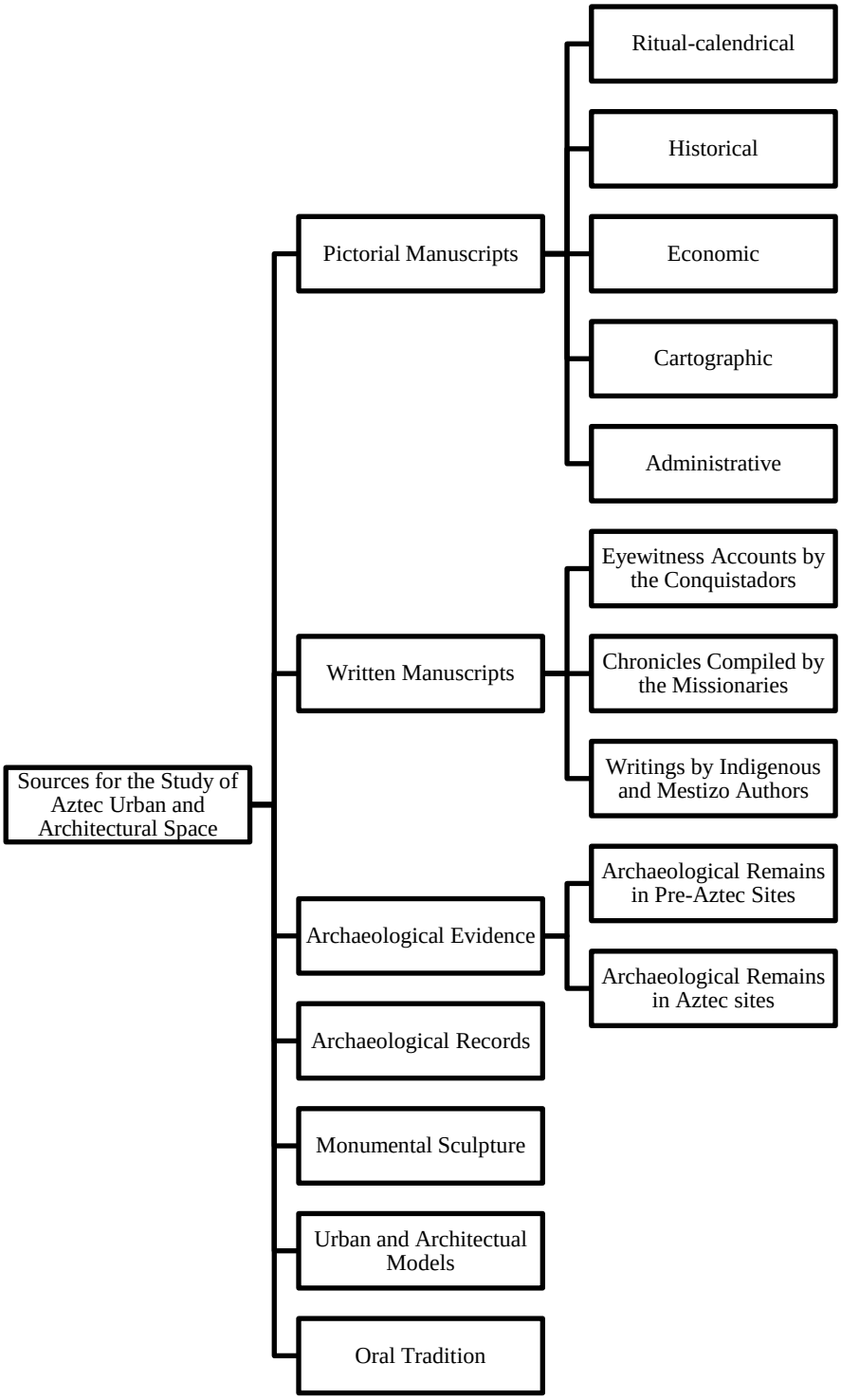


Figure 2.1. Classification of Primary Sources.

It should be emphasized that the proposed classification of primary sources for the study of Aztec urban and architectural space (see Figure 2.1) does not intend to cover the extensive body of ethno-historical material contained in the work of several scholars such as León Portilla, in the *Guide to Ethno-historical Sources* of the *Handbook of Middle American Indians* or in the *Códices y Pinturas Tradicionales Indígenas en el Archivo General de la Nación: Estudio y Catálogo*, but only the main published sources[5] where architectural manifestations were present.

These primary sources must be interpreted critically, as their purpose was not to provide a precise account of the past, but to serve the interests and motivations of the groups that participated in them. They are valuable for understanding Aztec architecture and thought even though the use of these sources to understand Aztec culture is problematic because of obvious biases due to Spanish influence and the specific native source which "leads us to know more about the life and ideology of the aristocracy rather than about common people, and more about religion than about any other aspect of life" (Pasztory 1983:33).

After the conquest, interpretations of these primary sources began to emerge when the objects, animals, and even Indigenous people began to arrive from the Colonies to European capitals. This caused a great impression among scholars who became increasingly interested in the New World and began to include this material in their work. They were particularly fascinated with Tenochtitlan, and by 1576, interpretations of the ceremonial precinct were already included in the *Civitates orbis terrarum* pictorial atlas of Georgius Braun and Franz Hohenberg, which contributed to the dispersal of the fame of the capital of the Aztec empire (Boone 1987:11). In 1590, José de Acosta used information provided by Juan de Tovar, who in turn copied either Diego Duran's *Historia* (finished in 1571 but not published until 1867-80) or the *Crónica X*, the lost prototype for much of Duran's history to introduce a distinct description of the ceremonial precinct in his *Historia natural y moral de las Indias*. The Belgian engraver Théodore de Bry and his sons (Figure 2.2) included a portion of the descriptions of Acosta in their volume of the

[5] Besides the material contained in the *Guide to Ethno-historical Sources* of the *Handbook of Middle American Indians*, there is a large collection of manuscripts housed in the *Archivo General de la Nación* that was collected in the *Códices y Pinturas Tradicionales Indígenas en el Archivo General de la Nación: Estudio y Catálogo* under a 15-year project lead by Galarza initiated in 1980. Besides a scant catalog, this material has not been published or analyzed.

Grands Voyages series, but accompanied it with a "wildly fanciful" engraving of the Templo Mayor in 1601 (Boone 1987:13).

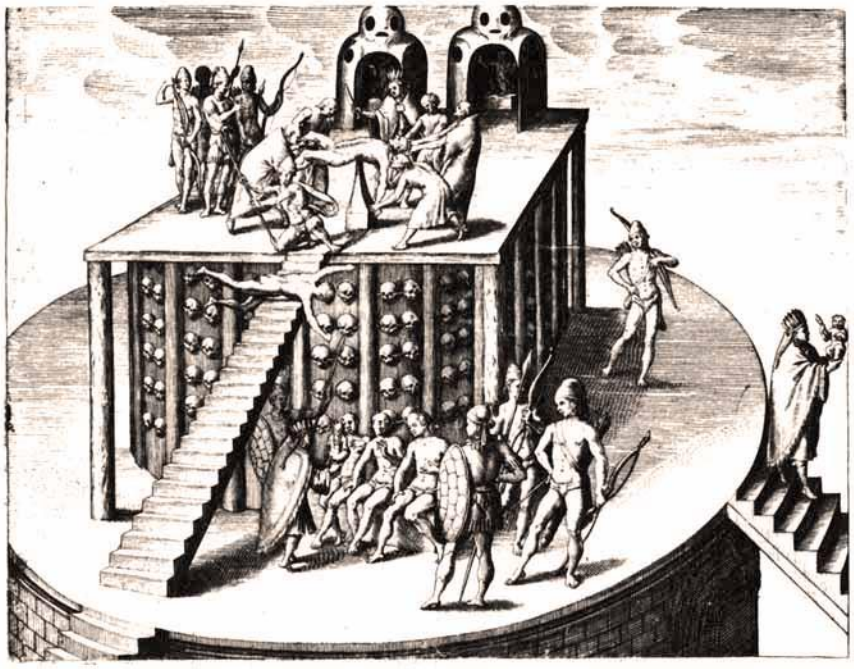


Figure 2.2. Engraving of the Templo Mayor by Théodore De Bry, published in 1601 to illustrate the history of José de Acosta (Boone 1987: Figure 6).

In New Spain, Franciscan friar and historian Juan de Torquemada ignored the work done by Acosta and de Bry and synthetized material taken from López de Gómara, Motolinía and Sahagún[6] for the description of the ceremonial precinct and the deities worshipped in the main temple in his *Monarchia Indiana* in 1601. After Torquemada, the work of Sahagún was not considered in subsequent histories that were written during the seventeenth and eighteenth centuries (Boone 1987:14). In contrast, Antonio de Solís, a Spanish historian who was chronicler of the Indies from 1661 to 1686, based his depiction and engraving of the ceremonial precinct (Figure 2.3) on the account of Antonio de Solís that he included in his *Historia de la Conquista de México, Población y Progresos de la América Septentrional, Conocida con el Nombre de Nueva España* published in 1684 (Boone 1987:14). The engraving of Antonio de Solís became

[6] Even though the *Historia General de las Cosas de la Nueva España* compiled by Sahagún from 1575-80, "was not fully published until 1829, his view of the Templo Mayor, including his list of the seventy-eight temples of the ceremonial precinct were known by some scholars in manuscript and entered the published literature early" (Hill Boone *Templo Mayor Research, 1521-1978:* 14).

the basis for numerous illustrations that were made for almost a century until the publication in 1780-81 of the multi-volume *Storia Antica* by mestizo historian Francisco Javier Clavijero. In his description of the ceremonial precinct, he combined the work and illustrations of several historians and accounts of Conquistadors, which he accompanied with an engraving of the Templo Mayor (Boone 1987:16).

Figure 2.3. Engraving of the Templo Mayor, published in 1684 to illustrate the history of Antonio de Solís (Boone 1987: Figure 7).

The literary approach to history that had prevailed since 1521 was transformed by the discoveries of 1790. In fact, scholars who have written about the history of archaeology in Mexico, agree that systematic studies about Aztec culture began when the Aztec Sun stone and the Earth Goddess Coatlicue were discovered in 1790 under the Plaza de Armas, the main plaza in the centre of Mexico City, where extensive public works were ordered by the Spanish viceroy, Juan Vicente de Güemes Pacheco de Padilla y Horcasitas, second count of Revillagigedo (Matos Moctezuma 1979:10). The viceroy, who had experienced the urban renovation of Madrid, decided to transform the insecure, chaotic and insalubrious Mexico City, into a more habitable city. He gave the responsibility to Ignacio de Castera, a Spanish architect and urban planner, who initiated various public works projects throughout the city including the widening of the streets, the construction of bridges and avenues, the installation of water supply and sanitation systems,

and the remodeling of the Plaza de Armas. This activity yielded the unexpected result of accidentally unearthing many monuments and archaeological artifacts from pre-colonial times (López Luján 2001:72). Many of these were drawn by the Spanish Captain Guillermo Dupaix in his *Descripción de Antiguos Monumentos Mexicanos* in 1794 (Figure 2.4), which is considered an invaluable document of the archaeological findings during the tenure of Revillagigedo at the end of the eighteenth century (López Luján 2001:81).

Figure 2.4. Front page and monuments number 8 and 19 in the *Descripción de Antiguos Monumentos Mexicanos* by Guillermo Dupaix (López Luján 2001: Figures on pages 72, 74 and 79).

These accidental discoveries also marked an attitude change towards the Aztec past. They were not only meaningful as monumental reminders of the Aztec past, but the decision of the authorities and the clergy to keep them was unusual (Manzanilla and López Luján 2001:322). Instead of destroying them, the Spanish viceroy Revillagigedo, ordered their protection and preservation and studies about them began to emerge. Antonio León y Gama, an astronomer, made the first studies of the Aztec Sun Stone and the Coatlicue. His *Descripción Histórica y Cronológica de las Dos Piedras* (*Historical and Chronological Description of the Two Stones*) is the first study that took an archaeological monument as a source to explain a "system of ideas;"

in this case, the calendrical and chronological conception of the Aztec articulated in the hieroglyphics (Florescano 1997:151).

Between 1780 and 1810, the *criollos'* interest in investigating their Indigenous past through material evidence that had survived the Conquest received extraordinary support from the Spanish authorities influenced by the ideas of the Enlightenment or the Age of Reason, which stimulated the archaeological excavations of Palenque from 1784 (Florescano 1997:152). The valuation of the archaeological and documental testimonies served as sources to comprehend the old Indigenous cultures. The *criollos* searched for an identity in their pre-Columbian past that was revived after the Independence of Mexico from Spain in 1821. The reintegration of the dismembered history of the country and the reconstruction of its past became central objectives for creating the identity of the new Mexican Republic (Florescano 1997:152). Scholars expanded their understanding of the past by interpreting the archaeological findings and complemented their scholarship with the publication of the works of Durán, Sahagún and the codices illustrated by Kingsborough that were made public during the time of Independence. Alfredo Chavero identified Coatlicue as the Earth goddess by employing documental testimonies in 1888. Discussions and studies proliferated about the precise location of the Great Temple, its appearance and the ceremonies performed in it.

The *Museo Nacional* (National Museum) experienced great development in all its areas and functions between 1876 and 1910. The research, teaching and diffusion functions expanded during this period, and in 1877 the museum undertook the first archaeological investigation in Oaxaca and another one in Cempoala in 1890 (Florescano 1997:158). The museum became the national centre of historical and anthropological research and acquired an international reputation under the leadership of Francisco del Paso y Troncoso (1889-1890 and 1892-1910). In 1900, Leopoldo Batres carried out the first official archaeological excavation in Mexico City after workers found archaeological remains when they began to build a sewer behind the Cathedral. Even though he had no training in archaeology, he recorded his findings with drawings (Figure 2.5) and pictures that he eventually published in his book *Exploraciones Arqueológicas en las Calle de Escalerillas* (*Explorations in the Escalerillas Street*) (Matos Moctezuma 1990:23).

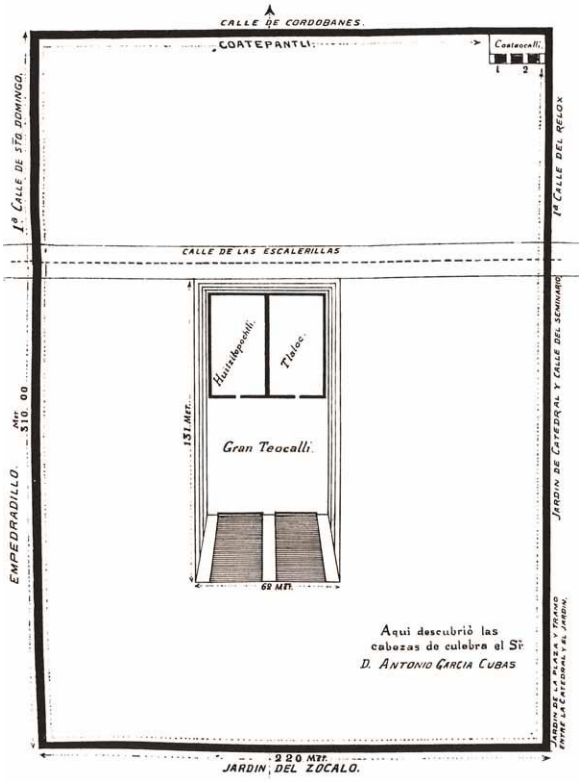


Figure 2.5. Plan of the ceremonial precinct and the Templo Mayor by Leopoldo Batres published in 1902 (Boone 1987:Figure 26).

In the period between 1910 and 1920, the social unrest and the political restlessness that fostered the revolutionary process introduced new characteristics to Mexican nationalism (Florescano 1997: 165). In 1917, Manuel Gamio, a former student of the Museo Nacional and the first Mexican who made specialized studies abroad, took advantage of the disruption that the Revolution generated, made several original propositions that would define a new cultural approach for the nation and set the foundations for the Indigenismo project. Gamio suggested the need for a new aesthetic that rejected Western Canons and valued the Indigenous creations under the framework of its own historical and cultural categories. When he projected this vision, he created programs that combined the anthropological interest in Indigenous populations with the decision to improve their situation and integrate them to the national development underway (Florescano 1997:166). Gamio was also the first to apply stratigraphic archaeology methods when he excavated a site one block northeast of the cathedral. This excavation led to the discovery of the southwestern section the Templo Mayor. Boone describes his findings:

> There he found a monumental serpent head at the base of a west-facing balustrade flanked by stairways, as well as a pyramidal nucleus of three stages and several superposed floors, which he recognized as representing various building phases. In addition, he uncovered more than five hundred objects, including two colossal masonry braziers on either side of a stone cist containing a cache of skulls, as well as stone merlons in the shape of shells, polychrome relief slabs carved with warriors, tenoned stone skulls and serpent heads, small idols, sherds, mica, and copper pyrite (Boone 1987:43).

This discovery revitalized the debate regarding the location of the Templo Mayor that had commenced with the studies made by Chavero, Seler and Batres. As a result of this finding, various scholars in Mexico and Europe, including Alfred Maudslay, Roque Ceballos Novelo and E. Guillemin-Tarayre, devoted many studies to this matter. Subsequent years were marked by accidental discoveries as a result of public or private works in downtown Mexico City (Boone 1987:45).

Throughout the post-revolutionary period, numerous other Aztec and Central Mexican sites were explored. Archaeologists continued excavating Teotihuacán through the 1930s, explored Tizatlán and Teopanzolco in the 1920s, Tenayuca in the 1920s and 1930s, Malinalco in the 1930s, Tula in the 1940s and Tlatelolco in the 1940s and 1950s (Boone 1987:48). Each discovery and subsequent study added material to the debate of the size and location of the ceremonial precinct of Tenochtitlan. Further findings were made in the mid-1960s and early 1970s in scattered excavations made during the repairs of several colonial buildings and during the construction of the subway. These included the temple dedicated to the wind god Ehecatl-Quetzalcoatl and other kinds of structures, such as small painted shrines with forecourts and circular base temples. These were soon interpreted and more studies were published.

This all changed when the accidental discovery of the Coyolxauhqui[7] led to the excavation of the Templo Mayor in 1978 (Figure 2.6). This massive archaeological excavation soon became the focus of the nation when the economy was disintegrating and the sense of national identity needed reinforcing. The Templo Mayor excavations, and those that followed such as the *Programa de Arqueología Urbana* (Urban Archaeology Program), benefited from the substantial support of the then President José López Portillo and of subsequent Presidents. Since the discoveries of 1978, the group in power has continuously provided the financial patronage needed for these excavations, which have often been utilized to legitimize their political agenda and further their economic interests. Furthermore, these excavations rekindled the interest in Aztec culture; and hundreds of studies have been completed by Mexican and foreign and academics.

Figure 2.6. Discovery of the Coyolxauhqui in 1978 (Photograph by *Rescate Arqueológico-INAH*).

Current studies about Aztec culture come from several disciples: anthropology, history, art history, religion and literature. Aztec culture provides a gateway to Mesoamerican studies for Central Mexico because it "represents the connecting point between the pre-Hispanic past and the globalized present" and "international attention continues to focus upon the ongoing

[7] Up to six representations of the Coyolxauhqui have been identified, but the monolith found in 1978 is the only complete full-body depiction of the goddess (Matos Moctezuma 1991:24).

excavations at the Templo Mayor" (Nichols and Evans 2009:265). Research has become interdisciplinary and now comprises subjects that range from the environment to the economy, politics, social relations, ideology and interregional relations (Nichols and Evans 2009:265).

The *Instituto Nacional de Antropología e Historia, INAH* (National Institute of Anthropology and History) has continued excavating several Aztecs sites and carrying out research about Aztec culture. This research corpus has been supplemented by several books about Aztec art, archaeology, and ethnohistory (Nichols and Evans 2009:265). It has also been accompanied by major international exhibitions sponsored by foreign companies involved in the tourism, energy, and resource industries in Mexico: the 2008 exhibition *The Aztec World* at The Field Museum in Chicago was funded by Exelon, the largest energy provider in the United States; the 2009 exhibition *Moctezuma: Aztec Ruler* at the British Museum was sponsored by Mexicana, a Mexican airline company and ArcelorMittlal, the largest steel producing company in the world; and the 2010 exhibition *The Aztec Pantheon and the Art of the Empire* at the Getty Villa was organized by INAH and the J. Paul Getty Museum after it had to return a considerable number of objects from its Roman and Greek collection obtained through the illegal international antiquity market.

2.3 Pictorial Manuscripts

Few pre-Hispanic pictorial manuscripts survive. Most were burned by the Spanish authorities and the missionaries in their zeal to obliterate Aztec beliefs. However, the church also commissioned missionaries to research Aztec customs and religion for their conversion, so many old books were copied and chronicles were illustrated by native artists.[8] While some were probably replicas of the originals, their style began to change after they learned European illustration techniques and integrated "realistic drawing, perspective, light and shade, and other elements of western art" with their native style (Pasztory 1983:179). This style consisted of Aztec and Mixtec traditions that utilized similar pictorial conventions, which enabled them to communicate. These conventions integrated representational, ideographic and phonetic

[8] The *Handbook of Middle American Indians* lists hundreds of these documents that survived in Mexican and European archives.

components, and facilitated the exchange between Postclassic cultures. The form of the pictorials followed their content and function (Boone 200b:39-61), hence they are a valuable source for the study of Aztec architecture.

Even though codices have been studied as a literary genre (León Portilla 1992) and as an intellectual, documentary, and pictorial genre (Boone 2000; Johansson 2004), they have not been analyzed from an architectural-urban point of view. Therefore, these sections include the meticulous analysis that was performed in each *original* source. Until this material became available in the past years, this analysis would not have been possible as neither the original documents nor their facsimiles had the high resolution of the digitized artifacts.

Hence, the dossier of each document consists of a description and content of the sources as well a summary of architectural and urban depictions identified by this research. The results of this material were later utilized to compile the inventory of Aztec building types.

2.3.1 Codex Aubin

Description

The Codex Aubin (15.5 x 13.4 cm, 81 leaves)[9] is a historical manuscript that records events from the years 1168-1591 and 1595-1596 with an addition for 1597-1608, through images and descriptions written in Nahuatl (Glass and Robertson 1975:88). The codex begins with the departure from Aztlan in 1168 and ends with the arrival of a new viceroy and archbishop in 1607-1608 (Leibsohn 2006).

Content

The codex is divided into a main account and an appendix. The main account is comprised of three sections that depict the migration from Aztlan to Tenochtitlan, the imperial history of Tenochtitlan and colonial events. The key events recorded in this section are "the New Fire ceremony at Coatepec, the Mexica defeat at Chapultepec, the founding of Tenochtitlan, the

[9] Measurements according to the description from the British Museum database.

installation and deaths of imperial tlatoque, enlargements of the Templo Mayor, comets and eclipses, the arrival of Spaniards, deaths from smallpox, local building projects and changes in altepetl leadership" (Leibsohn 2006). The appendix lists rulers from Tenoch through 1607 (Glass and Robertson 1975:89). The codex currently resides in the British Museum, although there are several copies and partial translations made in the nineteenth and twentieth centuries that are currently in collections in Europe and Mexico (Figure 2.7).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (plates 035-036_22v, 035-036_26r, 035-036_37v, 035-036_38r), double temple pyramids, a tzompantli (035-.36_11v), temazcal (035-036_24r , 035-036_24rv) and a view of the ceremonial precinct of Tenochtitlan (035-036_41v).

(a) (b)

Figure 2.7. (a) Calendar, folios 2v and 3r; (b) Departure from Aztlan, each group is represented as a house glyph, folio 4r, Codex Aubin (British Museum, CC-BY-NC-SA 4.0).

2.3.2 Codex Azcatitlan

Description

The Codex Azcatitlan (21 x 28 cm, 25 leaves) is a historical manuscript that chronicles Mexican history since their departure from Aztlan (Azcatitlan) and Colhuacan in 1168 to the Spanish Conquest and early colonial period (Glass and Robertson 1975:88).

Content

The codex is divided into three sections: the migration from Aztlán to Tenochtitlan and Tlatelolco; the rulers of Tenochtitlan from Acamapichtli to Motecuhzoma II Xocoyotzin, with their conquests and other important events of their reigns; and, in the final pages, the Spanish conquest and the early Colonial period. The key events recorded in the first part of the codex are the myth of Huitzilopochtli's birth and the battles of Chapultepec, Xochimilco and Colhuacan; the founding of Mexico; and the coronation of the first rulers of Tenochtitlan and Tlatelolco. The second part of the codex includes several conquests and other events such as plagues, the 1507 New Fire ceremony and the construction of important buildings. The last part of the codex depicts three incomplete scenes of the Spanish conquest, the meeting between Motecuhzoma II and Cortés, the battle scene where Motecuhzoma died, as well as the siege of Mexico (Graulich 2006). The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.8*)*.

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (plates 059-064_02, 059-064_03, 059-064_05, 059-064_10), double temple pyramids (plates 059-064_06, 059-064_18, 059-064_19, 059-064_20, 059-064_21, 059-064_22, 059-064_24), circular temple pyramids (plate 059-064_07), and tzompantlis (plates 059-064_08, 059-064_22).

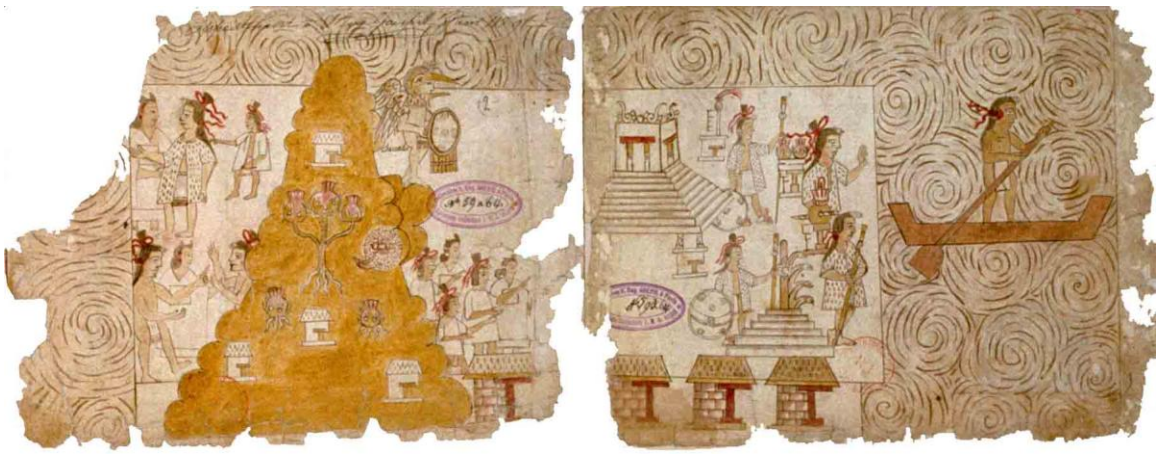


Figure 2.8. Departure from Aztlan, Codex Azcatitlan, folio 2 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

2.3.3 Codex Borbonicus

Description

The Codex Borbonicus (39 x 40 cm, 36 leaves) is a ritual-calendrical pictorial manuscript that is notable for "the insight it provides into Aztec rituals centered on two ancient Mesoamerican calendric constructs," the 260-day ritual calendar and the solar-based 365-day calendar (Quiñones 2006). The dating of this codex has been the object of much controversy, as E. T. Hamy, M.A. Aubin, E. Seler, G. Valliant and Alfonso Caso consider it pre-Hispanic while Nowotny and Robertson believe it is Post-Conquest (Mohar 1997:59).

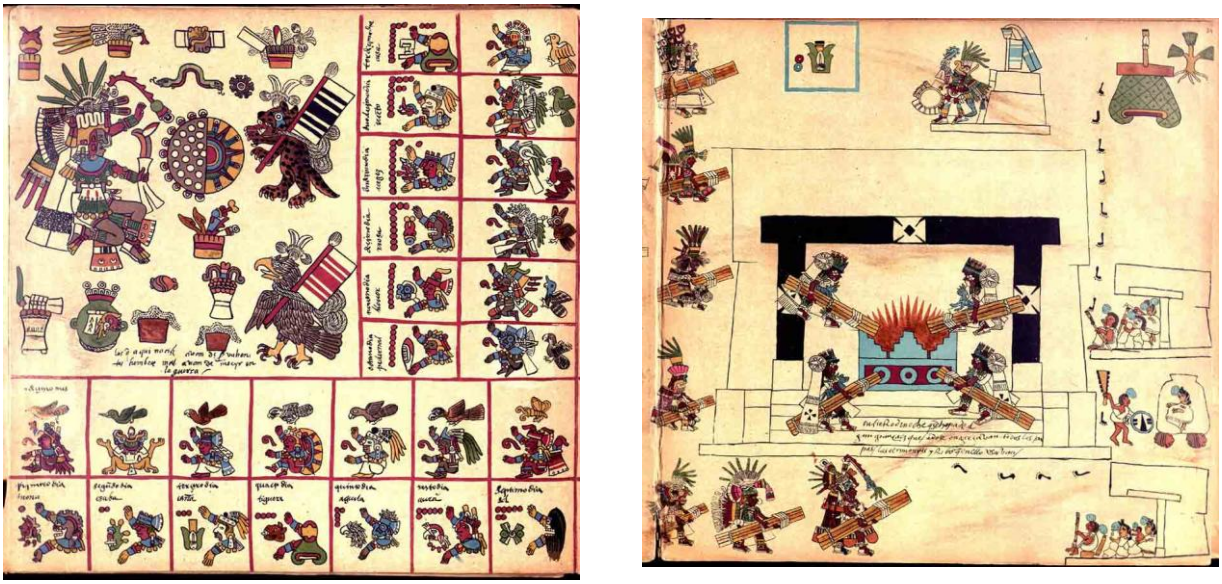
Content

The codex is divided into four sections (two major and two minor). The first section is a *tonalpohualli* or divinatory calendar of 260 days used to calculate the fate of a given day, with each plate containing the presiding deity flanked by two sets of smaller boxes. The first set contains the images of 13 of the 20-day signs and the numerals 1 to 13 which share space with 9 Night Lords; the second set encloses another set of 13 day lords with 13 associated flying creatures. The second section illustrates the association between the 9 Lords of the Night with each assigned day for a period of 52 years. The third section is the festive calendar that consists of 18 months of 20 days each and their corresponding ceremonies. The final section repeats an unfinished period of 52-years, (incomplete because of the loss of the last two panels) and

indicates the next New Year ceremony (Quiñones 2006). The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.9).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (plates 15, 33), tzompantli (plate 13), ball courts (plates 19, 27), and shrines (plate 29). The Titl and Ochpaniztli rituals show the two main forms of plan, with either tzompantli or banquet table, quauhxicalli and temple along the same axis.



(a) (b)

Figure 2.9. (a) Tonalpohualli (divinatory calendar) panel with deities looking at stars (represented by half circle with small white dots) and Sun (represented with the other half as a solar disk), folio 11; (b) Deities within a temple in the New Fire ceremony, folio, 34, Codex Borbonicus (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

2.3.4 Codex Borgia

Description

The Codex Borgia (26.5 x 27 cm, 14 strips folded to form 78 panels) is a ritual-calendrical pictorial manuscript from unknown origin, but its Mixteca-Puebla style and content are similar to codices from the Cholula-Tlaxcala area, the Tehuacán Valley and the Mixtec region (Jansen 2006).

Content

The content of the codex can be described in sections:

- The sacred count of 260 days (*tonalpohualli*), their patron deities, and an alternative list of the 20-day signs with patron deities or divinatory signs, or both.
- Predictions of climatic patterns in the different calendrical periods.
- Rituals, centered around the magical passages from darkness to light, from death to life, and from sacrifice to the creation of fertility and power.
- Complex scenes of trees, temples, deities and divinatory images associated with the four world directions and the center.
- Deities that influence the travels of merchants and ambassadors (55), the life-giving force of Quetzalcoatl with the death god Mictlantecuhtli (56) and the patrons of marriages.
- Depictions of the Sun god Tonatiuh, Mictlantecuhtli and Quetzalcoatl, Cihuateteo and Tonaleque, their associations with birds, and the numbers of day signs.

The codex currently resides in the *Biblioteca Apostolica Vaticana* (Figure 2.10*).*

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (plates 33, 34, 35, 37, 45, 46, 49, 50, 51, 52, 55, 61, 62, 63, 64, 65, 66, 68, 74), tzompantli (plate 13), ball courts (plates 9, 21, 35, 40, 42), and shrines (plate 42). It is worth noting that plates 49 to 52 contain depictions of single pyramid temples in both front and side view.

(a) (b)

Figure 2.10. (a) Tonalpohualli panel with deities playing on the Tlachtli (ball court), folio 21; (b) 20-day signs distributed over the bodies of four deities, surrounded by four great serpents, associated with the four directions, folio 72, Codex Borgia (*Biblioteca Apostolica Vaticana*, CC-BY-NC-SA 4.0).

2.3.5 Codex Boturini

Description

The Codex Boturini (19.8 x 549 cm, 21 ½ panels) is a historical pictorial manuscript that chronicles the Mexica migration from 1168 to their arrival in the Valley of Mexico in 1355 (Glass and Robertson 1975:100).

Content

The codex follows a linear narrative that commences with the Mexica journey from Aztlan overseen by Huitzilopochtli, continues through their arrival in Chapultepec to the period of their subjugation to Colhuacan. (Glass and Robertson 1975:100). The codex currently resides in the *Museo Nacional de Antropología* in Mexico City (Figure 2.11).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (plate 1), tzompantli (plate 10), and residences (plates 20, 21).

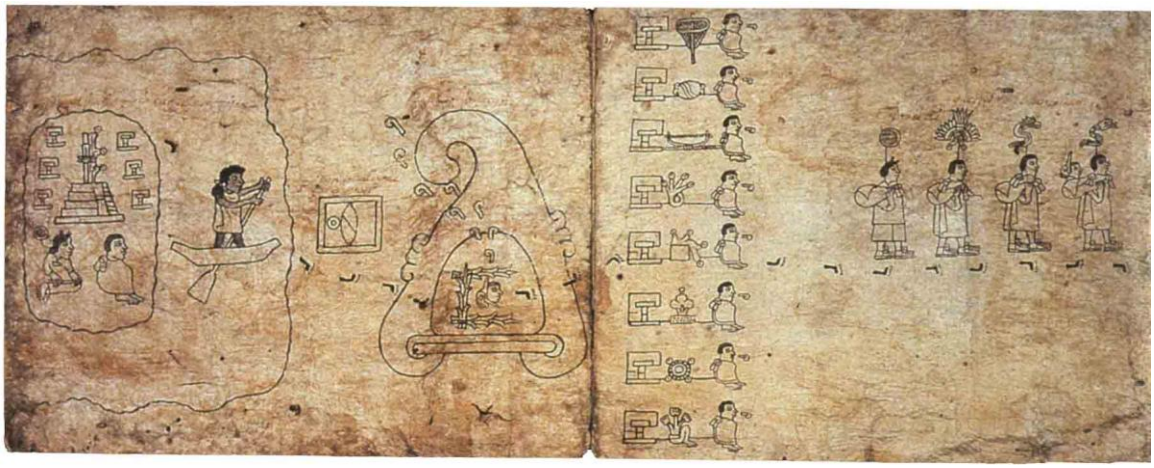


Figure 2.11. Departure from Aztlan, Codex Boturini (*Museo Nacional de Antropología,* CC-BY-NC-SA 4.0).

2.3.6 Codex Ixtlilxochitl

Description

The Codex Ixtlilxochitl (31 x 24 cm, 11 leaves) is a historical manuscript that consists of three unrelated parts, two of which are pictorial (Glass and Robertson 1975:147). They may have been compiled by Fernando de Alva Ixtlilxochitl, an early-seventeenth-century historian (Boone 2006).

Content

The first part (folios 94–104), dating from about 1600, is probably a partial copy of the Codex Magliabechiano. It includes an image and a description written in Spanish of the gods and ceremonies of 17 of the 18 months of the 365-day year, two drawings and texts of gods, and two drawings of funerary customs. The second part (folios 105–112) is comprised of six illustrations: four full-length portraits of Tetzcocan rulers, an illustration of the god Tlaloc and a depiction of the double temple pyramid in Tetzcoco (Glass and Robertson 1975:147-148). The third part (folios 113–122) is an explanation of the Aztec calendar written in Spanish (Boone 2006). The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.12).

Summary of Architectural and Urban Depictions

The architectural depictions include a single temple pyramids (folios 99v) and the double temple pyramid of Tetzcoco which has subsequently been used by scholars to illustrate the Templo Mayor of Tenochtitlan.

(a) (b) (c)

Figure 2.12. (a) Priest and sacrificed victim with temple in the background, folio 99v; (b) a representation of the god Tlaloc on top of platforms, possibly temalacatl, folio 110v; (c) Templo Mayor in Tetzcoco, folio 112v, Codex Ixtlilxochitl (*Bibliothèque Nationale de France* ,CC-BY-NC-SA 4.0).

2.3.7 Codex Magliabechiano

Description

The Codex Magliabechiano (15.5 x 21.5 cm, 92 leaves) is a ritual-calendrical and ethnographic pictorial manuscript that consists of native drawings facing Spanish texts, developed for the Spaniards to record the calendars, festival ceremonies and customs of the Aztecs. It is believed that it is a copy created before 1566 of an older manuscript (Glass and Robertson 1975:155).

Content

The codex is divided in five sections:

- A series of blankets with festival designs.

• The 20-day signs of the Aztec day-count.

• The year signs in the 52-year cycle

• The eighteen monthly feasts.

• Rituals and deities including funeral rites for people of different stations and occupations, and various forms of offerings and sacrifices.

The codex currently resides in the *Biblioteca Nazionale Centrale di Firenze* (Figure 2.13).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (40r, 70r, 79r, 87r, 91r), a ball court (80), and a temazcal (77r). The illustrations in this codex also demonstrate the transformation from the two-dimensional Aztec style to the three-dimensional European style that native painters started to incorporate in their paintings after colonization.

(a) (b)

Figure 2.13. (a) Priest and sacrificed victim with temple in the background, folio 40r (b) a representation of the god Tlaloc on top of platforms, possibly temalacatl, folio 70r, Codex Magliabechiano, Nuttal facsimile (*Biblioteca Nazionale Centrale di Firenze*, CC-BY-NC-SA 4.0).

2.3.8 Codex Telleriano-Remensis

Description

The Codex Telleriano-Remensis (32 x 22 cm, 50 leaves) is a ritual-calendrical and historical manuscript that was compiled from diverse local sources in the years following the conquest. It

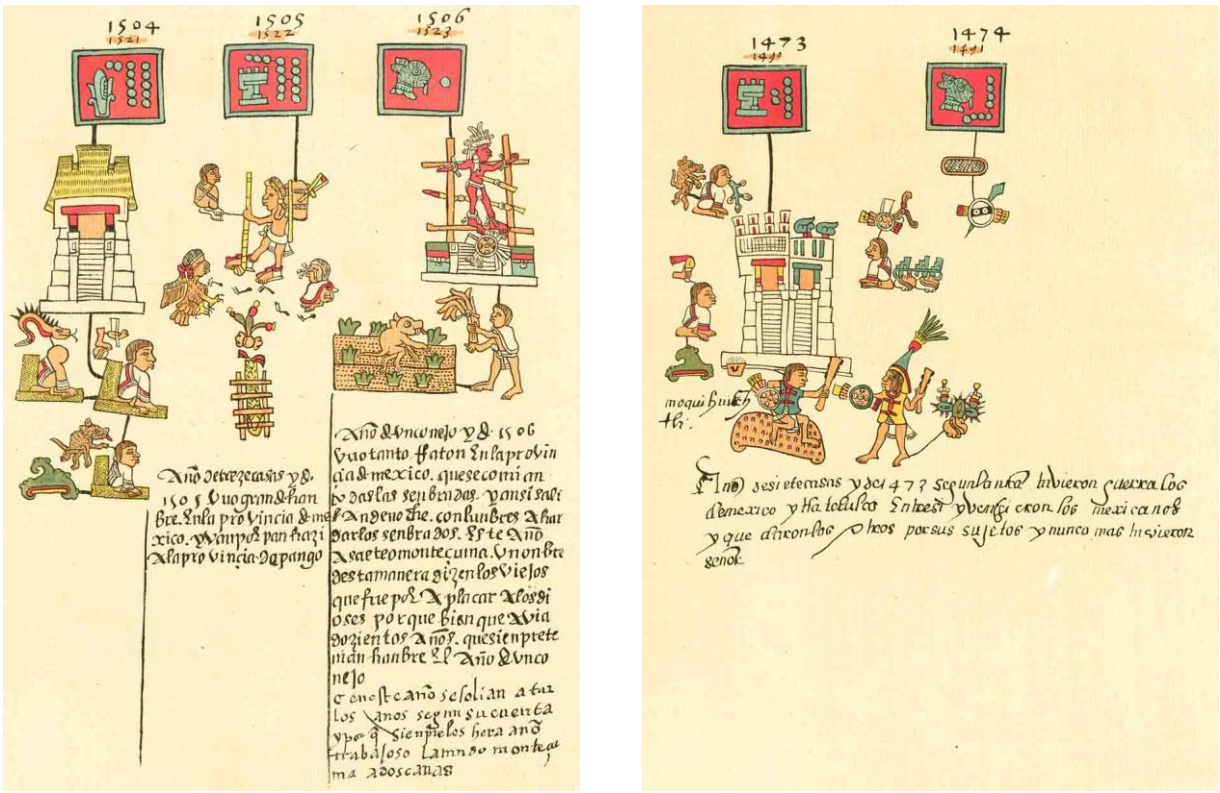
is a hybrid document in which Indigenous artists painted the images while Spanish and Indigenous writers added annotations (Quiñones Keber 2006).

Content

The codex has three sections with different narrative styles. The first section (folios 385_01r to 385_07r) is an 18-month calendar with drawings of the gods of each period and a symbol for the *nemontemi* (the extra five days in the solar calendar). The second section (folios 385_08r to 385_24r) is a *tonalpohualli* (260-day divinatory almanac). The third section (folios 385_25r to 385_48r) is a pictorial annal for the period 1198-1562 in two major styles. The two final folios contain historical notices in Spanish with no images. The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.14).

Summary of Architectural and Urban Depictions

The architectural depictions include single-temple pyramids (folios 385_29r, 385_38v, 385_41v, 385_42r), a single temple pyramid with two entrances (folio 385_40r), double temple pyramids (385_36v, 385_39r, 385_40r), and a ball court (385_41r). In these depictions, the Templo Mayor is illustrated in two contexts, within a battle and in its dedication scene in 1487. It should also be noted that a single temple pyramid with two entrances is also illustrated as well as a side and front view of a single temple pyramid.



(a) (b)

Figure 2.14. (a) Events related to famine suffered between 1504 and 1506 described in the context of a temple and sacrificial victim on frame assembled on platform, folio 41v; (b) battle between Mexico and Tlatelolco with double teocalli in the background, folio 26v, Codex Telleriano-Remensis, Loubat facsimile (*Biblioteca Nazionale Centrale di Firenze,* CC-BY-NC-SA 4.0).

2.3.9 Codex Xolotl

Description

The Codex Xolotl (approximately 42 x 48 cm, 10 leaves forming a series of 8 maps) is a historical cartographic manuscript[10] that details the history of the Tetzcocans from the initial migrations of the Chichimecs lead by Xolotl (1224) up to the "onset of the Tepanec war in

[10] Boone (2000a:183) describes de Codex as 10 leaves forming 8 maps; Douglas (19) as 6 leaves with 10 painted leaf and 3 fragments from one more painted leaf; and Glass and Robertson (241) as 6 leaves with 10 painted pages and fragments of a 7th leaf with 2 fragmentary pages based on the reproduction by Dibble in 1951. The painted sides of fragments 1A, 1B, and 1C were once attached to the backside of page 1, hence Dibble maintains that fragments 1A and 1B were part of the narrative of the Codex Xolotl. However, these fragments have noticeable compositional and stylistic differences.

1427"[11] when Texcoco and Tenochtitlan rebelled against Azcapotzalco (Boone 2000a:183; Glass and Robertson 1975:241).

Content

The codex follows a narrative that can be divided into two sections. The first section (maps 1 to 6) contains extensive genealogical and political information that serves as a background for the second section (maps 7 to 10) which recounts the aggressions of the Tepanecs from Azcapotzalco against the Tetzcocans and its intended ruler, Nezahualcoyotl, that resulted in the Tepanec War of 1427 (Glass and Robertson 1975:241). The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.15).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (maps 7 and 10), a ball court (map 9) and palaces (maps 8 and 9). Even though the Codex Xolotl focuses on Tetzcoco, it also serves as a map of the eastern region of the Valley of Mexico including Cholula across the mountains, Culhuacan and Chalco in the south, and Tenochtitlan across the lake (Boone 2000a:184).

[11] According to Thouvenot, the last date mentioned in the document is 1429 (67).

Figure 2.15. Map 9, Codex Xolotl (*Bibliothèque Nationale de France,* CC-BY-NC-SA 4.0).

2.3.10 Historia Tolteca-Chichimeca

Description

The Historia Tolteca-Chichimeca (30 x 22 cm, 52 leaves) is a historical and cartographic manuscript that chronicles the history of Cuauhtinchan from 1116 through 1544, although most of themes that dominate the manuscript, 49 of its 52 folios, focus on the pre-Hispanic period (Leibsohn 1993:12). It is one "of the major sources for the study of the early port-Toltec and subsequent history of the Chichimec migrations from Chicomoztoc to the Central Puebla region" (Glass and Robertson 1975:220).

Content

The Historia consists of three parts. The first two contain 22 leaves of the original and copies made by Aubin; modern editions combine the three parts, arrange the pages in logical sequence, and omit the Aubin copies. The narrative utilizes prose passages, songs, dialogues, glyphs and pictorial imagery to recount the migration of the Nonoalca and Toltec-Chichimec[12] from Tula, the conquest of the Olmeca-Xicalanca at Cholula, the migration from Chicomoztoc, the founding of Cuauhtinchan, and the later history and regional battles of the inhabitants of Cuauhtinchan (Aguilar Moreno 2006:274). The Historia currently resides in the *Bibliothèque Nationale de France* (Figure 2.16).

Summary of Architectural and Urban Depictions

The architectural depictions include single temple pyramids (folios 07v, 19v, 26v, 27r, 38v, 39r), a round-temple pyramid (folio 41r), palaces (folios 08v, 14r, 24v, 25r, 27r, 32r, 42v, 43v, 43r), a ball court (folio 16v), and a complex assemblage (Cholula, folios 26v, 27r). The illustrations in the Historia Tolteca-Chichimeca also demonstrate the acculturation process suffered by native artists who continued using the two-dimensional Aztec style to draw representations of architecture that was changing. This is evident in the illustrations of temples where European-style churches with towers started replacing the blood-covered temples on top of the trapezoidal bases.

[12] The first encounter between the Toltec and the Chichimec is at a sacred cave known as Colhuacatepec, "Place of the Mountain of the Ancestors" (Leibsohn 1993:101).

(a) (b)

Figure 2.16. (a) Migration scene in which two different temples are depicted, one in the traditional way (small mountain with stairs in the lower middle section), and the other with Spanish imagery (lower right), folio 7v; (b) players with ball in the characteristic I-shaped Tlachtli, folio 16v, Historia Tolteca Chichimeca (*Bibliothèque Nationale de France,* CC-BY-NC-SA 4.0).

2.3.11 Mapa de Cuauhtinchan No. 2

Description

The *Mapa de Cuauhtinchan No. 2*, also known as MC2 (109 x 204 cm, 1 map), is a historical and cartographic manuscript that chronicles the story of the migration of the people of Cuauhtinchan[13]. The "MC2 records events from the twelfth century, when the Chichimecs departed from Chicomoztoc, to the fifteenth century, when the Cuahtinchantlaca, pursued by the Tepeyacactlaca, fled across the Atoyac River with the Totomihuaque and Tecalca (Yoneda 2007:162-163). The manuscript also contains information about geography, religious rites, political activities, boundaries and chronology.

[13] The MC2 and the *Historia Tolteca-Chichimeca* are the only Cuauhtinchan documents that narrate the emergence from Chicomoztoc and subsequent journey to Cholula before arriving in Cuauhtinchan (Boone 2000a:182).

Content

The MC2 is part of a group of six cartographic histories from the Altepetl of Cuauhtinchan located southeast of the ancient city of Cholula. The narrative tells the story from their point of origin, the mythical cave, their journey through Cholula-an important civic and religious centre-to the vicinity of the Amozoc Tepeaca range (Boone 2000a:173). The left side of the MC2 concerns the events related to their departure and arrival to Cholula; the right side emphasizes socio-political events. The purpose of the MC2 was to prove the historical priority of Cuauhtinchan over Tepeaca (Yoneda 2007:165-166). The MC2 currently resides in the private collection of the late Angeles Espinosa Yglesias (Figure 2.17).

Summary of Architectural and Urban Depictions

Besides containing numerous toponymic glyphs, the MC2 has several architectural depictions including single temple pyramids, round temple pyramids, a round temple on a cliff, palaces, ball courts and a complex assemblage (Cholula). Furthermore the MC2 is one of the most outstanding visual representations of the sacred landscape comprised of mountains, rivers, and both natural and modified caves (Yoneda 2007:167).

Figure 2.17. Mapa de Cuauhtinchan No. 2 (Carrasco and Sessions 2007:Figure 1).

2.3.12 Mapa Quinatzin

Description

The Mapa Quinatzin (77 x 44 cm, 2 sewn leaves; 34.5 x 43.5 cm, 1 separate leaf) is a historical manuscript that depicts events in the time of Quinatzin and Techotlalatzin as well as the palace of Nezahualcoyotl in Texcoco in the late 15th century (Mohar Betancourt 110).

Content

The first sewn leaves of the manuscript illustrate events that happened in the time of Quinatzin and Techotlalatzin. The separate leaf shows the palace of Nezahualcoyotl, the various sections in which it was divided, and the towns subject to Texcoco and their rulers (Glass and Robertson 160). The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.18).

Summary of Architectural and Urban Depictions

Even though the first leaf contains several toponyms, the only architectural depiction of the palace of Nezahualcoyotl.

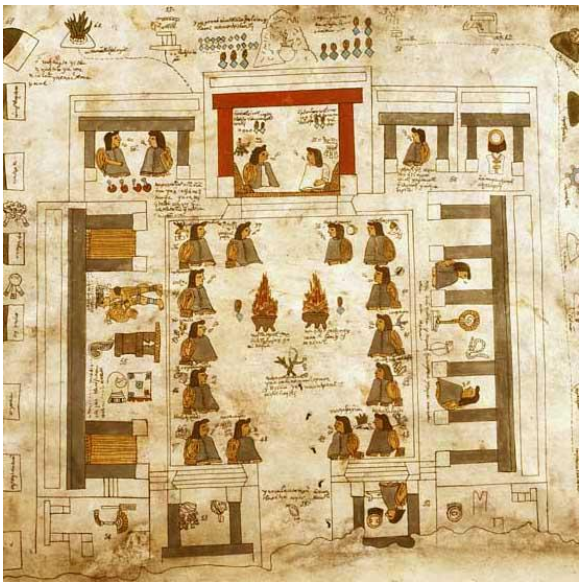


Figure 2.18. Depiction of Palace (Tetzcoco), Mapa Quinatzin (Enhanced copy, original *Bibliothèque Nationale de France* CC-BY-NC-SA 4.0),

2.3.13 Summary of Architectural and Urban Depictions in Pictorial Manuscripts

The analyses of the codices revealed that the most common types of architectural depictions in pictorial manuscripts are single temple teocallis, nobility dwellings, double temple teocallis, tlachtlis (ball courts), tzompantlis (skull racks) and circular base teocallis (Table 2.1). Single temple teocallis are consistently utilized throughout manuscripts as phonetically and semantically defined logograms to represent toponyms and personal names, and are often combined with other glyphs (Yoneda 2007:166).

Double temple teocallis appear only in reference to Tenochtitlan-Tlatelolco and Texcoco, the main city-states of the Triple Alliance, which dominated the Aztec empire from 1428 until the defeat by the Conquistadores in 1521. The representation of the double temple teocalli of Texcoco in the *Codex Ixtlilxochitl* provides unique architectural details of this structure: an ample base with priests precincts on both sides, four stepped platforms in the form of truncated pyramids, and two temples on top, one dedicated to Tlaloc (north) and the other to Huitzilopochtli (south). Even though the representations of the double teocalli of Tenochtitlan—the Great Temple of the Aztecs—in the Codex Azcatitlan are not architecturally accurate, they demonstrate the process of acculturation suffered by Aztec scribes after the Conquest. During this time, the traditional two-dimensional drawings began changing to three-dimensional representations of stories, people and architecture.

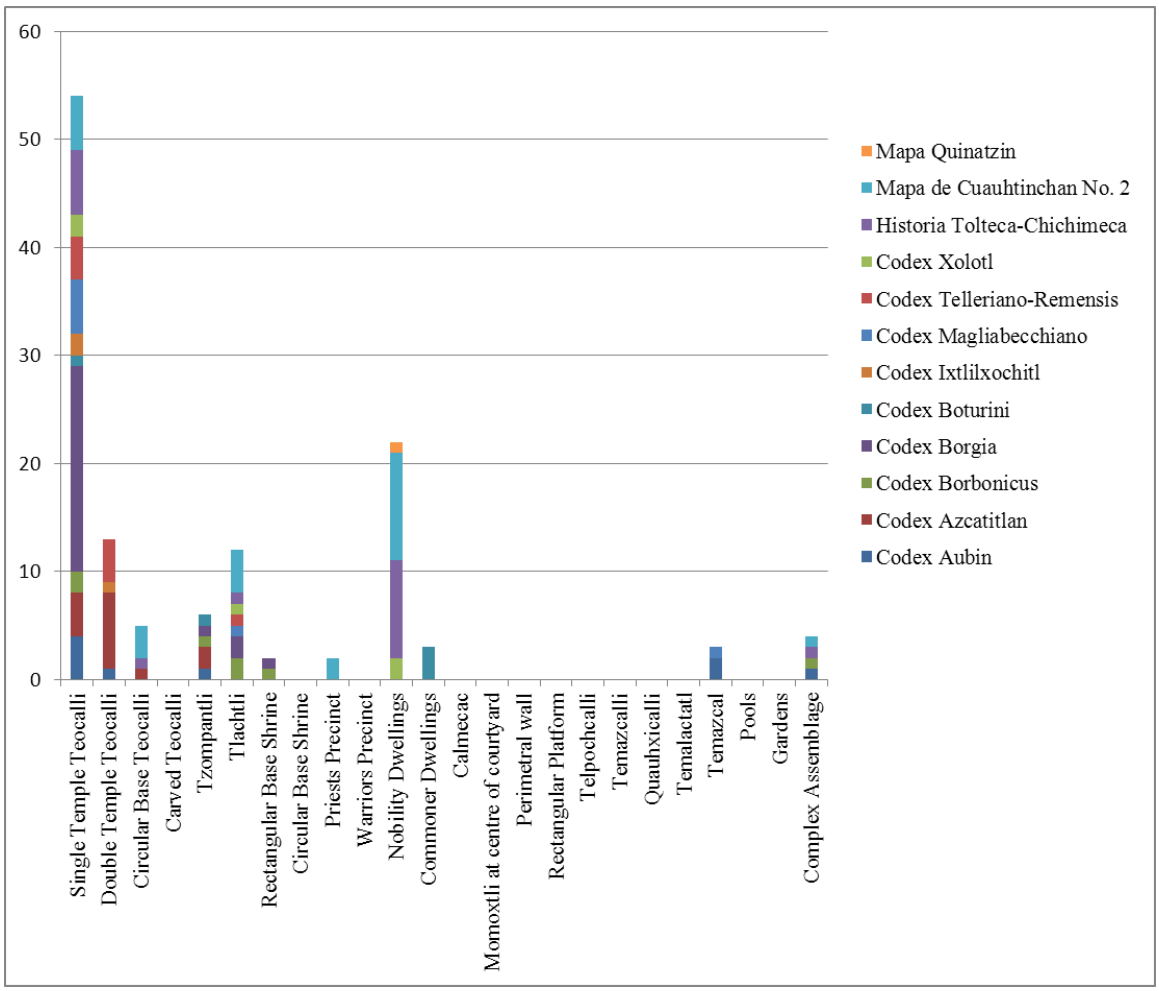
Table 2.1. Summary of the type of architectural and urban depictions in Pictorial Manuscripts.

Type of Architectural Structures	Codex Aubin	Codex Azcatitlan	Codex Borbonicus	Codex Borgia	Codex Boturini	Codex Ixtlilxochitl	Codex Magliabechiano	Codex Telleriano-Remensis	Codex Xolotl	Historia Tolteca-Chichimeca	Mapa de Cuauhtinchan No. 2	Mapa Quinatzin
Single Temple Teocalli	**4**	**4**	**2**	**19**	**1**	**2**	**5**	**4**	**2**	**6**	**5**	
Double Temple Teocalli	**1**	**7**				**1**		**4**				
Circular Base Teocalli		**1**								**1**	**3**	
Carved Teocalli												
Tzompantli	**1**	**2**	**1**	**1**	**1**							
Tlachtli			**2**	**2**			**1**	**1**	**1**	**1**	**4**	
Rectangular Base Shrine			**1**	**1**								
Circular Base Shrine												
Priests Precinct											**2**	
Warriors Precinct												
Nobility Dwellings									**2**	**9**	**10**	**1**
Commoner Dwellings					**3**							
Calmecac												
Momoztli at centre of courtyard												
Perimetral wall												
Rectangular Platform												
Telpochcalli												
Temazcalli												
Quauhxicalli												
Temalacatl												
Temazcal	**2**						**1**					
Pools												
Gardens												
Complex Assemblage	**1**		**1**							**1**	**1**	

After the single temple teocalli, the tlachtlis (ball court) and the tzompantlis, although not numerous, appear in most codices. In contrast, nobility dwellings, though abundant in the *Historia Tolteca-Chichimeca* and the *Mapa de Cuauhtinchan No. 2*, are not present in most manuscripts, the only clear exception being the *Mapa Quinatzin* (Table 2.2).

The circular base teocallis can easily be distinguished by their conical thatched roofs. The different views (front, side, isometric) of these teocallis included in the *Mapa de Cuauhtinchan No. 2* (MC2) reveal their unique architectural characteristics, particularly the cylindrical shape of the temple on top of their truncated conical stepped platforms. The MC2 also contains a circular base teocalli on the slope of a mountain, which might indicate their importance within the sacred landscape.

Table 2.2. Frequency of the type of architectural depictions in Pictorial Manuscripts.



In addition to architectural structures, there are also complex assemblages depicted in pictorial codices, mainly the ceremonial centres of Cholula and Tenochtitlan, as well as the ritual space in

the Codex Borbonicus. These assemblages reveal the two main forms of plan common in Central Mexico, with either tzompantli or banquet table, quauhxicalli and temple along the same axis.

2.4 Pictorial Administrative Manuscripts

When Hernán Cortes arrived in 1519 AD, the Aztec Empire had expanded from the Valley of Mexico to a vast area of Central Mexico in a system of tributary provinces and strategic provinces that extended from the Pacific Ocean to the Atlantic Ocean and as far south as Guatemala (Berdan et al. 1996:5). The tributary provinces had the obligation of sending regular payments of goods and services, however, the goods and services sent by the strategic provinces were defined as gifts rather than tribute obligations, thus making it a less oppressive relation (Evans 2004:470). These imperial relations resulted in a complex system of recordkeeping of various classes and at different territorial levels. Several imperial and local level records survived both in pictorial and written manuscripts. Imperial records such as the second section of the Codex Mendoza, have detailed lists of goods from the tributary provinces. Local level records, such as the pictorial codices from Tepetlaoztoc, have household censuses and household land cadasters (Williams and Jorge 2001:186).

Even though some land records had existed since the 19th century, they had barely been studied due to the lack of understanding of their mathematical conventions. It was not until 1980 that Harvey and Williams decoded the numerical portions of the *Códice de Santa María Asunción*. Williams and Jorge continued this research and later found geometric algorithms for surface area computation that may have been employed by Acolhua-Aztec surveyors (2001:185).

Another type of pictorial manuscript included colonial period administrative documents that were produced within the Spanish legal system. The information contained in these manuscripts gave a wealth of detailed local information before the Conquest and during the early Colonial period (Smith Aztec 2008:18). These documents comprise maps as well as legal processes.

In spite of the fact that collections such as the *Mapas, Planos e Ilustraciones* from the *Archivo General de la Nación* has more than 8000 documents in its archives or that other pictorial-

administrative documents haven been in foreign collections for centuries, some scholars have managed to study them. These studies have mostly focused on their economic and legal content or on their mathematical representations. However, they have not been analyzed from an architectural-urban point of view. Hence, a representative sample of these manuscripts was selected for analysis. A summary of these meticulous analyses is included in this section. Unlike the pictorial manuscripts that contain representations of Mesoamerican building types, the pictorial-administrative manuscripts demonstrate the utilization of precise geometric and mathematical system that allowed the Aztecs to divide property or settle legal disputes. These analyses provided the confirmation that this knowledge was applied when they planned their cities and constructed their buildings.

2.4.1 Codex Mendoza

Description

The Codex Mendoza (32.7 x 22.9 cm, 72 leaves) is a historical, economic and ethnographic manuscript that recounts history of the Mexica from 1325 to 1518,[14] their tributes to the Aztec empire and Aztec life through images and descriptions written in Spanish for sentences and Nahuatl for names. It is believed to have been commissioned by the first viceroy of New Spain, Don Antonio de Mendoza, for presentation to Charles V (Glass and Robertson 1975:160).

Content

The codex has three distinct sections. The first section (folios 2r-16v) documents the founding of Tenochtitlan and records the history of the conquests of the Mexica by individual ruler. The second section (folios 17v-55r) is a detailed account of the tribute obligations of 371 city-states grouped in 38 provinces. The third section (folios 56v-71r) provides a pictographic account of the daily existence of the Mexica as well a drawing of the royal palace of Motecuhzoma. The° first two sections appear to have been copied from extant pre-Hispanic documents, but the final section was created at the request of the Spanish (Berdan and Anawalt 1997:xii). The codex currently resides the Bodleian Library at Oxford (Figure 2.19).

[14] Glass and Robertson date it from 1325 through 1521 (1975:160), but this date is disputed among scholars who believe that three years were added at a later time.

Summary of Architectural and Urban Depictions

The significance of the Codex Mendoza in architectural research is twofold; it not only contains urban and architectural depictions, but also mathematical knowledge that can be deduced from the tribute owed by each province.

The architectural depictions include single temple pyramids (folios 2r, 2v, 3v, 4v, 5v, 6r, 7v, 8r, 10r, 10v, 12r, 13r, 13v, 15v, 16r, 16v, 19r, 20v, 23r, 24v, 27r, 32r, 33r, 37r, 38r, 39r, 40r, 42r, 44r, 46r, 48r, 49r, 51r, 52r, 63r, 64r, 67r), a double temple pyramid (folio 10r), tzompantlis (folios 2r, 35r), ball courts (folios 8r, 16r, 31r, 36r, 45r), calmecac (folio 61r), and the palace of Motecuhzoma(69r).

Nonetheless, it should be noted that the majority of these architectural depictions are the toponyms of the city-states that were under the political domination of the Aztec empire. These cities are represented with a temple glyph complemented by a place glyph. In the first section of the codex, the temples are on fire, as this signifies that they were conquered. The second section has simplified versions of toponyms, but few of them use a temple in their name. The third section has only three temples shown in the context of an activity.

(a) (b)

Figure 2.19. (a) Foundation of Tenochtitlan, folio 2r; (b) tribute list with number of items in Aztec units, folio 24r, Codex Mendoza (Bodleian Library, CC-BY-NC-SA 4.0).

2.4.2 Codex of the Marquesado del Valle

Description

The Codex of the Marquesado del Valle (28 single large-format leaves with paintings and text in Nahuatl written in Latin characters and two booklets totaling 102 leaves) is a pictorial legal manuscript that contains 28 separate petitions from different leaders and towns of the Marquesado del Valle protesting seizures of lands and sugar mills by Hernán Cortés.

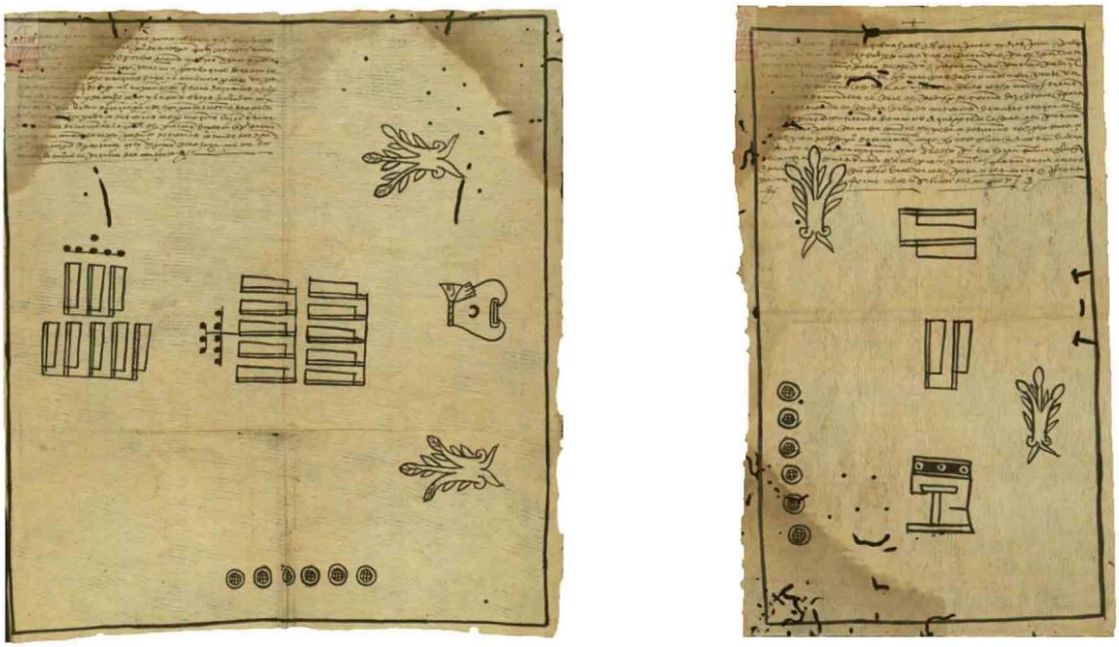
Content

This codex records ownership of land parcels, place names and parcel size. It also specifies the type of production and quantities and gives the names of ruling chiefs and other miscellaneous

information. The codex currently resides in the *Archivo General de la Nación de México* (Figure 2.20.)

Summary of Architectural and Urban Depictions

The significance of the Codex of the Marquesado del Valle is that it clearly illustrates parcel dimensions following mathematical conventions.



(a) (b)

Figure 2.20. (a) and (b) Perimeter dimensions of property in Aztec units and tribute owned, Codex of the Marquesado Del Valle (*Archivo General de la Nación de México*, CC-BY-NC-SA 4.0).

2.4.3 Plan and Title of a Property in Tenochtitlan

Description

The Plan and Title of a Property in Tenochtitlan is a pictorial legal manuscript that depicts the legalization of a genealogy (Caracas).

Content

The codex records family members, ownership of possessions and the plan of the property. The manuscript currently resides in the *Bibliothèque Nationale de France* (Figure 2.21).

Summary of Architectural and Urban Depictions

The significance of the Plan and Title of a Property in Tenochtitlan is that it clearly illustrates the use of two types of units, one to describe quantities (blue glyphs on top) and another to record the measurements of the property (hands, dots and arrows along the perimeter of the walls).

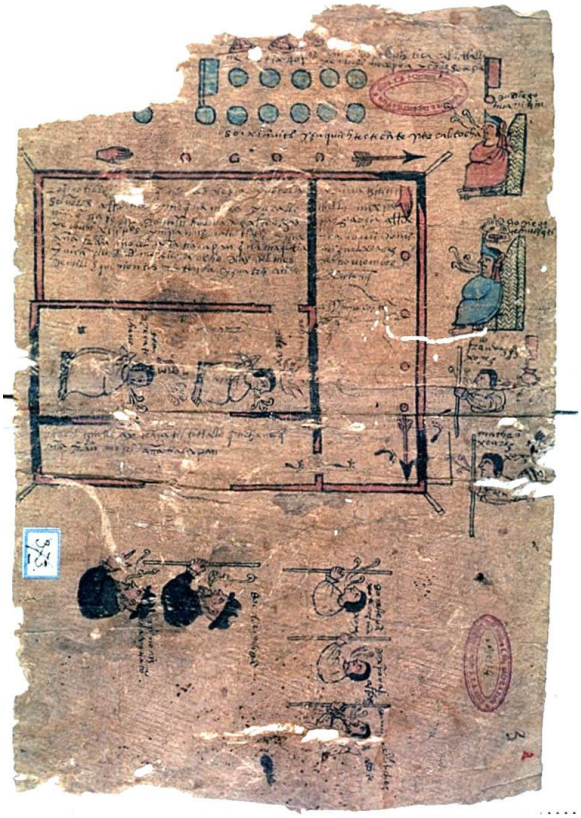


Figure 2.21. Plan and Title of a Property in Tenochtitlan (*Bibliothèque Nationale de France,* CC-BY-NC-SA 4.0).

2.4.4 Codex Vergara

Description

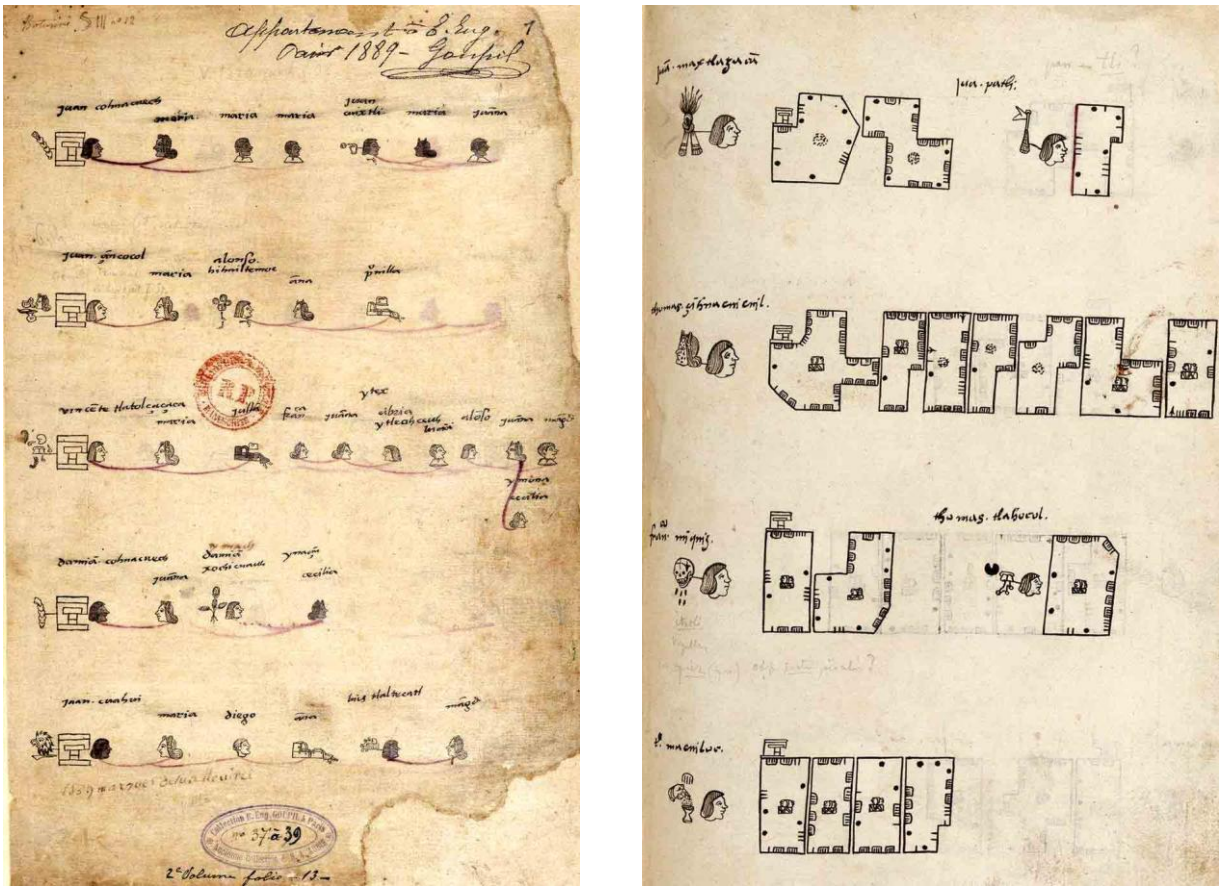
The Codex Vergara (31x22 cm, 55 leaves) is an economic (census and cadastral) manuscript that contains a pictorial census and two cadasters for each of the five named localities in the Tepetlaoztoc region. It is probably dated around 1539 (Glass and Robertson 1975:229).

Content

The codex has three sections of recorded information. The first section includes the demographic composition of each household; the second section has cadastral drawings of the land parcels; and the last section includes another cadastral register in a different format of the same landholdings. The codex currently resides in the *Bibliothèque Nationale de France* (Figure 2.22).

Summary of Architectural and Urban Depictions

The significance of the Codex Vergara is that it is one of the clearest demonstrations of the use of linear measurements in the context of properties with different geometric configurations.



(a) (b)

Figure 2.22. (a) Demographic composition of each household; (b) drawings of parcels with area and perimeter measurements in Aztec units (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

2.4.5 Codex Santa María Asunción

Description

The Codex Santa María Asunción (31x21 cm, 80 leaves) is an economic (census and cadastral) manuscript that contains pictorial registers of person and properties for a number of named localities in the Tepetlaoztoc region of the eastern valley of Mexico. The dates mentioned in the Nahuatl texts are 1550, 1571 and 1579 (Glass and Robertson 1975:88).

Content

Similar to the Codex Vergara, this codex has three distinct registers of information: a census by household (*tlacatlacuiloli*); a description of each household's landholdings, which includes perimeter measurement, general shape and soil type (*milcocoli*); a second register of the same lands which records the quantity of land in each parcel depicted (*tlahuelmantli*) (Harvey 1986:275). The codex currently resides in the *Biblioteca Nacional de México*.

Summary of Architectural and Urban Depictions

Similar to the Codex Vergara, the significance of the Codex Santa María Asunción is that it is one of the clearest demonstrations of the use of linear measurements in the context of properties with different geometric configurations.

2.4.6 Oztoticpac Lands Map

Description

The Oztoticpac Lands Map (76 x 84 cm) is a litigation map of Oztoticpac, an estate in Texcoco, related to a lawsuit concerning the estate of Don Carlos Ometochtli Chichimecatecotl. It is dated approximately 1540.

Content

The map contains detailed drawings of several houses and over 75 land parcels, including shapes and measurements, of properties once owned by Don Carlos. The map currently resides in the Library of Congress Geography and Map Division Washington, D.C. (Figure 2.23).

Summary of Architectural and Urban Depictions

The Oztoticpac Lands Map is the clearest demonstration of the use of linear measurements in the context of properties with different geometric configurations in a small scale and larger properties in an urban scale.

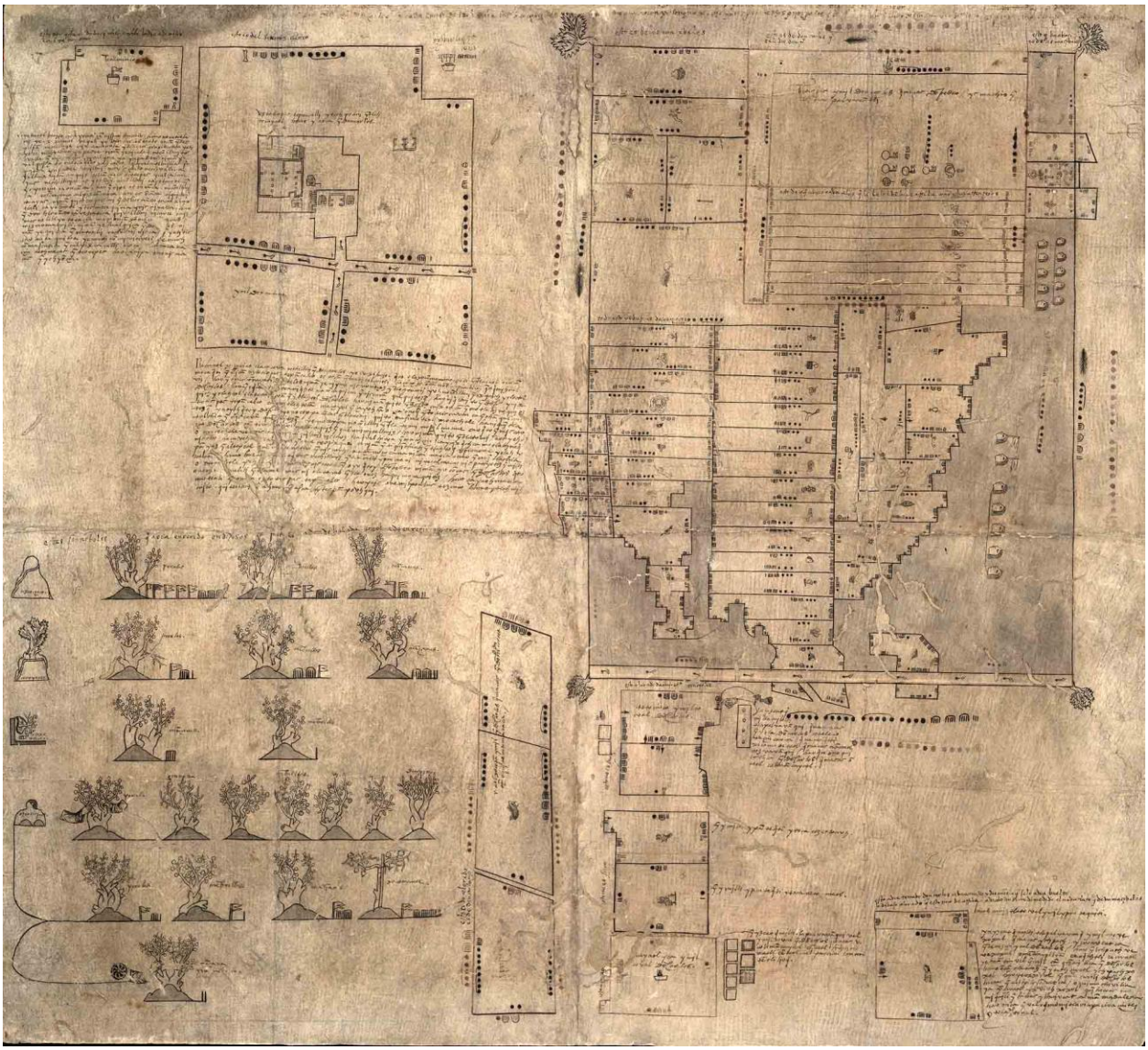


Figure 2.23. Plan of palace and surrounding land in Aztec units (upper left corner) and land parcels shape and dimensions in Aztec units (right half of image), Oztoticpac Lands Map (Library of Congress Geography and Map Division Washington, D.C., CC-BY-NC-SA 4.0).

2.4.7 Summary of Architectural and Urban Depictions in Pictorial-Administrative Manuscripts

The relevance of these pictorial administrative manuscripts rests on the fact that they reveal the clear mathematical and geometrical systems the Aztecs utilized for recordkeeping and land surveying. The *Codex Mendoza* is a clear visual representation of the base-20 mathematical system utilized by the Aztecs. On the other hand, the *Codex of the Marquesado del Valle*, the *Codex Vergara*, the *Codex Santa María Asunción* and the *Oztoticpac Lands Map* provide not only a wealth of administrative information including household composition, soil type and crops, but also land survey data comprising shape, perimeter and area of plots.

The information contained in these documents suggests a conceptualization of area attributes of geometric forms such as rectangles and triangles, as well as calculations of land areas. These calculations required utilizing several algorithms requiring the functional equivalents of addition, subtraction, multiplication and division (Williams and Jorge 2001:187), knowledge that was applied to urban planning and architecture by extension. Scholars such as Rivera (1997) and Clark (2010) have argued that this system of linear measurements was employed in the design of the ceremonial precinct of Tenochtitlan.

2.5 Eyewitness Accounts by the Conquistadores

There are a limited number of eyewitness accounts by Spanish participants in the Conquest including those of Hernán Cortes, Bernal Diaz del Castillo, Francisco de Aguilar, Andrés de Tapia and the "Anonymous Conqueror." These are supplemented by several smaller claims and legal testimonies, as well as other stories, written by people that did not accompany Cortés, such as Pedro Martir de Angleria and Francisco López de Gómara, who utilized the returning conquistadores as the sources of their accounts (Hassig *2006:*3). They were initially motivated by their desire to narrate the events in which they participated, but their motivations soon changed to suit their interests and to claim from the Spanish crown more slaves, properties or administrative positions to reward their exploits (Martínez 1989:679).

Even though the eyewitness accounts have been studied as a documentary or literary genre, they have only been utilized to illustrate the grandeur of Tenochtitlan in the context of other studies in spite of their detailed architectural and urban descriptions. However, two sources, the *Cartas de Relación (Letters from Mexico)* by Hernán Cortes and the *Historia Verdadera de la Conquista de la Nueva España (The True History of the Conquest of New Spain)* by Bernal Díaz del Castillo contain ample descriptions architectural and urban design of the city and its landscape surrounded by water and mountains. These descriptions are valuable because they saw Tenochtitlan and its ceremonial precinct relatively intact before the destruction that followed. Their accounts include descriptions of the ceremonial precinct, its size and the number of temples, as well as the layout of the Templo Mayor and the Quetzalcoatl temple. These simplified descriptions are not intended to be precise or provide a complete view of the complex layout of the ceremonial precinct, as Cortés and Díaz del Castillo selected different structures and omitted others. (Cortés does not include the ball court, for example.) Nonetheless, they complement other historical sources and archaeological evidence and transmit the grand design of the buildings, the city and its landscape.

2.5.1 Hernán Cortes

2.5.1.1 Description

The *Cartas de Relación* is a compilation of the five letters that Hernán Cortes wrote between 1519 and 1526 to Emperor Charles V of Spain. They narrate the main events of his exploits from his landing on the Mexican coast and the conquest of Tenochtitlan, to his failed expedition to Honduras (Martínez 1989:681).

2.5.1.2 Summary of Architectural and Urban Depictions

In the Second Letter, signed on October 30, 1520, Cortés narrates the wars and the alliances he made on his journey toward the Valley of Mexico. His account culminates in his impressive description of Tenochtitlan, the ceremonial precinct including the Templo Mayor, and the palace Motecuhzoma. Even though he is disgusted with the practice of human sacrifice, he conveys great admiration for the high degree of civilization he has witnessed, "to the point of frequently

comparing Aztec achievements with those of Arab and Christian civilizations" (Delgado 2006). When the Second Letter was first published in Seville in November 1522, this edition contained no map. Nonetheless, when it was translated into Latin and published in Nuremberg in 1524, it was accompanied by a woodcut map of Tenochtitlan. This map shows Tenochtitlan in the centre of an azure lake (in the hand-coloured versions) connected by causeways and surrounded by neighboring cities around the lake (Figure 2.24). This was the first image that Europe had of the city and eventually became the most widespread (Mundy 1998:11). Even though the map was carved by a European, it reveals many details that are not described in the Second Letter of Cortés, which leads Mundy to believe that it was based in an Indigenous map (1998:27). Together, the descriptions of Cortés and the Nuremberg map contain important urban, architectural and astronomic information including: the layout of Tenochtitlan, the design of the ceremonial precinct and its buildings, the connection to the landscape via its main urban axes and the rising Sun represented as a face rising between the double temples of the Huey Teocalli (Great Temple).

Figure 2.24. Map of Tenochtitlan from the Latin translation published in Nuremberg in 1524. The map is rotated 90° clockwise while the ceremonial precinct is rotated 90° counterclockwise (Newberry Library, Chicago, CC-BY-NC-SA 4.0).

2.5.2 Bernal Díaz del Castillo

2.5.2.1 Description

The *Historia Verdadera de la Conquista de la Nueva España* (Figure 2.25) is an account that not only chronicles the Spanish conquest from 1517 to 1521, but also the public affairs in New Spain through 1568. It is believed that Bernal Díaz del Castillo utilized as sources for his work the published letters of Cortés (1522–1526), the *History of the Conquest* of Francisco López de Gómara (1552) and even Mexican pictorial manuscripts (Adorno 2006).

2.5.2.2 Summary of Architectural and Urban Depictions

Similar to Cortés, the significance of the vivid descriptions of Díaz highlight the architectural and urban characteristics of the city and its surrounding landscape:

> And when we saw all those cities and villages built in the water, and other great towns on dry land, and that straight and level causeway leading to Mexico [i.e. Tenochtitlan], we were astounded. These great towns and cues [i.e., temples] and buildings rising from the water, all made of stone, seemed like an enchanted vision from the tale of Amadis. Indeed, some of our soldiers asked whether it was not all a dream. It is not surprising therefore that I should write in this vein. It was all so wonderful that I do not know how to describe this first glimpse of things never heard of, seen or dreamed of before…
>
> And when we entered the city of Iztapalapa, the sight of the palaces in which they lodged us! They were very spacious and well built, of magnificent stone, cedar wood, and the wood of other sweet-smelling trees, with great rooms and courts, which were a wonderful sight, and all covered with awnings of woven cotton (Diaz 2004:269).

Figure 2.25. Historia Verdadera de la Conquista de la Nueva España (University of British Columbia-Rare Books and Special Collections).

2.6 Chronicles Compiled by the Missionaries

Following the military conquest, the Catholic Church commenced the religious conquest and sent a group of missionaries in 1524. Far from the influence of church and civil authorities in Spain, they began to use unconventional approaches for the conversion of the natives such as building open chapels, organizing theatrical performances and utilizing their pictorial manuscript tradition to convey their message. A few of these friars "sought to document their role in the progress of evangelization as well as to preserve elements of indigenous culture" (V. Smith 1997:213). Some of them collected and recorded information from Aztec informants with the purpose of understanding their religion in order to aid their conversion to Christianity. Among these friars were Andrés de Olmos, Toribio de Benavente Motolinía, Bernardino de Sahagún, Juan de Torquemada and Diego Durán. In some cases, such as Sahagún and Durán, they had

images copied from native manuscripts for their own compilations, a practice that Felipe II outlawed in 1577 (García Ayluardo 1997:247).

The compilations by Fray Bernardino de Sahagún and Fray Diego Durán are considered one of the most valuable sources of information about the native culture in Central Mexico due to the wealth of information contained in them. However, in spite of the fact that they have been thoroughly analyzed and referenced by multiple scholars in several disciplines, their urban and architectural depictions have not been analyzed.

2.6.1 Fray Bernardino de Sahagún

2.6.1.1 Description

Fray Bernardino de Sahagún (1499-1590) arrived in Mexico in 1529 with a second group of Spanish missionaries at a turbulent time in the new colony. By 1536 he was appointed to teach Latin in the *Colegio Imperial de la Santa Cruz Tlatelolco*, a special school for the sons of the native nobility, some of whom eventually became his assistants. Even though he collected and compiled material during those years, it was not until 1558, when he was formally commissioned to write "all that he considered useful for the conversion of the natives," that he devoted himself to the investigation of Aztec religion, customs and natural history. He recruited informants and artists, worked with pictorial manuscripts, talked to elders, diviners, herbalists and merchants, and even prepared questionnaires to gather and record information (D'Owler and Cline 1975:186).

This material was eventually compiled and translated into a comprehensive encyclopedia of Aztec culture: the *Historia General de las Cosas de la Nueva España*, known as the *Florentine Codex*[15] (Anderson 1982:3), which is considered to be one of the most valuable primary sources for the study of Aztec culture at the time of European contact; it is a comprehensive and

[15] The name Florentine Codex was adopted as the standard appellation for the edition of Anderson and Dibble of the *General History of the Things of New Spain* because Edgar L. Hewett, the founder and first director of the School of American Archaeology, so designated it. More formally, Hewett referred to it as "the Great Florentine Codex." It has also other labels. Officially it is the manuscript of the *Biblioteca Medicea-Lorenziana Palat* in Florence (Anderson 1983:3).

methodical firsthand account of the indigenous peoples of Central Mexico (Nicholson 2000:21). The Sahaguntine oeuvre encompasses detailed descriptions in Nahuatl and in Spanish of the Aztec Gods, their religious beliefs and rituals, and the theology involved in the indigenous cosmology. It also offers a depiction of the Aztec people themselves, including their history, philosophy, society, politics, economics and medicinal practices and the natural history of New Spain. In the words of H.B. Nicholson, "it is the most remarkable account of a non-Western culture ever composed and a primary source about the Aztecs for modern-day scholars" (2000:34).

The interest of Sahagún in native culture caused his work to be scrutinized by the Inquisition in 1575. His writings were confiscated, and they were not found again until the eighteenth century. Nonetheless, a number of manuscripts representing successive stages in the compiling of the *Historia* survive. They are in Nahuatl, Spanish or both; some are illustrated. The Nahuatl texts and the drawings are considered the work of the native informants of Sahagún (Glass and Robertson 1975:187).

The main manuscripts are the *Codices Matritenses* and the *Florentine Codex*. The *Codices Matritenses* contain various early manuscripts of the *Historia*, but only two are illustrated: the *Primeros Memoriales* and the *Manuscrito de Tlatelolco*. Conversely, the *Florentine Codex*, his final compilation with parallel texts in Nahuatl and Spanish, is profusely illustrated (Glass and Robertson 1975:188).

2.6.1.2 Summary of Architectural and Urban Depictions

The *Primeros Memoriales* contains multiple architectural depictions of single temples, double temples, ball courts, skull racks, residential structures, and shrines. Most of these architectural depictions are inscribed in frames with descriptions of the festivities that took place during the 18 months of the Xiuhpohualli (solar) year. Hence, they place in urban context the locations of buildings, as different rituals were performed in each one of them following a certain order (Figure 2.26).

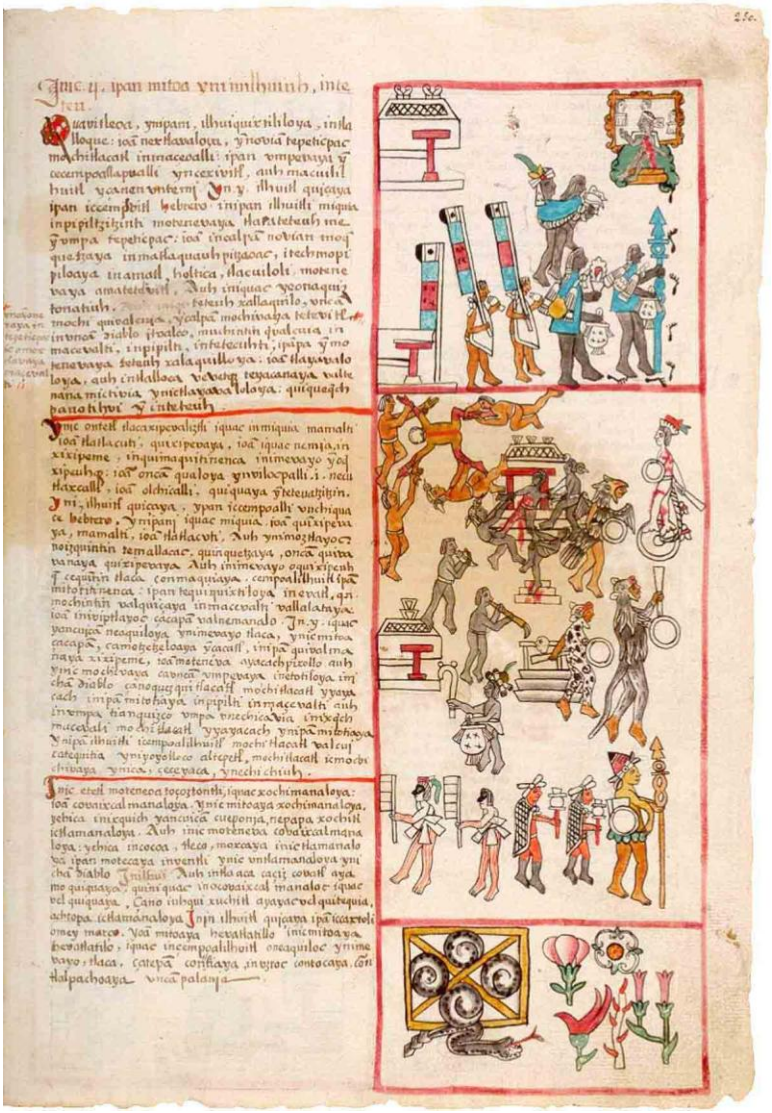


Figure 2.26. Quauitleoa (top); Tlacaxipehualiztli festival within an architectural arrangement that includes two temples, a central platform, and a tzompantli or skull rack (middle); and Tozoztontli festival (bottom), folio 250r, *Primeros Memoriales* (*Real Biblioteca de Madrid,* CC-BY-NC-SA 4.0).

It is believed that the architectural depiction of the ceremonial precinct is the most complete plan remaining of the centre of Tenochtitlan, because it contains the main elements of Aztec architecture: the main double teocalli, the tzompantli (skull rack), the tlachtli (ball court), the circular-base teocalli and other single temple teocallis; and the main elements of urban planning: an axial plaza plan with the main double teocalli at the intersection of its axes (Figure 2.27).

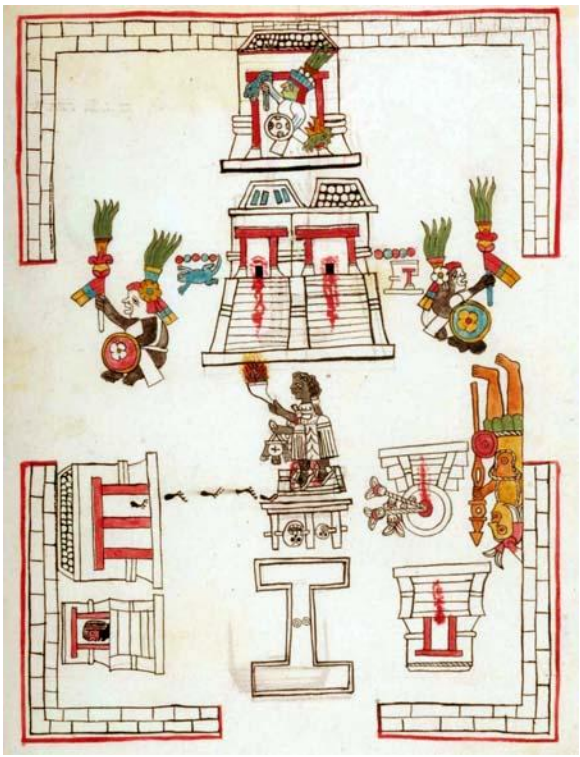


Figure 2.27. Depiction of the ceremonial precinct, Primeros Memoriales, folio 268ra (*Real Biblioteca de Madrid,* CC-BY-NC-SA 4.0).

Furthermore, the 12 volumes of the *Florentine Codex* are also extensively illustrated with 1 846 drawings, but it is *Book 2-The Ceremonies* where most architectural depictions are included in the detailed narrative of the Xiuhpohualli feasts. Nonetheless, this book includes an appendix where there is "a true [relation] of all [the temples] which were the temples of the Mexicans" comprised of 78 structures, but it does not include a map as it was apparently removed at some point (Anderson and Dibble 1982:15-21).

The written descriptions contained in the *Appendix* of *Book 2-The Ceremonies* reveal a standard arrangement of elements (temple, bathing place, calmecac, skull rack and ball court) that repeats in each temple grouping. The description of the ceremonies, along with the list of the temples, uncover an intricate system of relationships between the rites and architecture which were possibly reflected as a complex arrangement of temple groupings within the ceremonial precinct rather than the axial and almost symmetric arrangement depicted in the *Primeros Memoriales* plan. Hence, the oeuvre of Sahagún provides an extensive visual and written resource for the study of Aztec architecture and urban planning.

2.6.2 Fray Diego Durán

2.6.2.1 Description

Fray Diego Durán (1537-1588) arrived in New Spain as a child where he soon learned Nahuatl. He entered the Dominican order in 1556 and was later commissioned to study the religion and the ceremonies in Mexico for the purpose of evangelization. The result of this commission was one volume comprising *The Book of the Gods and Rites* (1574–1576) and *The Ancient Calendar* (1579), and a second volume titled *The History of the Indies of New Spain* (1581) (Heyden 1994).

2.6.2.2 Summary of Architectural and Urban Depictions

Durán included some meticulous descriptions of architecture in his works. In *The Book of the Gods and Rites,* he described the rituals performed in the temple groupings within the ceremonial precinct, but supplemented these descriptions with few illustrations. In *The History of the Indies of New Spain* he gave an account of the foundation of Mexico-Tenochtitlan and the construction of the temple dedicated to Huitzilopochtli.

The chapters of *The Book of the Gods and Rites* are organized according to gods, rituals or temples, hence it is possible to extract from each chapter the architectural descriptions and their locations as not all the festivals take place in Tenochtitlan.

Even though the descriptions of Durán are romanticized versions of the architecture that had already been destroyed, they are valuable for the study of Aztec architecture because they illustrate the type, quantity and relationships among buildings. Furthermore, his descriptions reveal that there were several temple complexes within the ceremonial precinct, the presence of other buildings in other places outside of Tenochtitlan, and the importance of the surrounding landscape, such as mountains are always an integral part of the illustration (Figure 2.28).

(a) (b)

Figure 2.28. (a) Double Teocalli dedicated to Tlaloc and Huitzilopochtli, Cerro Tlaloc and Cerro Telapon frame the twin temples, folio 131r; (b) victim on Temalacatl platform fighting warrior, *Historia de las Indias de Nueva España e islas de la Tierra Firme* by Diego Durán (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).

2.7 Archaeological Evidence

The body of archaeological research about Aztec sites is quite limited compared to other sites in Mesoamerica. Smith and Berdan have interpreted this invisibility as a lack of understanding of the Aztec empire due to several reasons. According to them, some scholars do not agree that the Aztec was a "real" empire, thus they do not acknowledge the existence of Aztec archaeological remains outside the Valley of Mexico. A second reason is that, even though the Aztec polity might be considered an empire, its organization in tributary and strategic provinces did not require major investments in construction. The third reason is that archaeologists have not performed enough problem-oriented fieldwork projects to evaluate the effects of Aztec imperial strategies in other provinces (Smith and Berdan 1992:353). However, their interpretation suggests a primitivist approach that ignores the socio-political context of archaeological research

and its role in the construction of state-sponsored national identities (Errington 1998: 161), which actually began with the Aztec themselves.

Scholars agree that the Aztecs constructed their identity by assimilating the cultural traits of people who had preceded them and deliberately setting out to perpetuate a tradition derived from the Toltecs with whom they wanted to be identified (Molina 1987:104). They incorporated Toltec myths, some forms of social, politic and economic organization, as well as rituals and ceremonies with their own. In the case of architecture and urban planning, there is enough archaeological evidence of the integration of these characteristics in their architectural manifestations (Matos 1981:259). When the Aztecs arrived to the Valley of Mexico around 1250 AD, they had no power and no land, but by 1430 they had begun their military expansion. The resulting wealth and power enabled them to start the expansion of the island city.

Furthermore, the interpretation of Smith and Berdan (1992) does not take into account the extensive research carried out by scholars in Mexico who have constructed a "succession of powerful secular images and texts that have moulded the consciousness of the past, and beliefs in destiny, that are closely identified with distinct political regimes" (Shelton 1995:69). Even though a large part of archaeological research has focused on sites with monumental architecture such as Teotihuacan and Tenochtitlan, other Aztec city states have also undergone archaeological fieldwork. However, access to this research has been limited as it has been barely published. This has produced a dissimilar body of knowledge, as the quality and quantity of available information for Aztec sites varies from scattered reports of smaller sites to a considerable number of studies about the ceremonial precinct of Tenochtitlan, particularly the Huey Teocalli (Templo Mayor) of Tenochtitlan.

Apart from this unbalanced research corpus, the biggest challenge is the location of archaeological remains and the amount of excavations done on these sites. Some sites lie within—or under—larger colonial cities such as Tenochtitlan, Tlatelolco and Tenayuca; some within smaller colonial cities such as Santa Cecilia, Tenayuca, and Teopanzolco (Figure 2.29); others scattered among small villages and farmland such as Calixtlahuaca and Huexotla; while

still others on areas than have been barely excavated, such as Quauhtochco, or not excavated at all, such as Cuentepec.

An additional challenge is the level of conservation of architectural structures. Even though some can be identified by their architectural characteristics, like the double temple teocalli, the circular base teocalli and the tlachtli (ball court), others such as a rectangular base shrine could be considered as a platform or a small single temple teocalli. Larger structures with several rooms can also be interpreted as palaces, nobility dwellings, or calmecacs (schools) unless they can be identified through ethno-historical sources such as the calmecac of Tenochtitlan.

Despite these challenges, single temple teocallis, rectangular base shrines, nobility dwellings, circular base teocallis and circular base shrines are the most common architectural structures in Aztec archaeological sites. However, the most distinctive Aztec architectural structure, the double temple teocalli, is only present in five sites: Tenochtitlan, Tlatelolco, Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. Consequently, the study of the Aztec architecture and urban planning is a complex endeavour, as it involves searching for published and unpublished information in several types of media such as archaeological reports, books, articles in scholarly and popular literature, image databases and recorded material on video. Since most sites are located in urban areas, digital applications such as Google Maps, Google Earth and custom geometric applications are needed to analyze sites in the context of the existing city, as scholars such as Tichy (1976) and Šprajc (2001) have demonstrated that churches and their surrounding areas follow the same orientation as the Aztec site located there before the Conquest.

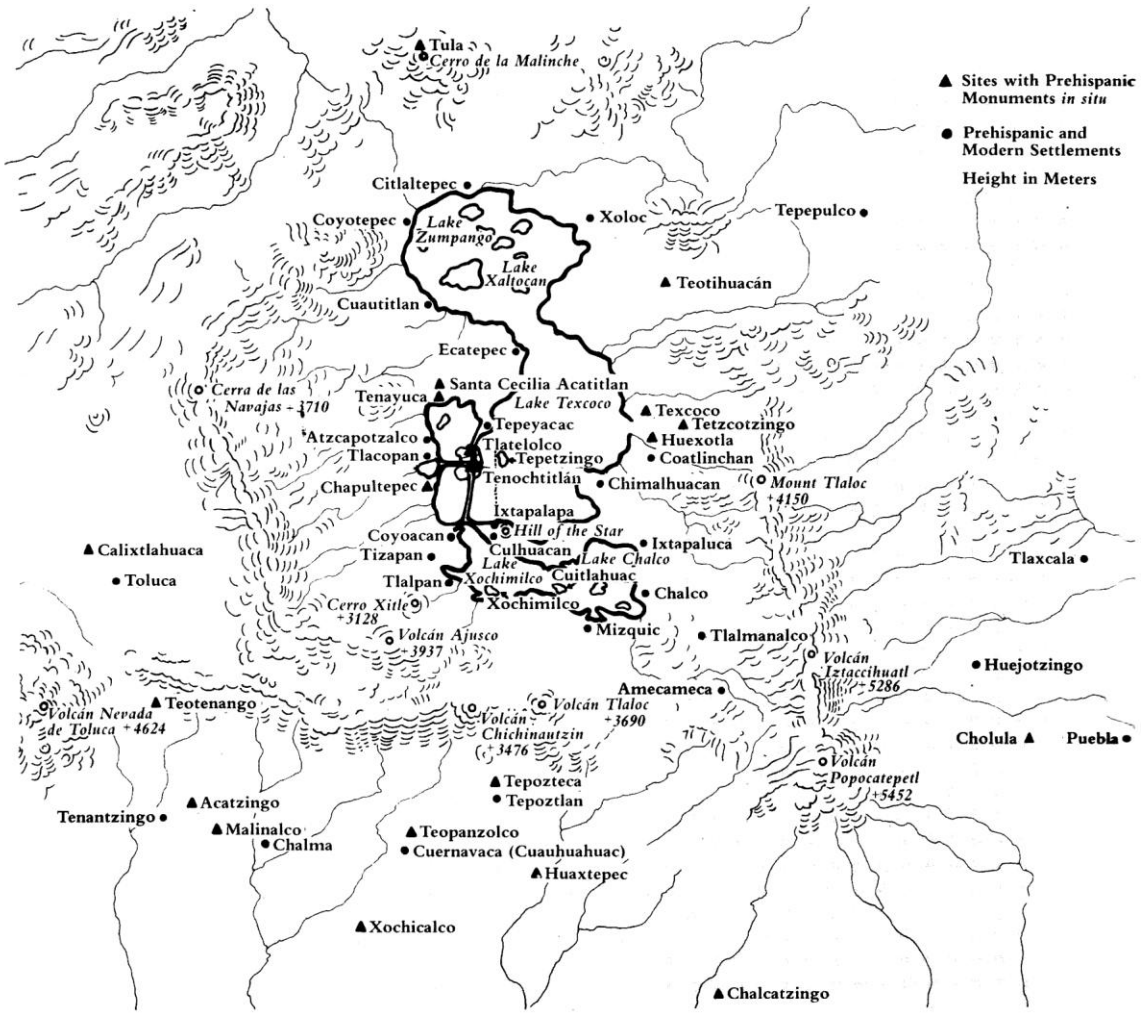


Figure 2.29. Map of Valley of Mexico in 1519 (Pasztory 1983: Figure 1).

2.8 Monumental Sculpture

Since the discovery of the Aztec Sun Stone, the Coatlicue and the Stone of Tizoc and the subsequent publication of *A Historical and Chronological Description of Two Stones which were found in 1790 in the Principal Square of Mexico During the Current Paving Projec*t by Antonio León y Gama in 1792, most studies have concentrated on interpreting their religious, political, and artistic imagery, mainly of the Sun Stone.[16] Albeit some of these studies marveled at the geometry of these monumental sculptures, only Alfonso Caso measured the Sun Stone so that its geometric properties could be analyzed. A mathematical analysis of several sculptures was done by Raúl Noriega in 1953, but it was not until 1978 that architect Carlos Chanfón Olmos attempted a geometrical analysis of the Sun Stone. Ramírez Bautista continued this work in 1995 by painstakingly measuring the Sun Stone, the Stone of Tizoc and the Ex-archbishopric's Palace Stone and analyzing their regulating lines. He demonstrated that a series of geometrical principles were embedded in the design of these monumental sculptures (Ramírez 1995).

Furthermore, in 1996 Rivera applied a geometrical analysis approach on Aztec architecture on the digital interpretation of the ceremonial precinct of Tenochtitlan, where archaeoastronomical and geometrical principles were utilized for reconstructing the ceremonial precinct of Tenochtitlan. Martinez del Sobral furthered explored geometrical principles on several examples of Mesoamerican art, sculpture and architecture in 2000.

Aztec monumental sculpture should be considered as a source for understanding Aztec architecture as it contains the underlying mathematical and geometrical principles that must have been applied to architecture (Figure 2.30). Furthermore, the only existing piece of *monumental sculpture* in the form of a temple, the *Teocalli de la Guerra Sagrada* (Teocalli of the Sacred War or the Temple Stone), displays a solar geometric design in its centre which confirms the direct relationship between the rising and the setting of the Sun in the context of carved Tlaloc and Huitzilopochtli figures on each side representing Cerro Tlaloc and Cerro Telapon.

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[16] A selection of the multiple studies that refer to the Aztec Sun Stone can be found in *The Aztec Calendar Stone* by Khristaan Villela and Mary Ellen Miller.

Figure 2.30. (a) The Aztec Sun Stone, (b) the ex-Archbishopric's Stone, (c) the Teocalli *(Museo Nacional de Antropología*, Mexico CC BY-NC-SA 4.0).

2.9 Urban and Architectural Models

In the historiography of the Aztecs, there are few references to urban and architectural models, possibly due to a perceived lack of importance compared with monumental sculptures such as the Sun Stone or the Coatlicue. The best known example of a model is the one illustrated in the book *Mexico y sus alrededores* published in 1856, where there is a small architectural model in the bottom left corner among a large group of archeological artifacts (Figure 2.31). This model shows a stepped base, a sacrificial stone and a temple on top with its enormous cresting (Schávelzon 1982:361).

Figure 2.31. "Mexican Antiquities," the back of the Teocalli de la Guerra Sagrada and a small single teocalli can be seen in the lower left corner (Lithograph by Decaen 1856).

This same model was reproduced by Desirée Charnay in 1884 and by Chavero in 1889 who utilized it to illustrate the religious architecture of Mexico. In 1910, Newel Warale conducted a study entitled *Miniature Clay Temples of Ancient Mexico* in which he analyzed a dozen models of the more than 200 that were in the *Museo Nacional* at the time (Schávelzon 1982:362). To date, no one has continued this research and the whereabouts of many of the models is unknown. That said, some of them were located for this research in public and private collections in the United States of America, the United States of America, Spain and France (Figure 2.32).

Figure 2.32. (a) Model in the American Museum of Natural History, New York; (b) model in the *Museo de las Américas,* Madrid; (c) model in the *Musée du quai Branly, Paris* (CC BY-NC-SA 4.0).

In 1936, H. D Pollock published the book *Round Structures of Aboriginal Middle America* that remains a key study on the subject. Pollock analyzed circular structures drawing on various historical sources, manuscripts, paintings and models. In the years that followed, other models were published but always in the context of art not architecture. Decades later, in1960, Ignacio Marquina used some models as inspiration for his reconstructions of the ceremonial precinct of Tenochtitlan, and in 1975, Paul Gendrop and Doris Heyden utilized a photograph of the model by Marquina and other photos of previously unpublished models to illustrate the chapter on Aztec architecture (Schávelzon 1982:362-364).

Figure 2.33. Three teocalli models with different representations on the top platform. The first model has a temple, the second a solar deity and the third a single deity (British Museum, CC BY-NC-SA 4.0).

Even though the size, material, quality and detail vary among models, the main characteristics of certain building types can be inferred from all of them. The teocallis always have either a temple or a representation of the gods to which they were dedicated on the top platform; the stairs are flanked by balustrades, and stepped platforms can be seen in some of them (Figure 2.33).

In the few books that were published about pre-Columbian architecture (Marquina 1964; Gendrop and Heyden 1973), models were seen as isolated examples of architectural types but not within the context of an urban plan. This changed in 1995 when nine urban plans were discovered carved in stone at the site now known as Plazuelas in Guanajuato, Mexico (Figure 2.34). This was the first model that represented a specific urban complex in which the carved figures corresponded exactly to the group of buildings found on the site (Schávelzon 2004:11).

Figure 2.34. (a) Google Earth view of Plazuelas, (b) model of Plazuelas carved in stone (Photograph by Juan Antonio Siller - CC:BY), (c) aerial view of Plazuelas (Map data: Google Earth).

This finding allowed the researcher to see the Aztec petroglyphs from Acalpixan — known to archaeologists since 1894 — in a different light. In spite of the fact that these petroglyphs have multiple representations of stairs carved on the rocks, they had never been interpreted in the context of urban design.

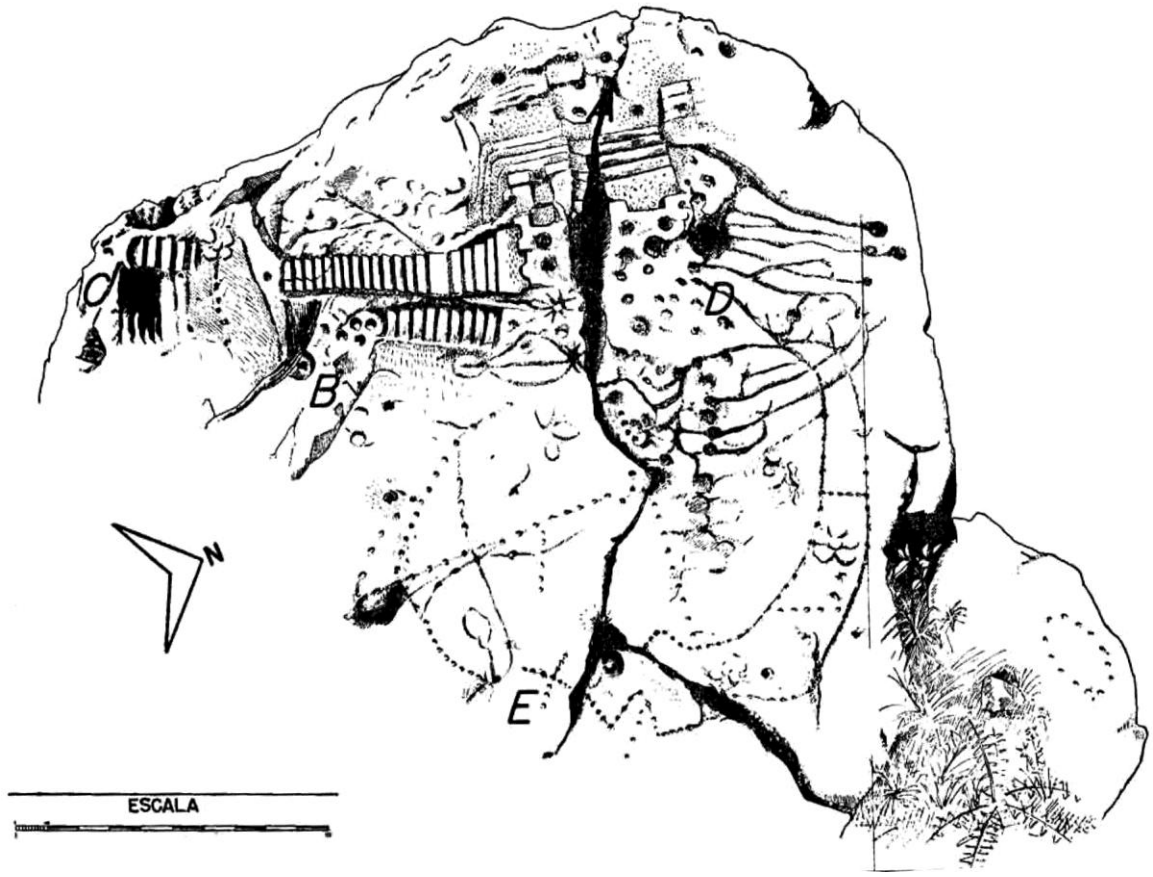


Figure 2.35. Drawing of the model at Acalpixan (Broda 2000:Figure 17).

On this model (Figure 2.35), the main group consists of a complex architectural structure and multiple representations of stairs which have an overlaid pecked cross similar to the known crosses found in Teotihuacan and other places in Mesoamerica. The relevance of this model resides in the fact that it interrelates architecture, urban planning and astronomy, as the pecked crosses served to orient urban complexes and buildings as scholars such as Aveni, Hartung and Buckingham (1978), among others, have demonstrated (Figure 2.36).

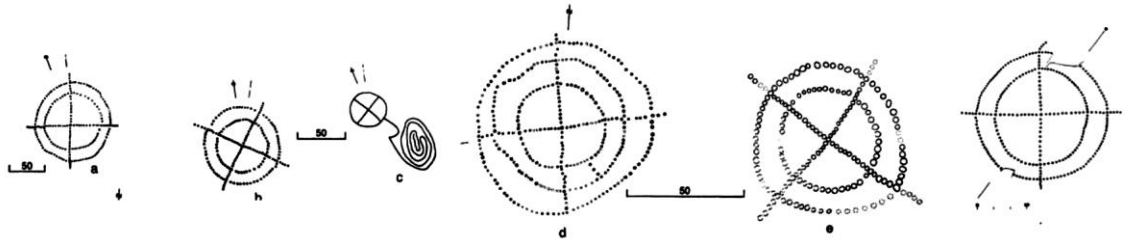


Figure 2.36. A collection of pecked cross petroglyphs from Teotihuacan (Aveni 2001:Figure 126).

2.10 Oral History

Indigenous scholars such as Jo-ann Archibald have emphasized the interrelationship between place, Indigenous identity and place-based stories and our responsibility as keepers of this cultural knowledge (Archibald 2008:29). Therefore, stories of places passed from generation to generation should also be considered as sources for the study of Aztec architecture and urban planning. An example of this source is the legend of the Tepozteco recorded and analyzed by Vargas-Betancourt (2004) or the research on Aztec and contemporary sacred landscape carried out by ethnohistorians such as Broda (1991a, 1991b).

2.11 Chapter Summary

This chapter demonstrated that number, scope and variety of sources available to study the Aztec culture is extraordinary. Nevertheless, this body of knowledge had not been analyzed from an architectural or urban point of view. Therefore, this chapter presented the architectural and urban representations that were extracted from these sources as well as the relevant information that can be obtained from them. These sources ranged from traditional research material such as pictorial manuscripts, eyewitness accounts by the Conquistadores, chronicles compiled by the missionaries and archaeological evidence, to non-traditional research material like pictorial administrative manuscripts, monumental sculpture, urban and architectural models and oral history. While traditional sources contained material that had to be filtered through the screen of architectural and urban depictions, non-traditional sources contributed a wealth of mathematical and geometric information that was applied to architectural and urban design. In addition, non-traditional sources such as the architectural and urban models demonstrated the interrelation of architecture, urban planning and astronomy (Figure 2.30 and Figure 2.35).

Consequently, this chapter presented most of the sources that were utilized to compile the inventory of Aztec building types (Chapter 3); to describe the concepts of space and time (Chapter 4); and to explain the concepts of astronomy, mathematics and geometry embedded in Aztec architecture and urban planning (Chapter 5).

Chapter 3: Aztec Typology

3.1 Introduction

This aim of this chapter is to present a visual sample of the inventory of Aztec architectural types that was done for this research. This inventory was based on the meticulous analyses of the ethno-historical sources carried out in Chapter 1 so as to investigate the common features of each architectural type. To this end, the first section introduces the concept of typology following the ICOMOS *Principles for the Recording of Monuments, Groups of Buildings and Sites* and discusses the role of typological studies within the context of architectural research in Latin-America. The second section argues the need to define Aztec building types within their cultural context and serves as the antechamber for the third section, a representative sample of probably the most thorough inventory of Aztec building types in Aztec scholarship. Each sub-section presents a dossier of each building type following ICOMOS principles: Nahuatl name, form, cultural functions and examples of a pictographic depiction, a physical representation as well as a plan and photograph of archaeological remains of that building type. The fourth and last section discusses the application of the urban planning principles of Tula and Teotihuacan in the design of Tenochtitlan.

3.2 Aztec Typology

Except for the urban studies of Aztec city-states performed by Smith, the few discussions about Aztec architecture (Marquina 1960; Hardoy 1973; Heyden and Gendrop 1973; Pasztory 1983; Matos 1999; Aguilar Moreno 2006; Uriarte 2010) have mostly concentrated on its individual qualities rather than its common characteristics. A study of Aztec typology [typologies?] was therefore needed in order to understand Aztec architecture.

Since the research performed in the ethno-historical sources had already provided the depictions of Aztec architectural and urban forms, this information was utilized to build an inventory of Aztec building types according to the *Principles for the Recording of Monuments, Groups of Buildings and Sites* ratified by the 11th International Council on Monuments and Sites

(ICOMOS) General Assembly in Sofia, October1996[17]. This document sets out the principal reasons, responsibilities, planning measures, contents, management and sharing considerations for the recording of the *cultural heritage*, defined in this document as "monuments, groups of buildings and sites of heritage value, constituting the historic or built environment." These principles state that the records should include some or all of the following information:

a) The *type*, form and dimensions of the building, monument or site;
b) The interior and exterior characteristics, as appropriate, of the monument, group of buildings or site;
c) The nature, quality, cultural, artistic and scientific significance of the heritage and its components and the cultural, artistic and scientific significance of:
- the materials, constituent parts and construction, decoration, ornament or inscriptions
- services, fittings and machinery,
- ancillary structures, the gardens, *landscape and the cultural, topographical and natural features of the site*;

d) The traditional and modern technology and skills used in construction and maintenance;
e) Evidence to establish the date of origin, authorship, ownership, the original design, extent, use and decoration;
f) Evidence to establish the subsequent history of its uses, associated events, structural or decorative alterations, and the impact of human or natural external forces;
g) The history of management, maintenance and repairs;
h) Representative elements or samples of construction or site materials;
i) An assessment of the current condition of the heritage;

The use of typology for recording and analyzing archaeological sites in Latin-America was proposed by Waisman. She considered "typology as an instrument of architectural historiography

[17] Principles for the Recording of Monuments, Groups of Buildings and Sites ratified by the 11th International Council on Monuments and Sites (ICOMOS) General Assembly in Sofia, October 1996:

As the cultural heritage is a unique expression of human achievement; and

As this cultural heritage is continuously at risk; and

As recording is one of the principal ways available to give meaning, understanding, definition and recognition of the values of the cultural heritage; and

As the responsibility for conserving and maintaining the cultural heritage rests not only with the owners but also with conservation specialists and the professionals, managers, politicians and administrators working at all levels of government, and with the public; and

As article 16 of the Charter of Venice requires, it is essential that responsible organizations and individuals record the nature of the cultural heritage.

has broad possibilities as a guideline for chronological frameworks, as object of study, as guideline for the classification of the historical material and, finally, as base for the critical-historical analysis of the architectural expressions (Waisman 1998:80)"[18].

Consequently, a classification that took into account the particular characteristics of Aztec architectural forms was necessary in order to analyze and evaluate them. However, this typological classification had to be done from a different standpoint; because Western classifications systems should not be applied to Aztec architectural forms. Waisman argued that Latin-American architecture always seemed less when it was analyzed in the context of the original European works and by the criteria developed for them. She rejected the basic Western criteria, such as the division into periods according to stylistic typologies, and claimed that they are irrelevant for local architecture "as they are not original creations of our culture, they are not essential elements for understanding our architecture." Waisman claimed that the analysis of the architectural forms in relation to their environment and to their specific context would necessarily bring different and more precise criteria that enable their evaluation. Furthermore, she suggested creating a system that takes into account the factors that characterize the architectural form, such as its formal, structural and functional typologies, as well as its relationship with the environment.

[18] Translated from "La tipología como instrumento de análisis histórico" (Waisman 1998:80):

> "La tipología como instrumento de la historiografía arquitectónica presenta varias posibilidades como pauta para la periodización, como objeto de estudio, como pauta para el ordenamiento del material histórico y, por último, como base para el análisis crítico-histórico de los hechos arquitectónicos."

3.3 Aztec Building Types

In *The Beginnings of Architecture,* Sigfried Giedion (1941) dedicated an entire chapter to the differences between ziggurats and pyramids: ziggurats were built inside the cities of the living, while pyramids were built in the cities of the dead; ziggurats had temples on top, while the top of pyramids were totally inaccessible; ziggurats were dedicated to deities, while pyramids were built for kings; ziggurats were integrated to the life of the city, while the pyramids were built in remote locations. Regarding their form, ziggurats were constructed as a series of stepped platforms with a temple on top, while pyramids were built just as pyramids ending in a perfect apex. Regarding their function, ritual sacrifices were performed in ziggurats, while pyramids protected the dead king.

Aztec stepped truncated pyramids with a temple on the upper platform are neither pyramids nor ziggurats, they are their own architectural type: Teocallis.

The term Teocalli was initially used by Batres in 1904 and frequently thereafter by Mexican scholars, however, the word had fallen out of use by 1973 when Heyden and Gendrop published *Pre-Columbian Architecture of Mesoamerica*. The reasons for this change could be related to the increased involvement of foreign scholars in Mesoamerican archaeology in the second half of the twentieth century, and the urge to disassociate the research of foreign scholars (mostly Anglophone) from the research by Mexican scholars.

Even though these classifications often emerged based on the needs of cross-cultural observations and analyses, they sometimes resulted in inconsistent and geometrically implausible Aztec architectural forms: Single Temple Pyramids, Double Temple Pyramids, and Circular or Round Pyramids. Furthermore, these types ignored the physical and cultural environment in which they were built.

Consequently, in order to define Aztec architecture, an alternative classification of Aztec forms was proposed for this research. This classification is based on three aspects from the ICOMOS *Principles for the Recording of Monuments, Groups of Buildings and Sites:* type, form and

cultural function. Even though this classification was limited by the quantity and quality of information publicly and privately available (especially archaeological records that can vary from primary field notes to exhaustive analyses), it provided a clear and consistent overview of each building type. Its main limitation was that some structures were partially destroyed or were not fully excavated, hence they could fall in more than one architectural type. In these cases, they were placed in the most likely category based on their size and location. In other cases, where there was debate among scholars regarding the type of structure, buildings were placed in the architectural type recognized by the *Instituto Nacional de Antropología e Historia (INAH).*

The following section consists of a representative sample of the inventory of Aztec building types performed for this research. Each sub-section presents a dossier of each building type following ICOMOS principles:

- Nahuatl[19] name (which defines the type name when it refers to an exclusive Aztec form)
- Form (a succinct description of its geometrical form)
- Cultural function
- A collection of pictographic depictions, physical representations, and archaeological evidence

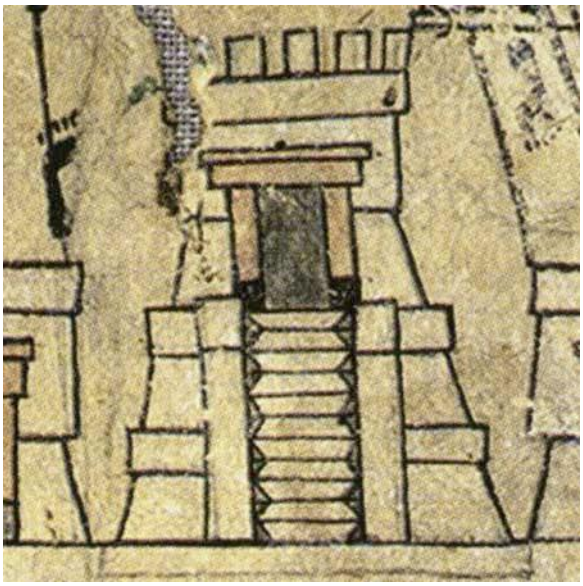
It is neither the intent nor the scope of this architectural research to examine these building types further as some of them have already been discussed within Aztec scholarship, as well as in side references or chapters about Aztec architecture in more general sources (Marquina 1960; Hardoy 73; Heyden and Gendrop 1975; Pasztory 1983; Mangino 1990; Matos 1999; Evans 2004; Fernández and García 2006;Aguilar 2006; Smith 2008; Manzanilla 2009; Uriarte and Toca 2010). However, this inventory can be viewed as one of the first attempts to establish an area of study for Aztec architectural and urban research.

[19] Nahuatl entries come from the ***Nahuatl Dictionary***, a Wired Humanities Project supported by the National Science Foundation and the National Endowment for the Humanities, and major input from John Sullivan and the Zacatecas Institute for Teaching and Research in Ethnology, and the European Research Council, University of Warsaw, and Universidad de Sevilla.

3.3.1 Single Temple Teocalli

Nahuatl name	**[Single Temple] Teocalli (**Figure 3.1**)** *English Translation:* A temple or church (synonymous with teopan); or, something smaller, such as a chapel; or, a devotional building in a private residence.
Form	A stepped truncated rectangular base pyramid with one stairway and a single chamber on top.
Cultural function	Symbolic form of a mountain utilized by priests and some members of the nobility to perform rituals and ceremonies (including fasting, vigils, offering of prayers and hymns, as well as sacrificial rituals involving foodstuffs, birds, animals, war captives, and self-let blood) in order to communicate with the gods on behalf of the community (Kowalski 2006).

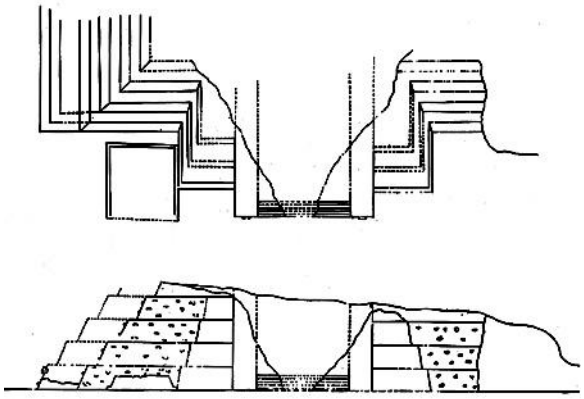
Single Temple Teocalli (continued)



Depiction of Single Temple Teocalli in the Mapa de Cuauhtinchan No. 2 (Figure 2.17).

Single Temple Teocalli model (*Museo Regional de Puebla, CC-BY-NC-SA 2.0*).

Single Temple Teocalli "C" in Tula (Photograph by Javier García Muñoz - CC:BY).



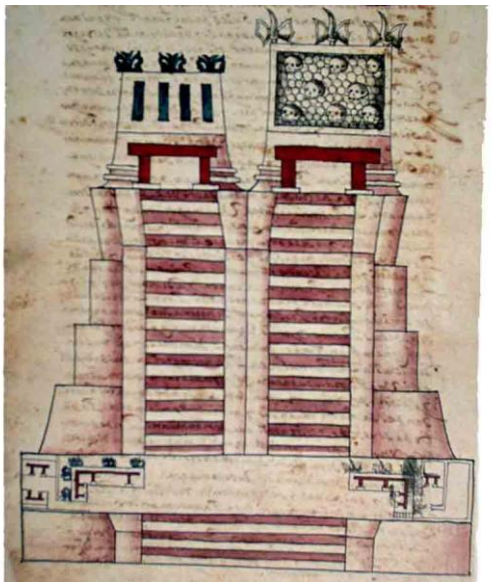
Single Temple Teocalli "C" plan, Tula (López Austin and López Luján 2009:Figure 2).

Figure 3.1. From left to right, examples of the Single Temple Teocalli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

3.3.2 Double Temple (or Twin Temple) Teocalli

Nahuatl name	**Double Temple Teocalli (**Figure 3.2**)** *English Translation:* A temple or church (synonymous with teopan); or, something smaller, such as a chapel; or, a devotional building in a private residence. **Huey Teocalli** *English Translation:* Great Temple
Form	A stepped truncated rectangular base pyramid with two stairways and two chambers on top; one temple is associated with Tlaloc and the other to Huitzilopochtli. These structures were usually built in several stages and are considered to be a unique architectural type as the birth of Huitzilopochtli was enacted on its temples.
Cultural function	Symbolic form of a mountain utilized by priests and some members of the nobility to perform rituals and ceremonies (including fasting, vigils, offering of prayers and hymns, as well as sacrificial rituals involving foodstuffs, birds, animals, war captives, and self-let blood) in order to communicate with the gods on behalf of the community (Kowalski 2006).

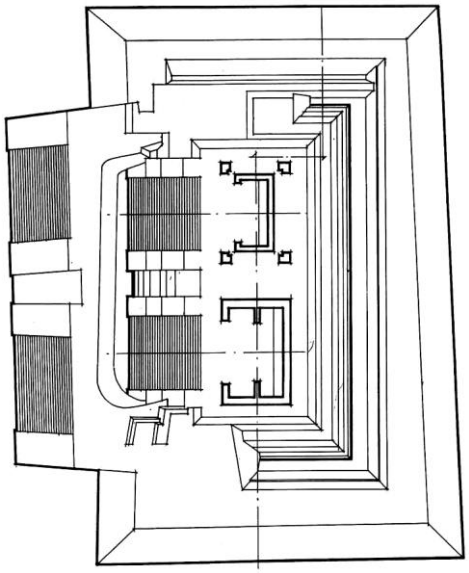
Double Temple (or Twin Temple) Teocalli (continued)



Depiction of Double Temple Teocalli of Tetzcoco in the Codex Ixtlilxochitl, folio 112v (Figure 2.12).

Double Temple Teocalli model (American Museum of Natural History, CC-BY-NC-SA 4.0).

Double Temple Teocalli, Teopanzolco (Photograph by Raul Muñiz - CC:BY).



Double Temple Teocalli plan, Teopanzolco (Marquina 1964:Figure 63).

Figure 3.2. From left to right, examples of the Double Teocalli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

3.3.3 Circular Base Teocalli

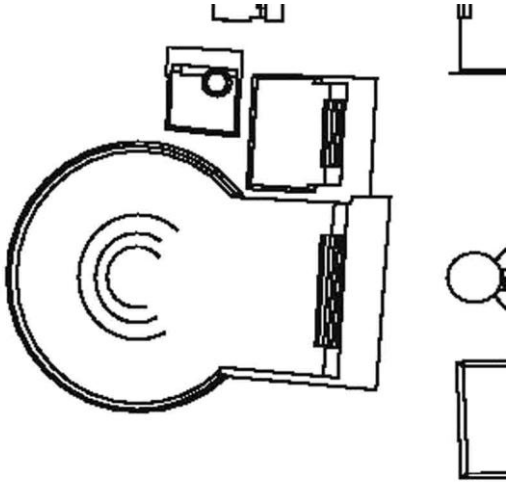
Nahuatl name	**Circular Base Teocalli (**Figure 3.3**)** *English Translation:* A temple or church (synonymous with teopan); or, something smaller, such as a chapel; or, a devotional building in a private residence
Form	A stepped truncated circular base cone with one stairway and one chamber on top
Cultural function	Symbolic form of a mountain utilized by priests and some members of the nobility to perform rituals and ceremonies (including fasting, vigils, offering of prayers and hymns, as well as sacrificial rituals involving foodstuffs, birds, animals, war captives, and self-let blood) in order to communicate with the gods on behalf of the community (Kowalski 2006). This particular form is associated with Quetzalcoatl, the Feathered Serpent deity, who had multiple functions and aspects such as creativity and fertility; the Feathered Serpent was also known as Ehecatl, or Wind, so it is sometimes called Ehecatl Quetzalcoatl (Nicholson 1975).

Circular Base Teocalli (continued)

Depiction of Circular Base Teocalli in the Codex Azcatitlan, plate 059-064_08 (Figure 2.8).

Circular Base Teocalli model (*Museo Nacional de Antropología* CC-BY-NC-SA 4.0).

Circular Base Teocalli, Tlatelolco (Photograph by César Tenorio - CC:BY).



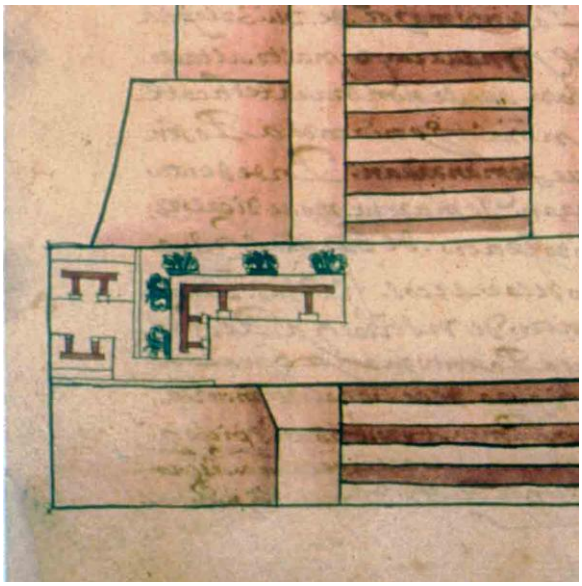
Circular Base Teocalli, Tlatelolco (*Proyecto Tlatelolco - INAH*).

Figure 3.3. From left to right, examples of the Circular Base Teocalli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

3.3.4 Warriors / Priests Precinct

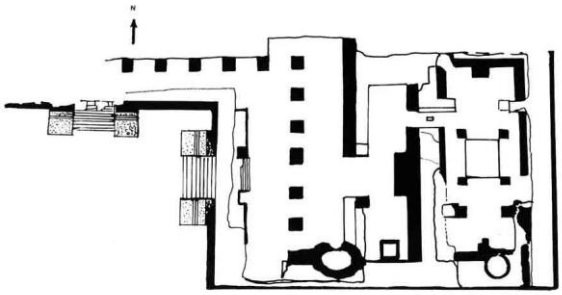
Nahuatl name	**Warriors / Priests Precinct in Teocalli (**Figure 3.4**)** **Teocalli** *English Translation:* A temple or church (synonymous with teopan); or, something smaller, such as a chapel; or, a devotional building in a private residence.
Form	An L-shaped plan precinct constructed north of the Huey Teocalli with two stairs at the western end; and several interior rooms; there was probably another Teocalli precinct at the south of the Huey Teocalli, although no archaeological evidence has been found.
Cultural function	The immediate proximity of this warrior precinct to the Huey Teocalli demonstrates the sacred character of warriors in warfare Carrasco 145); it was a place where elite warriors gathered, "no one could enter that house of knightly order unless he was a warrior or a son of a known knight" (Durán 1994:192).

Teocalli (Priests and/or Warriors) Precinct (continued)



Eagle Warriors Precinct within the Main Double Teocalli of Tetzcoco in the Codex Ixtlilxochitl, folio 112v (Figure 2.12).

Warriors Precinct within the Huey Teocalli (Templo Mayor) of Tenochtitlan (Photograph by George and Eve DeLange - CC:BY).



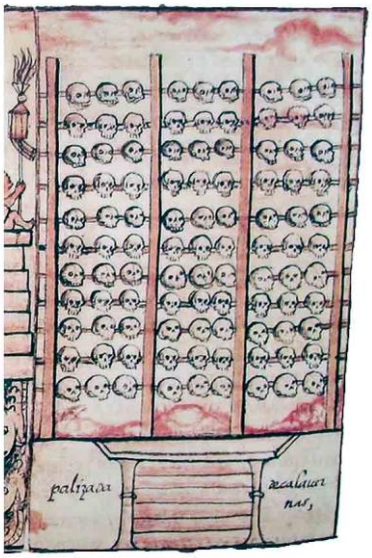
Plan of the Warriors Precinct within the Huey Teocalli (Templo Mayor) of Tenochtitlan (Umberger and Klein 1993:304).

Figure 3.4. From top to bottom, examples of the Warriors Precinct within the Teocalli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

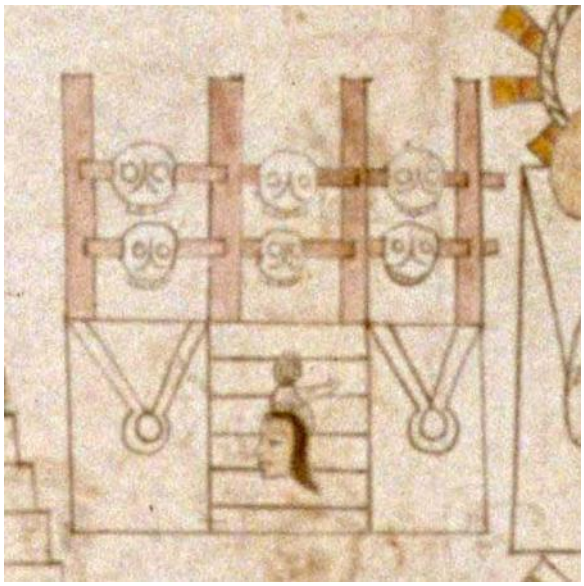
3.3.5 Tzompantli

Nahuatl name	**Tzompantli (**Figure 3.5**)** *English Translation:* Skull rack
Form	An elongated rectangular base characterized by the "exhibition of human skulls (either real or sculpted) in horizontal rows"; the real human skulls were held along a series of wooden frames made of horizontal crossbeams connected to a series of vertical posts; some scholars suggest that the platforms with sculpted human skulls held a wooden frame for real human skulls on top.
Cultural function	Besides utilizing them to display the skulls of ritualistically-executed victims, scholars have offered several interpretations of their meaning: Matos (1988) associates them with the Land of the Dead and Carrasco (1991) with Tezcatlipoca, while Hassig (1988) believes they were used to intimidate enemies (Mock 2001).

Tzompantli (continued)

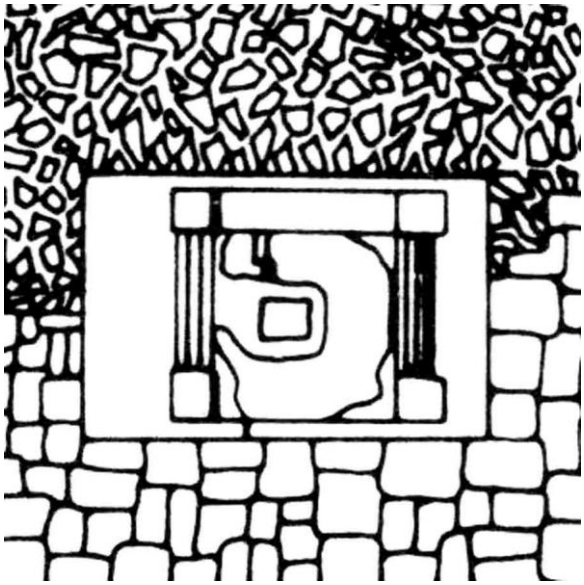


Depiction of Tzompantli in the *Book of the Gods and Rites* by Durán (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).



Depiction of Tzompantli (front view) in the Codex Azcatitlan, plate 059-064_22 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

Tzompantli in the Huey Teocalli of Tenochtitlan (Photograph by Ihiro Alfonso - CC:BY).



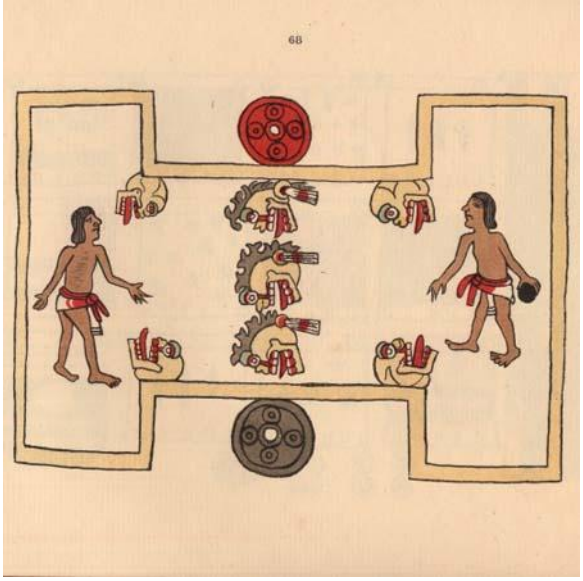
Tzompantli Plan, Huey Teocalli of Tenochtitlan (Matos 1988b:Figure 34).

Figure 3.5. From left to right, examples of the Tzompantli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

3.3.6 Tlatchtli

Nahuatl name	**Tlatchtli (**Figure 3.6**)** *English Translation:* Ball court
Form	I-shaped court with raised inclined platforms along the vertical axis and a vertical disk in the middle of these platforms.
Cultural function	Ullamaliztli, the name of the ancient Mesoamerican ball game in Nahuatl, was played in the Tlatchtli; the ball court mirrored the celestial ball court as the western axis symbolizes the underworld through which the Sun, represented by the ball, passes each night, thus the game reenacted the "battle between the Sun and Moon, or the gods of youth and maturity, each vying for supremacy" (Aguilar 2007:361-362).

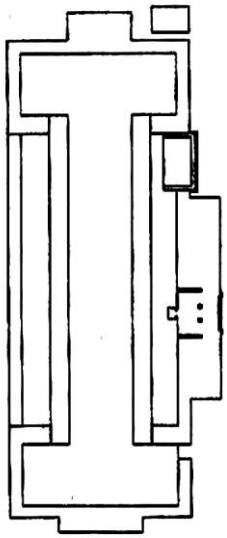
Tlatchtli (continued)



Depiction of Tlatchtli, folio 80 in the Codex Magliabechiano, Nuttal facsimile (*Biblioteca Nazionale Centrale di Firenze*, CC-BY-NC-SA 4.0).

Tlachtli model carved on rock (Photograph *Museo de Sitio de San Miguel Ixtapan, Tejupilco, Mexico*).

Tlachtli, Tula (Photograph by Ramón Hernández - CC:BY).



Tlachtli, Tula (Healan 2012:Figure 6).

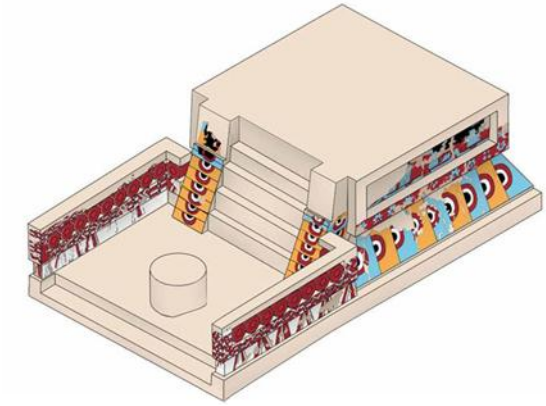
Figure 3.6. From left to right, examples of the Tlachtli architectural type: depiction within a codex, small scale model, archaeological remains and plan view.

3.3.7 Momoztli

Nahuatl name	**Momoztli (**Figure 3.7**)** Platform or raised altar for sacrifices and displays in pre-conquest style; mound, platform, etc., in colonial times.
Form	This type encompasses a wide variety of small rectangular base and circular base low platforms with a stairway in the front, built individually or in groups along public locations. Noguera describes them either as small altars erected at the junction of roads or as small platforms that were placed in front or at the sides of a temple (Noguera 1973:111). Hence this typological study made the distinction between Momoztlis built around temples and the Central Momoztlis placed at the centre of major axes.
Cultural function	There is scarcely any research about Momoztli as the interpretations of scholars vary from being a seat for the Emperor to the Teocalli at Castillo de Teayo (Olivier 2003:320). However, they are abundantly present in pictographic and written sources within the context of ceremonies, which suggests that they were utilized by priests, nobility and commoners alike. Durán describes them as a place where gods sat and rested (2003:93).

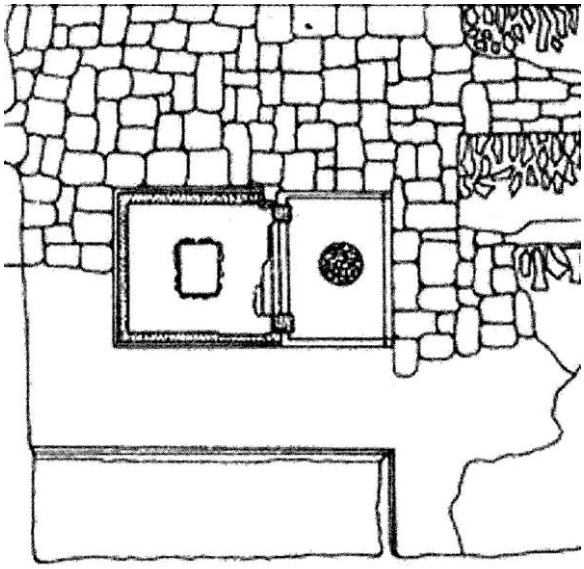
Momoztli (continued)

Depiction of Momoztli in Codex Borgia, plate 42 (*Biblioteca Apostolica Vaticana*, CC-BY-NC-SA 4.0).



Digital reconstruction of Momoztli (Templo Rojo) in the ceremonial precinct of Tenochtitlan (Model by Michelle de Anda, *Proyecto Templo Mayor-INAH*).

Momoztli (Templo Rojo) in the ceremonial precinct of Tenochtitlan (*Proyecto Templo Mayor-INAH*).



(sh3b) "Templo Rojo" Momoztli, Great Teocalli, Tenochtitlan (Matos 1988b:Figure 34).

Figure 3.7. From left to right, examples of the Momoztli architectural type: depiction within a codex, digital reconstruction, archaeological remains and plan view.

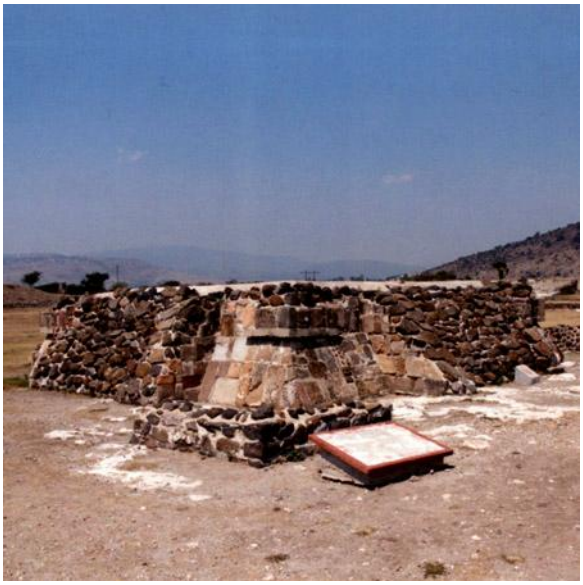
3.3.8 Central Momoztli

Nahuatl name	**Central Momoztli (**Figure 3.8**)** Platform or raised altar for sacrifices and displays in pre-conquest style; mound, platform, etc., in colonial times.
Form	Small square base platform with stairs on its four sides found at the centre of ceremonial precincts.
Cultural function	Except for the study performed by Noguera (1973), there is scarcely any research about Central Momoztli. However, pictographic and archaeological evidence suggests they were utilized by priests to perform rituals and ceremonies at the centre of temple precincts at an urban level and at the centre of patios at a domestic level.

Central Momoztli (continued)

Depiction of Central Momoztli (rotated 90 degrees), Codex Borbonicus, folio 36 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

Depiction of Momoztli, Primeros Memoriales, folio 268r (*Real Biblioteca de Madrid*, CC-BY-NC-SA 4.0).



Central Momoztli, Tula (Photograph by Antonio Rafael- CC:BY).

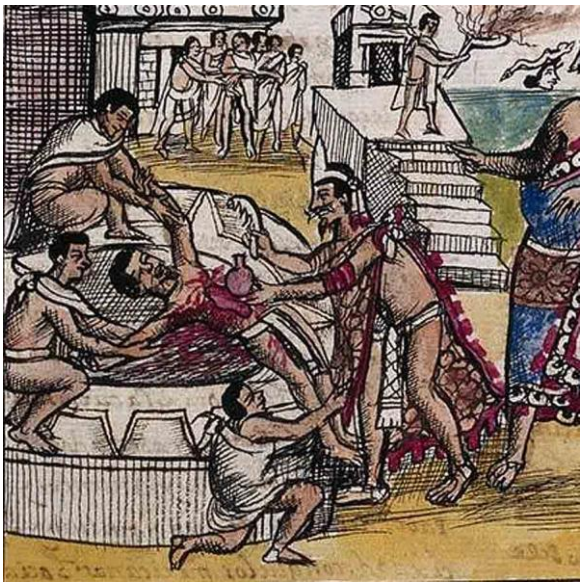
Momoztli, Tula (Healan 2012:Detail within Figure 6).

Figure 3.8. From left to right, examples of the Central Momoztli architectural type: depictions within codices, archaeological remains and plan view.

3.3.9 Quauhxicalli and Temalacatl

Nahuatl name	**Quauhxicalli** (according to Molina and Sahagún) A wooden pan or vessel (Molina); eagle vessel for containing hearts and blood of sacrificial victims (Sahagún). **Temalacatl** (according to Molina and Sahagún) Circular, flat, sacrificial stone. **Quauhxicalli** (according to Berdan) Flat platform with or without a central cavity (Berdan 97). **Temalacatl** (according to Berdan) Similar but had a bar or ring in the centre for the attachment of captive warriors during gladiatorial sacrifice (Berdan 97). Illustrations in Figure 3.9.
Form	A circular base platform.
Cultural function	Symbolic form of the Sun utilized for gladiatorial sacrifice.

Temalacatl (continued)



Depiction of Temalacatl in the *Historia de las Cosas de la Nueva España*, folio 70r (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).

Temalacatl, ex Archbishopric's Palace Stone (*Museo Nacional de Antropología-INAH*).

Depiction of Quauhxicalli, Florentine Codex, volume 2, folio 635 (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0).

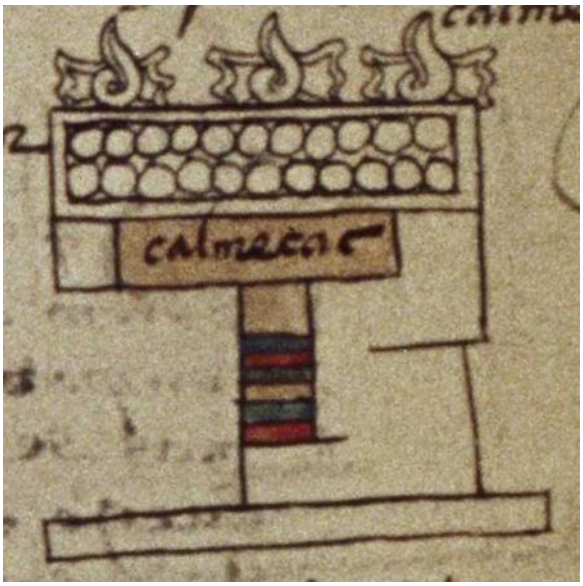
Quauhxicalli, Plaza Manuel Gamio, Tenochtitlan (*Proyecto Templo Mayor-INAH*).

Figure 3.9. From left to right, examples of the Temalacatl architectural type: depictions within a codex, monumental sculpture and archaeological remains.

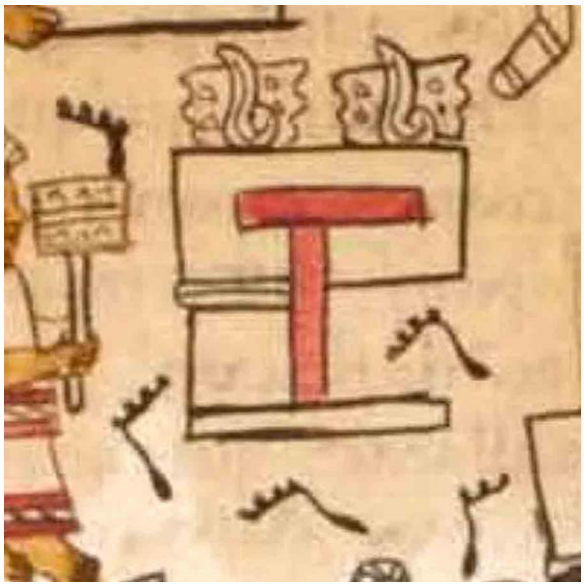
3.3.10 Calmecac

Nahuatl name	**Calmecac (**Figure 3.10**)** *English Translation:* School, primarily for noble youths (mostly boys), that offered religious training.
Form	A rectangular patio surrounded by several interior rooms.
Cultural function	A school where priests taught noble youths religion, mythology, history, calendrics, writing, engineering and law, along with thorough military training (López Austin and López Lujan 2001:221-223).

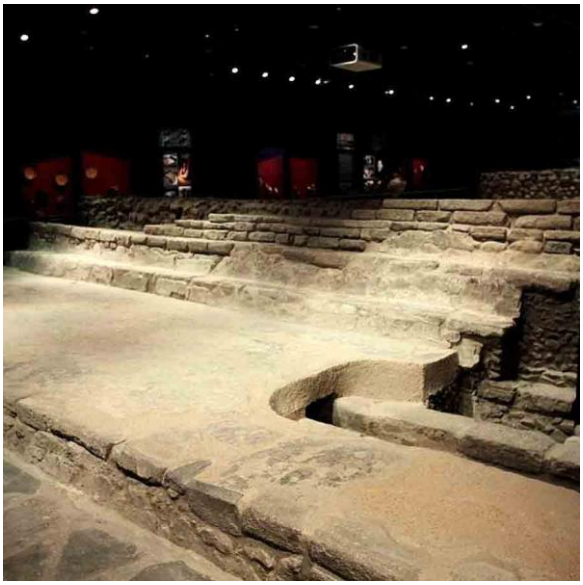
Calmecac (continued)



Depiction of Calmecac, Codex Mendoza, folio 61r (Bodleian Library, CC-BY-NC-SA 4.0).



Depiction of Calmecac, *Primeros Memoriales*, folio 252v (*Real Biblioteca de Madrid*, CC-BY-NC-SA 4.0).



Calmecac under the building of the Centro (*Museo de Sitio del Centro Cultural de España en México*).

Remains of 2.38 metres tall crenels from the roof of the Calmecac (Photograph by Boris de Swan-Raíces).

Figure 3.10. From top to bottom, examples of the Calmecac architectural type: depictions within codices and archaeological remains.

3.3.11 Coatepantli of Huey Teocalli and Perimeter Wall of Ceremonial Precinct

Nahuatl name

Coatepantli (Figure 3.11**)**

English Translation:

Serpent-wall, snake-wall, a ceremonial wall decorated with snakes.

Perimeter Wall of Ceremonial Precinct (Figure 3.11**)**

Even though there has been confusion among scholars between the coatepantli of the Huey Teocalli and the perimeter wall of the ceremonial precinct, ethnohistorical sources and archaeological excavations have confirmed that these were two different architectural types.

Form

The **coatepantli** is a row of snakes in the forecourt or around the Huey Teocalli, while the **perimeter wall** is a platform that surrounds a ceremonial precinct (Boone 1987:59).

Cultural function

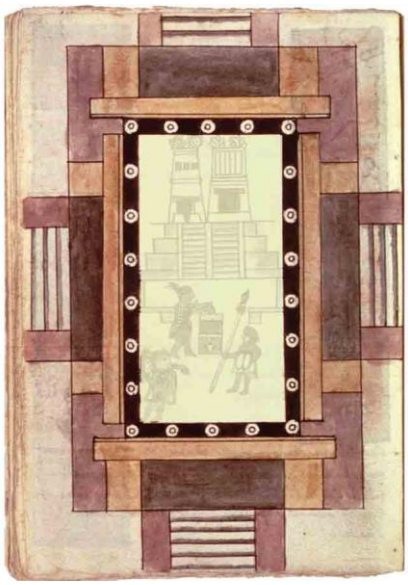
The snakes of the coatepantli symbolize the Earth and are one of the most important symbols in Mesoamerica. Since the Aztecs saw their world as a flat disk where the Huey Teocalli was the centre of the axis mundi, the snakes represent the great body of Earth itself. Furthermore, Huey Teocalli is an embodiment of Coatepec, "Snake Mountain," where the god Huitzilopochtli was born.

The **perimeter wall** of the ceremonial precinct separated the sacred space of the ceremonial precinct from the profane space surrounding it (Matos 1987:200).

Coatepantli of Huey Teocalli and Perimeter Wall of Ceremonial Precinct (continued)

Depiction of the Coatepantli in the Huey Teocalli, *Book of the Gods and Rites* (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).

Coatepantli of the Huey Teocalli in Tenochtitlan (Photograph by Maghenzani - CC:BY).



Depiction of the Perimeter Wall, Codex Aubin, plate 035-036-41v (British Museum, CC-BY-NC-SA 4.0).

Perimeter Wall in Tlatelolco (Photograph by Renata Martínez- CC:BY).

Figure 3.11. From left to right, examples of Coatepantli and Perimeter wall of ceremonial precinct architectural type: depictions within a codex and archaeological remains.

3.3.12 Nobility Dwellings: Calli and Tecpan

Nahuatl name

Calli (Figure 3.12**)**

English Translation:

House, structure, container; also, a calendrical marker.

According to Sahagún:

Tlatocacali: ruler's house

Tequioacacali: war leader's council house

Tecali: palace court house

Pilcali: nobleman's house

Achcauhcali : constable's house

Tecpan

English Translation:

Unit of social organization of high nobles; noble house; royal palace, government building.

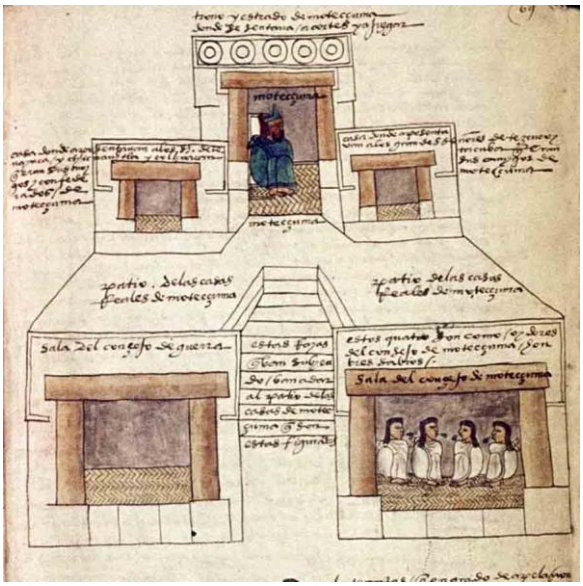
Form

A rectangular patio dominated by a dais room and surrounded by several rooms with different civil and military functions.

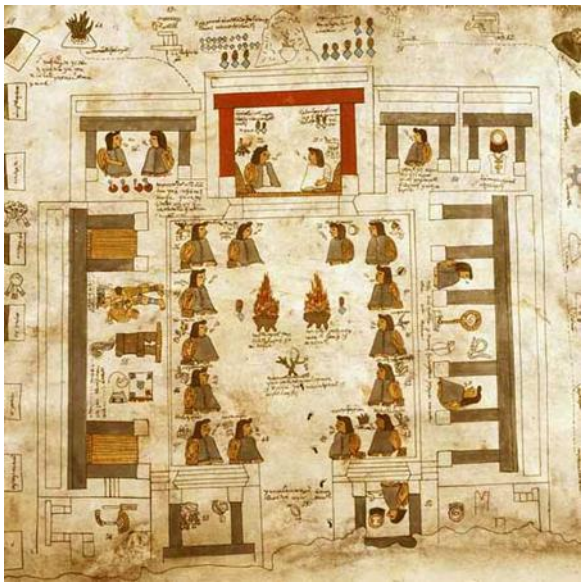
Cultural function

The Tecpan reflects the societal structure of the Aztecs. They were "extraordinarily hierarchical and richly nuanced, with administrative places, pleasure palaces, and mansions, all designed to cosset their noble denizens, and advertise themselves to the world as seats of authority" (Evans 2004:7).

Nobility Dwellings: Calli and Tecpan (continued)

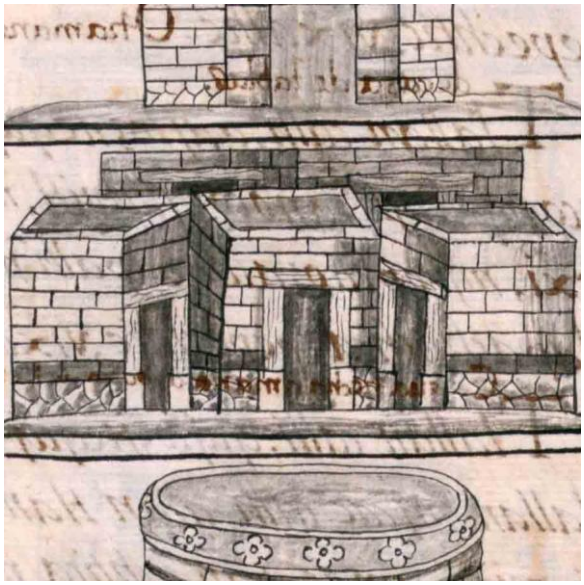


Depiction of the Palace of Motecuhzoma in the Codex Mendoza, folio 69r (Bodleian Library, CC-BY-NC-SA 4.0).



Enhanced copy of the depiction of the Palace at Tetzcoco in the Mapa Quinatzin *(Bibliothèque Nationale de France* CC-BY-NC-SA 4.0).

Depiction of Nobility Dwelling in Mapa de Cuauhtinchan No. 2 (Figure 2.17).



Depiction of Nobility Dwelling, Florentine Codex, volume 3, folio 802 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).

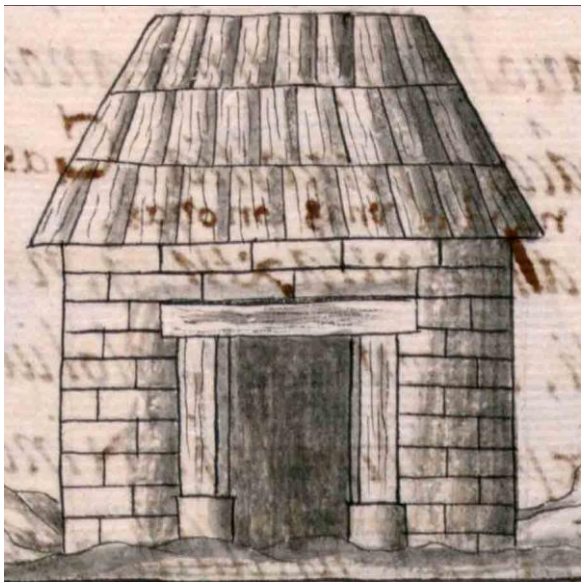
Figure 3.12. Examples of Nobility Dwellings architectural type within codices.

3.3.13 Commoners Dwellings: Calli

Nahuatl name	**Commoner Calli (**Figure 3.13**)** *English Translation:* House, structure, container; also, a calendrical marker. According to Sahagún: **Callli**: house or room **Caltepiton**: small house **Caltontli**: small house **Caltzintli**: small (or honored) house
Form	Form varies from a cave, to a single rectangular room, to a patio surrounded by rooms along two, three, or four of its sides.
Cultural function	The form, spatial distribution and construction materials reflect the societal structure of the Aztecs.

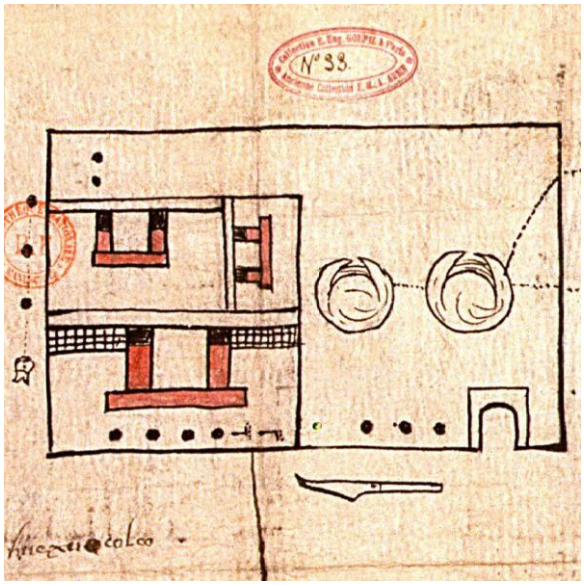
Commoner Dwellings: Calli (continued)

Depiction of House (wood walls, straw roof), Florentine Codex, volume 3, folio 799 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).



Depiction of House, Florentine Codex, volume 3, folio 801 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).

Depiction of House, Florentine Codex, volume 2, folio 499cd5 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).



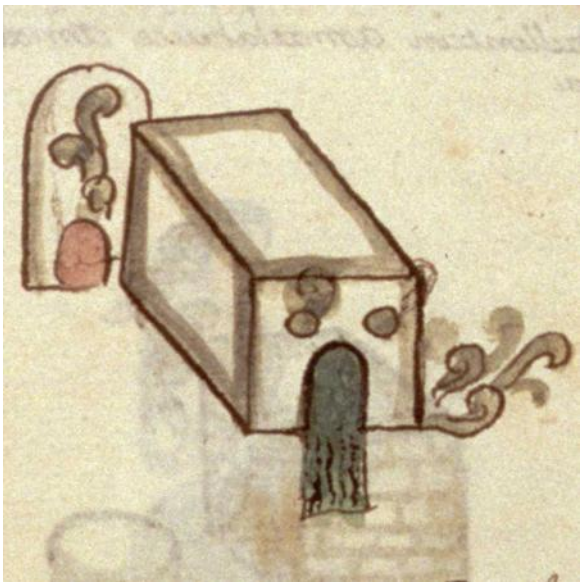
Plan of the house and property title located in Huexocolco (*Archivo General de la Nación* CC-BY-NC-SA 4.0).

Figure 3.13. Examples of Commoner Dwellings architectural type within a codices and administrative-legal documents.

3.3.14 Temazcalli

Nahuatl name	**Temazcalli (**Figure 3.14**)** *English Translation:* A sweat house or sweat bath.
Form	A rectangular room with a circular dome.
Cultural function	In Mesoamerica, a Temazcalli is a vapour bath for therapeutic purposes; it is a representation of a cave, a symbol of the beginning of life.

Temazcalli (continued)



Depiction of Temazcalli, Codex Aubin, folio 035-036_24v (British Museum, CC-BY-NC-SA 4.0).

Depiction of Temazcalli, Codex Magliabechiano, folio 77r (*Biblioteca Nazionale Centrale di Firenze* CC-BY-NC-SA 4.0).

Depiction of Temazcalli, Codex Tudela, folio 62r *(Museo de América, Madrid* CC-BY-NC-SA 4.0).

Depiction of Temazcalli, Florentine Codex, volume 3, folio 675 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).

Figure 3.14. Examples of the Temazcalli architectural type within codices.

3.3.15 Gardens and pools

Nahuatl name

Xoxochitlatli (Figure 3.15)

English Translation

A garden.

Acaxitl (Figure 3.15)

English Translation

Pool, watering trough.

Form

Gardens were sacred spaces modeled to convey the idea of a terrestrial paradise.

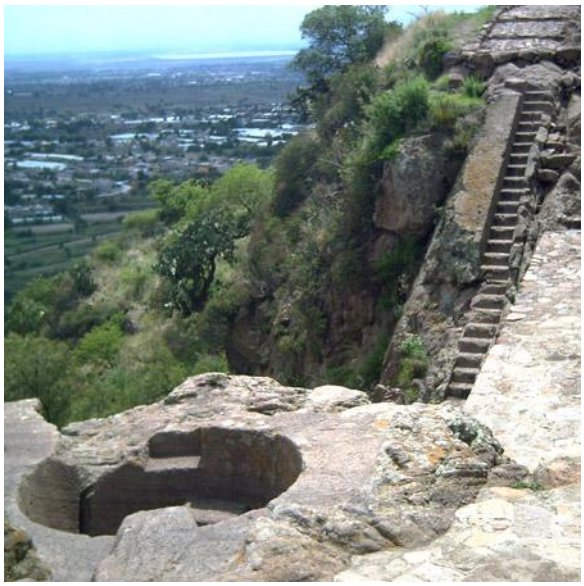
Cultural function

Aztec cosmovision was reflected in the layout of the gardens regardless of their size. The largest gardens were built around ritual places such as mountains, springs and caves, while there were small gardens built beside the palaces of the nobility that held also a wide variety of flora, fauna and pools.

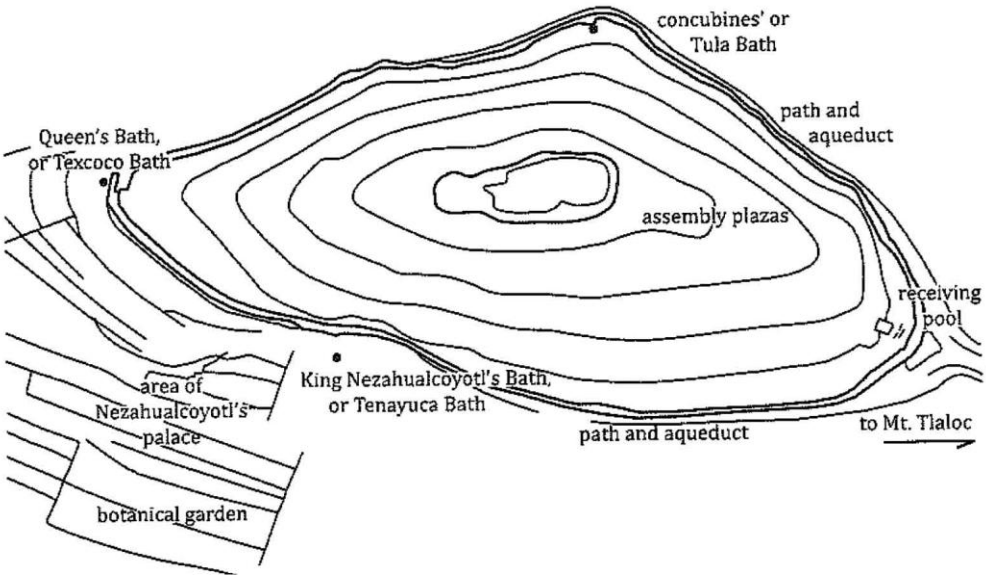
Gardens were not only for the enjoyment of the Emperor and royal nobles, but were also multi-purpose botanical gardens associated with the curing of physical and spiritual ills as they also kept a wide array of ornamental, aromatic and medicinal plants. The pools were filled with spring water that came from sophisticated aqueducts and contained several types of fish and waterfowl. There were royal gardens in and near Tenochtitlan, Chapultepec, Iztapalapa, el Peñón and Tetzcoco, as well as in more distant locations such as Tetzcotzinco and Huaxtepec (Aguilar 2007:225, Avilés 2006:143, Granziera 2001:208).

Gardens and Pools (continued)

Depiction of Gardens and pool in Chapultepec, *Historia de las Cosas de la Nueva España*, folio 11r (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).



King's baths in Tetzcotzinco garden (Photograph by Lia Sali - CC:BY).



Tetzcotzinco plan, also known as "Nezahualcoyotl's baths" (Evans 2010:Figure 15.3).

Figure 3.15. Clockwise, examples of the Gardens and Pools architectural type: depiction within a codex, archaeological remains and plan.

3.3.16 Markets

Nahuatl name

Tianquiztli (Figure 3.16**)**

English Translation:

Market, place of commerce.

Form

Large open-air markets were located in close proximity to the main ceremonial precincts of cities; smaller open-air markets were located throughout the city as Cortés describes:

> "This city has many plazas where there are ongoing markets and dealings to buy and sell…"[20]

Cultural function

Aztec markets varied in size and the type of products sold. Besides the markets that supplied food, there were others who were specialized in certain products. Azcapotzalco was dedicated to the sale of slaves; Cholula traded only jewelry, gems and the feathers of birds; Tetzcoco focused on clothing, cups and earthenware; and Acolman sold dogs for domestication and meat (Attolini 436).

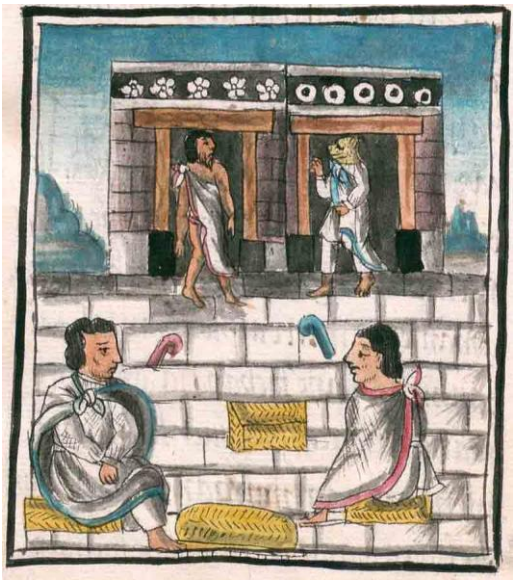
---

[20] Translated from Cortés (1866:103):

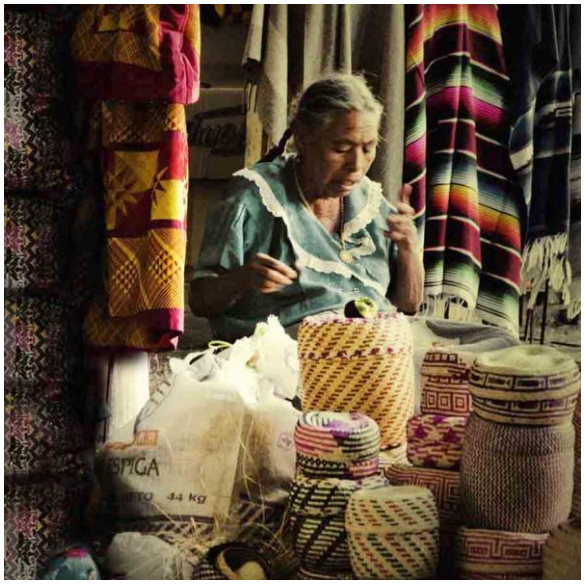
Tiene esta ciudad muchas plazas, donde hay continuo mercado y trato de comprar y vender…

Markets (continued)

Depiction of Market (feathers, gold, precious stones, and textiles) , *Florentine Codex*, book 3, chapter 9 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).



Merchants buying feathers, *Florentine Codex,* book 2, folio 742 (*Biblioteca Medicea Laurenziana, Firenze* CC-BY-NC-SA 4.0).



Weaver selling textiles and baskets in market (Photograph by Montaldo Vera - CC:BY).

Figure 3.16. From top to bottom, examples of the Market architectural type: depictions within a codex and a contemporary market.

3.3.17 Engineering Works - Chinampa, Dams, Embankments, Dykes, Roads, Piers, Canals, and Bridges

Nahuatl name

Chinampa (Figure 3.17**)**

English Translation:

A long narrow extension of farmland built by human hands and stretching into the lakes around Mexico City.

Axoxōhuīlli

English Translation:

dam, lake.

Metepantli

English Translation:

Terrace, **embankment**, or a sloping semi-terrace field.

Atenamitl (Figure 3.17**)**

English Translation

Parapet, eve or the sides of a rooftop; wall; or, **dyke.**

Calotli

English Translation

The **road** or path that leads to some house; street.

Acaltecoyan

English Translation

seaport or an embarkation site [**pier**].

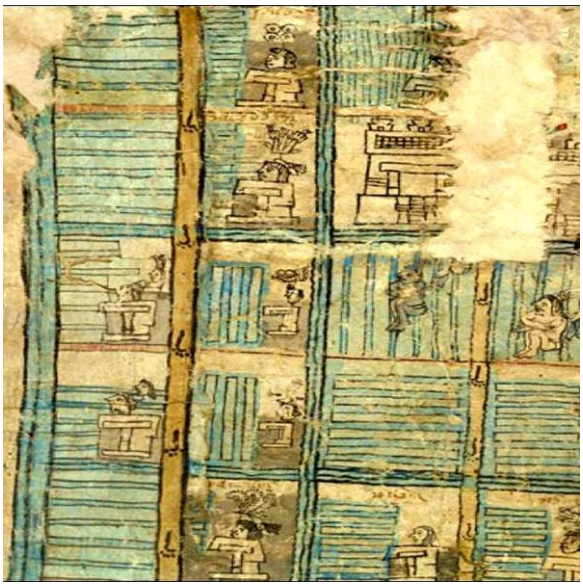
Acallotli

English Translation

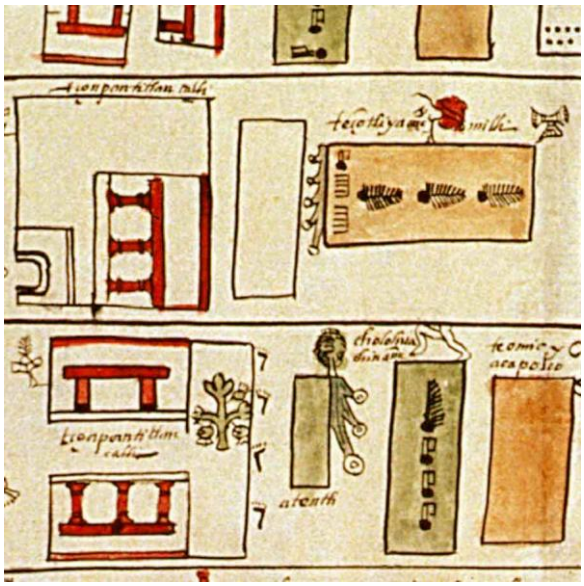
Canal.

	Aquappanahuaztli *English Translation* A wooden **bridge.**
Form	Varied, depending on function.
Cultural function	To control frequent flooding, increase agricultural areas and facilitate communication within the complex lake system in the Basin of Mexico, the Aztecs developed sophisticated engineering and hydraulic works. These works included chinampas, dams, embankments, dykes, roads, piers, canals and bridges, among others.

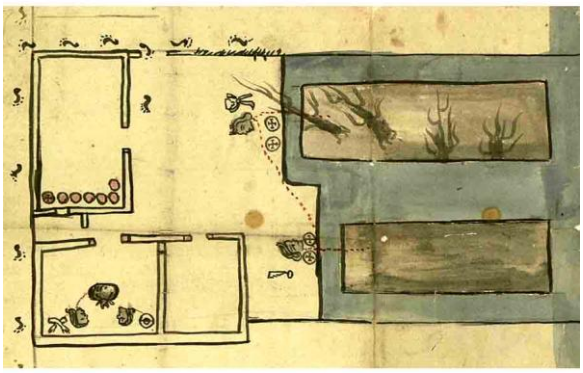
Engineering Works - Chinampas (continued)



Depiction of chinampas (canals, roads and two Teocallis in upper right), *Plano Parcial de la Ciudad de Mexico (Biblioteca Nacional de Antropología e Historia* CC-BY-NC-SA 4.0).



Depiction of properties including house and chinampas, *Propiedades en Xochimilco* (*Archivo General de la Nación* CC-BY-NC-SA 4.0).

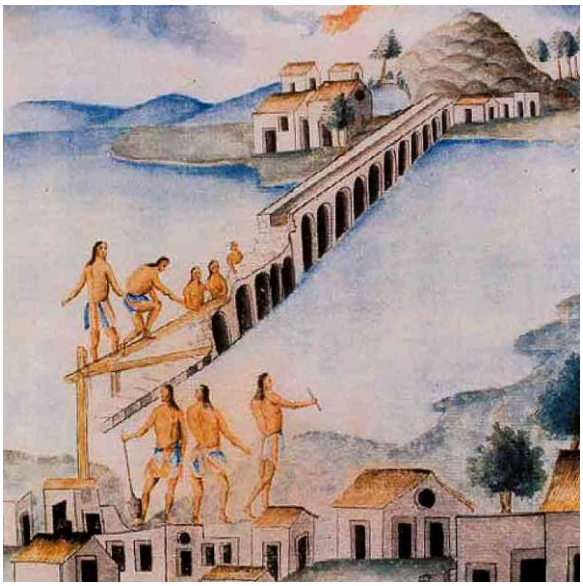


Depiction of property including house and chinampas, *San Juan Tepiztlan* (*Archivo General de la Nación* CC-BY-NC-SA 4.0).

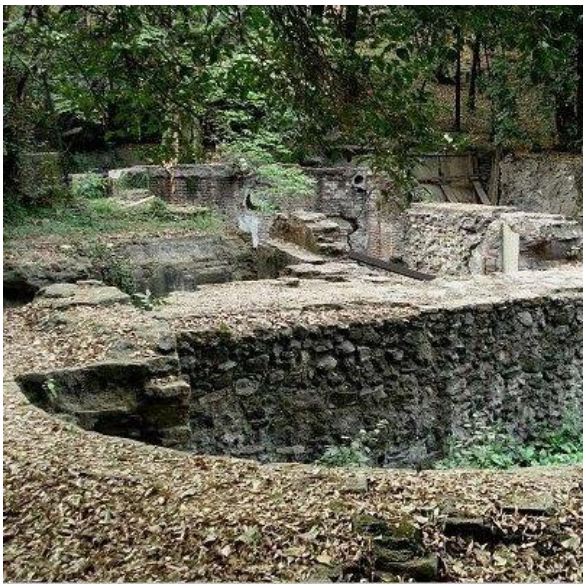
Aerial view of Chinampas, Xochimilco (Photograph by *Imágenes Aéreas de México* - CC:BY).

Figure 3.17. From top to bottom, examples of Chinampas: depictions within a codex and administrative-legal documents and contemporary chinampas.

Engineering Works - Aqueducts and Dykes (continued)



Aqueduct from the spring of Chapultepec to Tenochtitlan, *Codex Panes Abellán,* vol. 4, folio 148 (*Archivo General de la Nación* CC-BY-NC-SA 4.0).



Aqueduct section from Moctezuma's pool to the Cincalco cave, Chapultepec (Photograph by Alfonso Marroquin - CC:BY).

Dyke of Nezahualcoyotl to separate Lake Texcoco from Xochimilco, *Nuremberg map (Newberry Library CC-BY-NC-SA 4.0).*

Remains of the Dyke of Nezahualcoyotl (Photograph by Benjamin Arredondo - CC:BY).

Figure 3.18. From left to right, examples of Aqueducts and Dykes: depiction of aqueduct within codex and contemporary aqueduct; depiction of dyke within map and contemporary dyke.

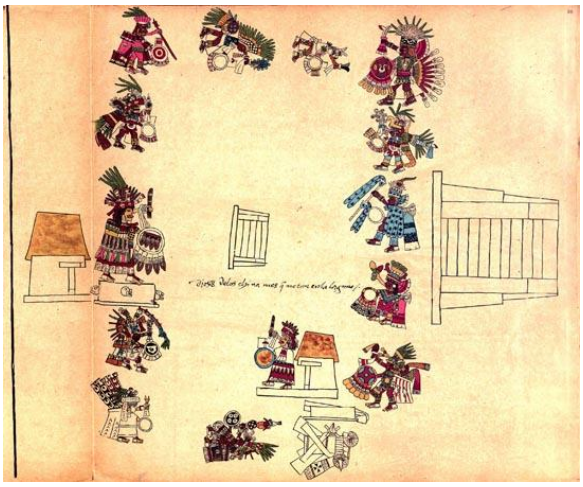
3.4 Aztec Urban Forms

The influence of the urban layouts of Teotihuacan and Tula has been thoroughly discussed in Aztec scholarship (Marquina 1964; Cobean, Mastache, and Healan 1989, 1995, 2003; López Luján 1995, 2006, 2009; Matos 1999; Guilliem 2003; Smith 2008; López Austin and López Luján 2009). These sites were even studied by the Aztecs, who utilized them as sources for Aztec identity. Teotihuacan was the place where time began and Tula was the source of power to justify its right to military expansion. They drew upon Teotihuacan and Tula to design their city, which were considered sacred sites that were visited, honoured and deprived of the vestiges of their ancient glories by the Aztecs and their contemporaries (López Luján and López Austin 2009: 411). By borrowing from the past, they validated their rights to power as heirs of these ancient cultures. Even though Teotihuacan was already in ruins, its urban design and the inter-relationship of its architecture with the landscape were still evident, so the Aztecs laid out Tenochtitlan following the same urban principles. The division of Teotihuacan into four quadrants, defined by the urban north-south urban axis of the Avenue of the Dead and east-west axis of the Pyramid of the Sun, were reflected on the division in quarters of Tenochtitlan (Matos 1981:260). Tula, with its architecture, sculptures, paintings and ritual objects, was a model for Tenochtitlan. López Austin and López Luján summarize it in these words:

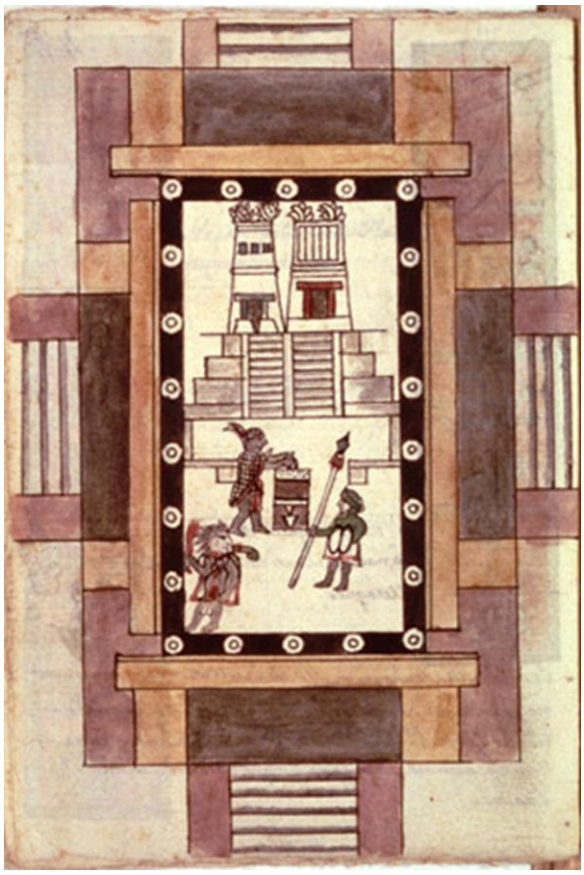
> There is evidence that one incentive for copying Tula must have been political: the ostentatious display showing that the Mexica capital was the successor of the former city's power and held an unbroken legitimacy. However, other evidence suggests much more profound causes: the use of forms that invited divine beings to occupy their space (López Luján and López Austin 2009:411-412).

Teotihuacan and Tula shared similar Mesoamerican planning principles such as clockwise orientation east of north of its main urban axes, orthogonal grid planning and ceremonial plazas, as well as some Mesoamerican architectural building types. Although the main layout of Teotihuacan followed a central axis —the Avenue of the Dead— it culminated in the plaza of the Pyramid of the Moon, and the perpendicular axis was dominated by the Pyramid of the Sun. Although Tula had three formal plazas—the south small plaza (unexcavated), the central public plaza and the north plaza (dominated by the Tlachtli)—its urban arrangement was characterized by a central ceremonial plaza, with the main teocalli on the east and other buildings in an

orthogonal layout. In the urban arrangements of both Teotihuacan and Tula, the two main teocallis are perpendicular to each other, with the larger teocalli facing east. This axial plan arrangement can also be found in ethno-historical sources where this arrangement served as an organizing principle of the ceremonies that were organized in these urban spaces (Figure 3.19).



Depiction of complex assemblage with axial plan (Titl ritual), *Codex Borbonicus*, plates 35 and 36 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).



Depiction of complex assemblage (ceremonial precinct of Tenochtitlan) with axial plan, Codex Aubin, plate 035-036-41v (British Museum, CC-BY-NC-SA 4.0).

Figure 3.19. Examples of the central ceremonial plaza plan characterized by a major teocalli serving as a focal point in an orthogonal layout within a plaza.

3.5 Chapter Summary

This chapter demonstrated that the study of Aztec architectural types is necessary for the understanding of Aztec architecture and urban planning. Even though some of these architectural types had already been in use in Mesoamerican architecture, the Aztecs appropriated their forms and meanings into the design of their buildings. Therefore, an inventory of Aztec architectural types—based on the *ICOMOS Principles for the Recording of Monuments, Groups of Buildings and Sites*—was carried out so as to define the common characteristics of each building type, particularly the unique Aztec double temple teocalli architectural type. This inventory helped to define Aztec architectural types in traditional sources such as codices and archaeological remains, and non-traditional sources such as pictorial-administrative manuscripts and sculpture. It also validated the double temple teocalli as an Aztec architectural type, which was found in seven main Aztec cities: Tenochtitlan, Tlatelolco, Tenayuca, Santa Maria Acatitlan and Teopanzolco as archeological remains, and Texcoco and Tlacopan as pictorial representations.

Regarding Aztec urban forms, this chapter presented the influence of the urban design of Teotihuacan and Tula in the layout of Tenochtitlan as several scholars have argued. These planning principles included the clockwise east-of-north deviation of the urban axes; the orthogonal planning or the urban grid; the organization of the main buildings into a central axial plan; the utilization of common Mesoamerican architectural types; and the orientation of the larger teocalli along the east-west urban axis.

Consequently, the findings of this typological research provided the architectural and urban information that were taken into consideration for the archaeoastronomical analyses of the Aztec sites where a double temple teocalli—the most distinct Aztec architectural type—has been excavated (Chapter 6).

Chapter 4: The Aztec Cosmological Concept of Space and Time

4.1 Introduction

The aim of this chapter is to introduce the Aztec cosmological concepts of space and time in order to understand how they were embedded in Aztec architecture and urban planning, as the research carried out in the ethnohistorical sources (Chapter 2) and the typological studies (Chapter 3) revealed their intrinsic connections . The first section presents the concept of cosmovision and its relationship with the landscape, skyscape and religious beliefs the embedded in the symbolism the Huey Teocalli according to ample research done in this area of Aztec scholarship. The second section narrates two fundamental stories in Aztec religion and mythology: the creation of the world and the birth of Huitzilopochtli —god of Sun, fire, war and patron deity of the Aztec— and the relationship of these myths with the four directions, the movement of the Sun across the sky and the symbolic meaning of mountains. The third section describes the concept of space and time in the Aztec calendar. The fourth section describes how these cosmological concepts were integrated into the sacred landscape comprised of mountains, caves and bodies of water, and emphasizes the importance of Tlaloc — god of rain, water and lighting— and the rituals performed on Cerro Tlaloc. The last section introduces the research carried out in the field of high mountain archaeology and its relevance for the understanding of the sacred landscape in the Valley of Mexico.

4.2 The Concept of *Cosmovision*

Several scholars such as Calnek, Arnold, Broda, Townsend, and Aveni agree that in order to comprehend the arrangement and planning in the ceremonial space of Tenochtitlan, one must "become familiar with the landscape and *skyscape* of both the city and the space in the Valley of Mexico" and recognize that the reenactment of religious myths took place within this environment as certain ceremonies were required "to take place in both the proper *spatial* and *temporal* order" (Aveni 1999: 58).

Thus, to fully understand the symbolism embedded in Aztec architecture and urban planning, it is necessary to understand both the physical space and the Aztec multifaceted religious system that consisted of various, and at times, contradictory myths, as well as a multiplicity of gods who were sometimes venerated as multiple personifications of the same gods. This religious system was connected by some shared concepts, the intrinsic sacredness of all aspects of life and a cyclical pattern of transformation (Pasztory 1983:56).

These shared concepts were founded on two basic characteristics of ancient societies: agriculture and rain, which have economic importance to society as they are the main basis of agricultural activity, which in turn is closely related to seasonal changes. Thus, it was necessary to understand the cycles of nature to forecast different seasons. The basic concept in the worldview of the Aztecs is the structured order of the universe, in which nature was created out of dual opposing forces: day and night, light and dark, cold and heat. This conception of the universe was closely associated with the origin of all things: the gods, the stars, the Earth and humankind. Matos defines this set of ideas and its explanation as *cosmovision* (Matos 1989:95).

4.3 The Conception of Space in Aztec Cosmology and Mythology

A creation myth that illustrates the concept of the world divided in four quarters is the story of Cipactli, the original being, the primordial feminine sea monster that swam in the vastness of the waters. Two gods cut her body in two parts; they built the heavens with one part and the underworld with the other part. The heavens were fertilizing and giving, the underworld producing and receiving. To separate the two parts, the gods placed five posts, one at the center and the remaining four at each corner of the Earth. The intermediate part created by this separation was the world inhabited by humankind. Everything was grouped in accordance to the four cardinal points of the compass and the central direction of up and down. Therefore, the numbers four and five were extremely important and manifested as four quadrants and five directions. These four directions and corners of the Earth are religious symbols for the cardinal points. This myth is complemented by the myth of Ometecuhtli and Omecihuatl (Figure 4.1), the supreme divine couple who resided in Omeyocan, where they engendered four divinities: Xipe or the red Tezcatlipoca, the black Tezcatlipoca, Quetzalcoatl and Huitzilopochtli. After 600 years,

the two Tezcatlipocas entrusted to their younger brothers, Quetzalcoatl and Huitzilopochtli, fire, a half Sun, the first humans, the calendar, the lords of the underworld, twelve other heavens, the gods of water and the Earth and the first humans (Graulich 2006b) These four gods are the lords of the four directions of the Earth, or holders from heaven, and are associated with four colours: red to east, black to north, blue to south, and white to west.

Figure 4.1. The aged primordial couple, Oxomoco engaged in divining with maize kernels and her partner, Cipactonal, holding an incense container and burner, Codex Borbonicus folio 19 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).[21]

Meanwhile, the god Huitzilopochtli also has great importance as a Sun god. The myth of Huitzilopochtli recounts how the goddess Coatlicue -Earth- was sweeping the temple stairs on the hill of Coatepec, when she was supernaturally impregnated by a little ball of feathers that floated down from the sky and that she tucked away next to her bosom. Her other children, her daughter, Coyolxauhqui -Moon- and his four hundred brothers, Centzon Huitznahua -the stars- were angered by this fact and decided to kill her. Coatlicue was saddened by the decision of her

[21] "A passage in Book 4 (The Soothsayers) of the *Florentine Codex* links this ancient pair to the invention of the *Tonalamatl* [ritual calendar], adding that their painted images adorned this book. A mural with a similar scene was recently unearthed in the Templo Mayor of Tlatelolco, painted on one side of a rectangular structure known as the Calendar Templo, which features reliefs of the days signs of the first three *trecenas* of the *tonalpohualli* carved around the remaining sides" (Quiñones Keber).

children, but her son Huitzilopochtli -the Sun- who was in her womb consoled her and offered to defend her. When the Moon and stars came to slaughter Coatlicue, the Sun Huitzilopochtli was born fully armed for war with a fire serpent called Xiuhcoatl (Figure 4.2 (a)), with which he decapitated his sister, and pushed her down from the top of Coatepec hill. As her body fell, her body dismembered with each turn (Figure 4.2 (b)). He then turned to the Centzon Huitznahua and put them to flight from the summit of Coatepec Hill (Matos 1988b:40-42).

(a) (b)

Figure 4.2. (a) Huitzilopochtli armed for war with a fire serpent called Xiuhcoatl, Codex Tovar, 1a (Jean Carter Library at Brown University, CC-BY-NC-SA 4.0); (b) Coyolxauhqui Stone found at the Huey Teocalli (*Museo del Templo Mayor-INAH*).

Matos considers this myth particularly important for different reasons: it represents the daily struggles of the Sun against the Moon and stars; it explains the celestial phenomenon in which the Moon dies every month and is born in phases; it gives a theological justification to the warlike character of the Aztecs, as its main god, Huitzilopochtli "was created precisely to do battle" (Matos 1988b:42).

These myths, as well as the interpretation by Eduard Seler and Alfredo López Austin of the layers of heavens, Earth and underworld depicted in the *Codex Vaticanus A*, reveal the Aztec conception of the universe (Figure 4.3). "This structured way of viewing the heavenly bodies and

the Earth as well as the placement of the gods and of man himself in the cosmos, forms part of their complex philosophy and religion, their worldview. In this view, the universe consists of three levels: the highest or celestial level; the central or terrestrial level; and the lowest level or the underworld" (Matos 1988b:123).

Figure 4.3. The deity Ometeotl and the layers of the heavens (left); two lowest layers of heavens, above the layer of the Earth and the underworld, Codex Vaticanus A/Loubat, folios 1v and 2r (FAMSI CC-BY-NC-SA 4.0).

The celestial was further divided in thirteen layers or heavens. The last double heaven, the twelfth and thirteenth, known as Omeyocan, the "Place of Duality," was inhabited by Ometecuhtli and Omecihuatl: the eleventh, the red sky; the tenth and ninth, yellow and white. Down in the eighth, called yztapol nanazcaya, interpreted as "place where the corners are of obsidian knives," is the place of Tonacatecuhtli and where tempests are said to form. The seventh, the blue sky, is where Huitzilopochtli lives. The sixth heaven is green; the fifth is considered the "rotating heaven" where the comets and stars move; the fourth is inhabited by the planet Venus or, according to some sources, Uixtocihuatl, the goddess of salt waters; the third is

the path of the Sun, Tonatiuh, and is the heaven where the Sun leaves each day to cross the sky; the second heaven is the place of the stars, the Milky Way, inhabited by Citlalatonac and Citlalicue, both gods of the night sky; and finally, the heaven closer to Earth is inhabited by the Moon and clouds (González Torres 1975:21-34; Matos 1988b:124).

The terrestrial level was where humans live, and from the centre of this level emanate the four world directions, each identified with a creator god, a calendrical symbol, a colour and a plant as illustrated in the Codex Fejérváry-Mayer (Matos 1988b:124) (Figure 4.4).

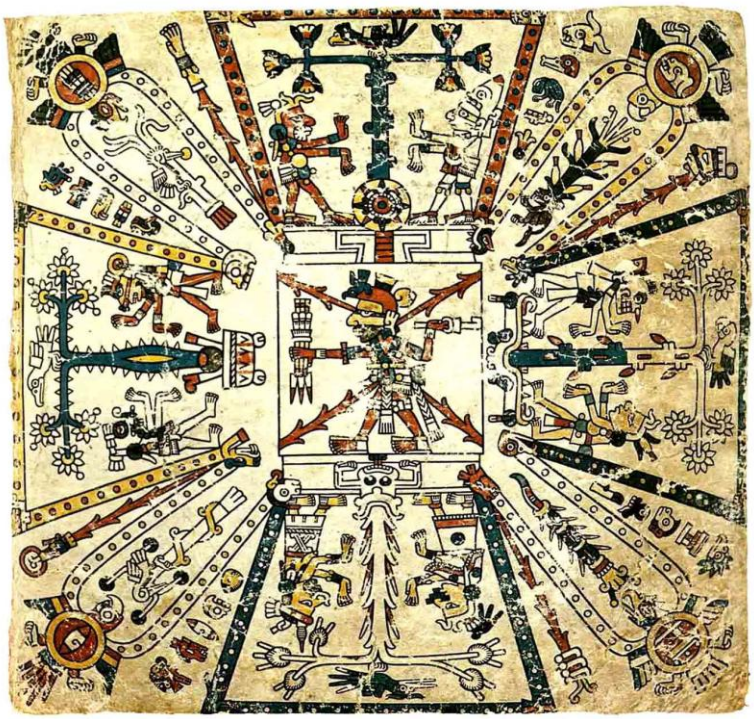


Figure 4.4. The cosmogram in the Codex Fejérváry-Mayer, folio 1, depicting time and space[22] (Museum of the City of Liverpool CC-BY-NC-SA 4.0).

[22] "Around a central figure of Xiuhtecuhtli, the lord of the year and of time, the painter arranged the 260 days of the ritual calendar in a multicolored ribbon that defines a Formée cross (often called a Maltese cross). The cross' broad arms are oriented toward the four cardinal directions, with east at the top. Narrower loops between the arms are oriented toward the intercardinal points. The 260 days of the ritual calendar flow along this ribbon in twenty groups of thirteen days, called trecenas. Each trecena is represented by the first day sign of the period followed by the twelve dots that serve as spacers standing in for the other twelve days. Beginning with the first day (Crocodile), the count reads counterclockwise around the cross: the first five trecenas are associated with east and northeast, the second five with north and northwest, the third five with west and southwest, and the fourth five with south and southeast. Each arm of the cross, and thus each direction, has its own color: red in the east, yellow in the north, blue in the west, and green in the south" (Boone 2006b).

There were nine subterrestrial levels through which the deceased must pass before reaching the underworld, Mictlan, the "Land of the Dead." These levels were "the Earth, the path through where hills are found, the hill of obsidian, the place of winds formed by obsidian knives, the place where flags wave, the place where people are shot by arrows and where hearts are eaten, the 'Obsidian place of the dead' and the place where no opening exists for smoke to escape" according to the Codex Vaticanus, although Sahagún had a different description of some these levels (Matos 1988b:129).

Furthermore, the geometry of the universe, expressed through the worship of the four directions, is one of the most important ideas of Aztec cosmology. The universe is conceived as the union of four constituent parts of the cosmos in a conceptual pivot through which heaven, the four directions of Earth and the underworld communicate along an axis mundi. Hence, the Aztec space was conceptualized as a vast horizontal disk surrounded by water and intersected by a perpendicular axis conceived as a series of layers, "this disk, sometimes picture as a rectangle, was organize into five major sections (the quincunx), with four quarters" (Aguilar 2007:302) (Figure 4.5).

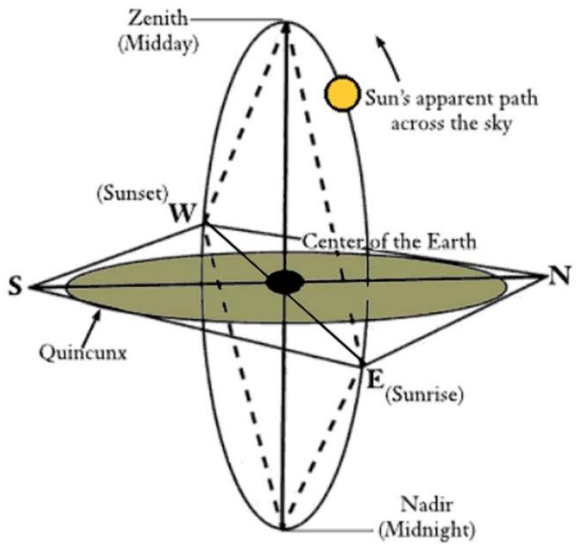


Figure 4.5. The Aztec concept of space and time (Aguilar 2007:Figure 11.5).

In Aztec cosmology, this cult of the four directions is closely related to the Sun. The Aztecs called this space *nauhcampa* and it was represented in native codices with east at the top. This is

distinct from the European way of representing space with north at this position, which shows the importance of this direction to Aztec society. According to González, each quadrant in nauhcampa was bounded by the solstice points of the rising and setting Sun in its annual journey of 365 days (Figure 4.6). This route had a rectangular plan, whose vertices made it possible to delimit the four quadrants and perhaps where the four holders of heaven were located (1975:51-84).

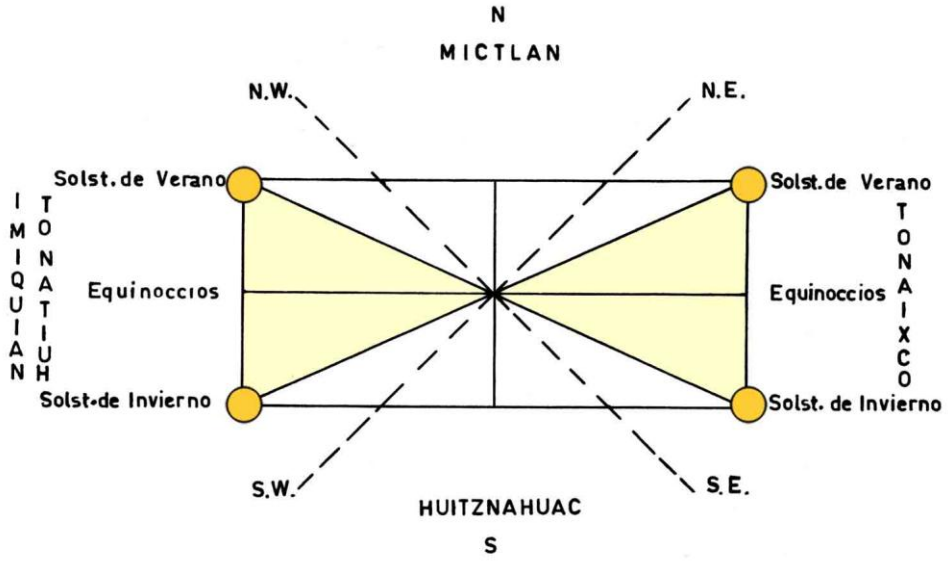


Figure 4.6. The four quadrants in the universe bounded by solstice points (González 1975:140).

The Aztecs integrated these concepts into architecture and urban design by skewing their sites clockwise from cardinal directions in order to record sunrises in autumn and winter and sunsets in spring and summer (Šprajc 1999b:73). This axial orientation has been confirmed by archaeoastronomers such as Tichy (1974) who found that post- conquest fields, villages and towns were generally aligned east of north. Likewise, Aveni (1975, 1976a), and other scholars have reported that the north-south axes of several pre-Columbian buildings in Central Mexico had a tendency to align slightly east of true north (Figure 4.7).

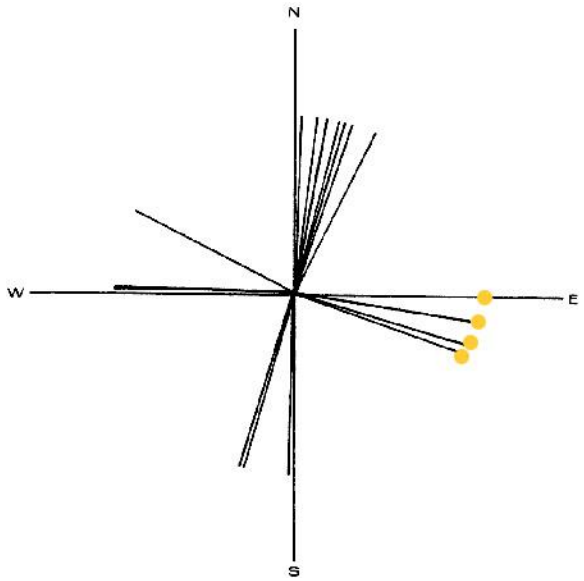


Figure 4.7. Axial orientations of Central Mexican Ceremonial Centres (Aveni and Gibbs 1976: Figure 1).

4.4 The Coordination of Space and Time in the Aztec Calendar

Each of the four cardinal directions ruled 65 days in the *Tonalpohualli* (ritual calendar*)*, besides influencing each *veintena* (20 days period); therefore space and time were embedded in the calendar (Aguilar Moreno 302) (Figure 4.8). The origins of this calendar system go back at least as far as the Preclassic period; it was widely utilized among the peoples of Mesoamerica, which is well known through historical and archaeological sources (Pasztory 1983:60).

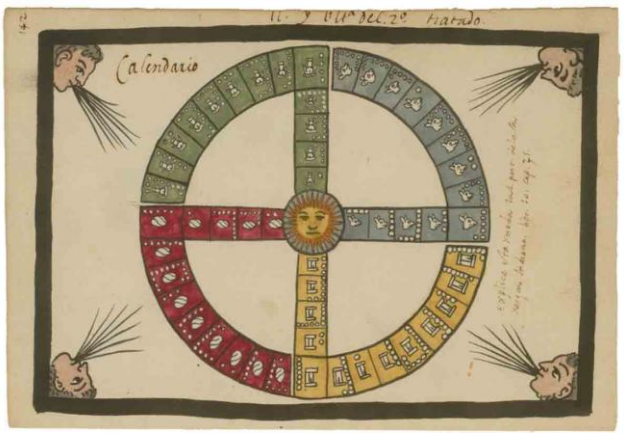


Figure 4.8. The Aztec Tonalpohualli calendar and the four directions of the world with the Sun in the centre, Codex Tovar, folio 142 (John Carter Library at Brown University CC-BY-NC-SA 4.0).

The Aztec calendar system was based on multiple interlocking sets of cycles:

- The ritual calendar (*Tonalpohualli*)
- The annual calendar (*Xiuhpohualli*)
- The 52-year calendar round (*Xiuhmolpilli*)

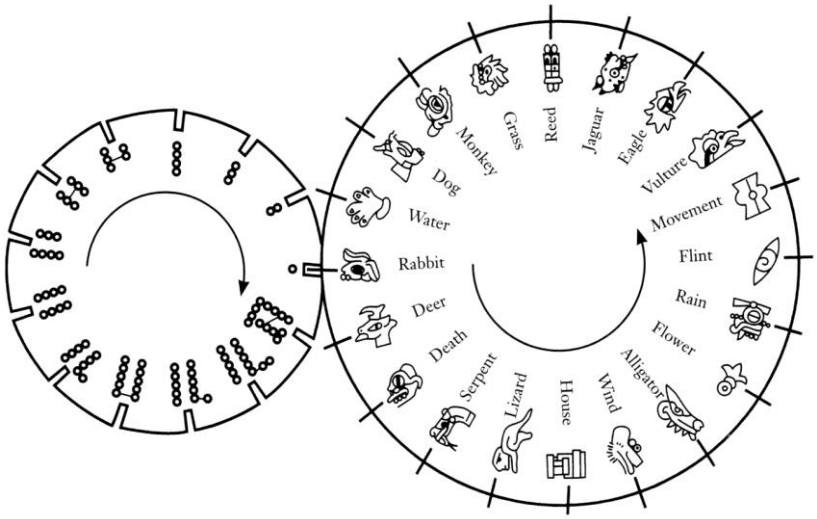


Figure 4.9. Representation of the Tonalpohualli cycle in which 20 day names interlock with 13 day numbers (Aguilar 2007:Figure 11.1).

The three calendars represented two methods of Aztec time counting. The *Tonalpohualli*, "counting of the days," was a 260-day cycle, which functioned as a ritual and astronomical calendar used for divination. Its basic units were the trecenas (13-day numbers) and the veintenas (20-day symbols). The 13 day numbers combined with each of the 20-day symbols to generate the 260 days of the tonalpohualli cycle (20 x 13 = 260 days) (Figure 4.9). The *Xiuhpohualli*, "counting of years," was a 365-solar count that functioned as calendar to organize the recurrent cycle of agriculture and annual seasonal festivals. Under this calendar, the year, *xiuhuitl*, consisted of 18 "months" of 20 days each plus five additional *nemontemi* or "leftover" days (18 x 20 = 360 + 5 = 365 days). The combination of the Tonalpohualli and the Xiuhpohualli created a larger cycle of 52 years. The change from one 52-year period, or "bundle of years" (*Xiuhmolpilli*), into the next was celebrated with the New Fire ceremony, one of the most important religious festivals (Aguilar Moreno 2007:290-298).

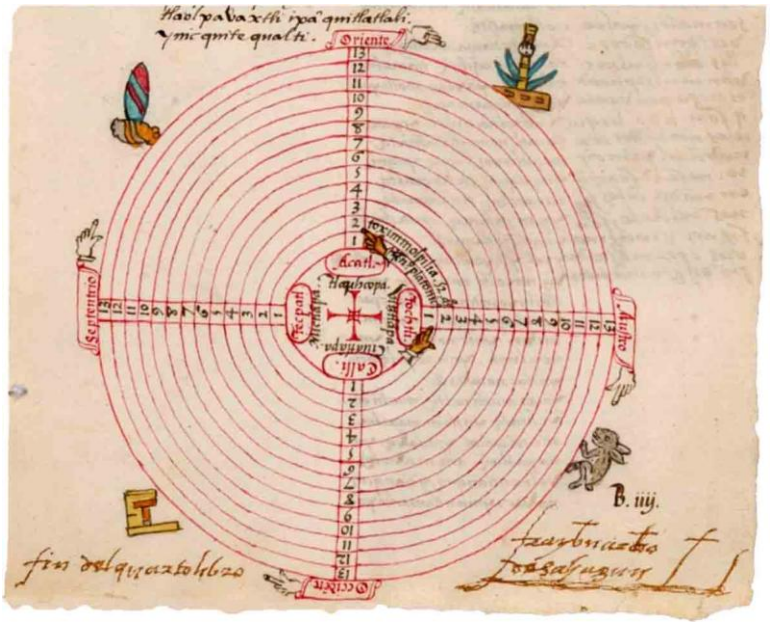


Figure 4.10. Calendar wheel illustrating the division of the 52-year cycle, Códices Matritenses, folio 188 (Real Biblioteca de Madrid, CC-BY-NC-SA 4.0) .[23]

The count of 52 years, comprised 73 tonalpohualli (52 x 365 = 73 x 260 = 18980 days) (Figure 4.10). After this period, the combinations of the cycles of 365 and 260 days were exhausted, so another cycle began with exactly the same dates. Two cycles of 52 years, (52 x 2 = 104 years) *huehuetiliztli* were called "old age" and were further characterized by the coincidence with the cycle of Venus. The Venus year contains 584 days, and five Venus years correspond to eight solar years, so every 65 Venus years coincide with 104 solar years and with 146 tonalpohualli (65 x 584 = 365 = 104 x 146 x 260 = 37960 days) (Broda 2005).

The development of the calendar reflected an astronomical and mathematical knowledge that emerged from the need to adjust agricultural cycles to seasonal cycles. During each month of the solar year, a major festival was celebrated at the temples. The ceremonies of the rain gods and the deities of maize and the Earth constituted a basic calendrical structure, and "it is worth noting that this basic structure of the Aztec ritual calendar coincided closely with the four dates of the year corresponding to the sacred Teotihuacan orientation of 15.5°: April 30, August 13, October 30 and February 12" (Broda 2000:251).

[23] The four sets of 13 years are associated with the four cardinal directions, which illustrates the relationship between space and time.

This coordination of space and time in the Mesoamerican world (Figure 4.11)was not only expressed in the orientation of architectural structures and urban settlements, but also in the number of days separating the solstitial sunrises and a defined date associated with the beginning of the solar year. These structures are, in most cases, oriented towards the sunrises or sunsets on specific days in the solar cycle, while some of them are also connected with stellar phenomena (Broda 2005).

Figure 4.11. The Boban Calendar Wheel where Aztec architectural building types such as a double temple teocalli and nobility palaces are utilized to describe three main events in the history of Texcoco. These buildings are surrounded by a calendar wheel containing the 20-day glyphs (John Carter Library at Brown University CC-BY-NC-SA 4.0). [24]

[24] The Boban calendar wheel is the result of a succession dispute between the family of Don Antonio Pimentel Tlahuitoltzin, and Don Carlos Ometochtli Chichimecatecotl, who was backed by Spain. This document was intended to prove that Don Antonio Pimentel Tlahuitoltzin had the legal right to be ruler of Texcoco de Mora.

4.5 The Sacred Landscape

It is said that when Cortés described the topography of Central Mexico to Emperor Charles V, he took "a sheet of parchment, crumpled it in his hand," threw it down upon a table and told his monarch that it was like "*un papel arrugado*" (a crumpled piece of paper). The great mountain ranges running from what is now the Mexican territory are part of the landscape that so impressed the Spaniards. The Trans-Mexican Volcanic Belt (TMVB), that crosses the country from west to east on two primary fractures that cut the terrestrial crust: the Clarion fracture and the Chapala-Acambay fracture, created minor tensional fractures that contributed to the formation of dynamic volcanic system. In the central area of the country, the fracturing of the great volcanoes originated binary volcanic systems such as the Popocatepetl–Iztaccihuatl, the Volcán de Fuego–Nevado de Colima, the Ajusco–Xitle and the Sierra Negra–Pico de Orizaba (Montero 2004:2).

This geographic environment formed a landscape where mountains, caves and rivers established a framework in which daily life was tied to the physical interaction with the environment. The mountains were sacred because they kept a relationship with the sacred.

Broda proposed the concept of sacred landscape for further understanding the orientation of architectural structures and urban settlements, an ideological interpretation of space that connects their geographical space with their cultural space (Broda 1991:74). Time and space converged in the landscape as the annual course of the Sun was tracked on the local topography through a horizon reference system; architecture itself and its coordination with the natural environment were the "writing" (Figure 4.12).

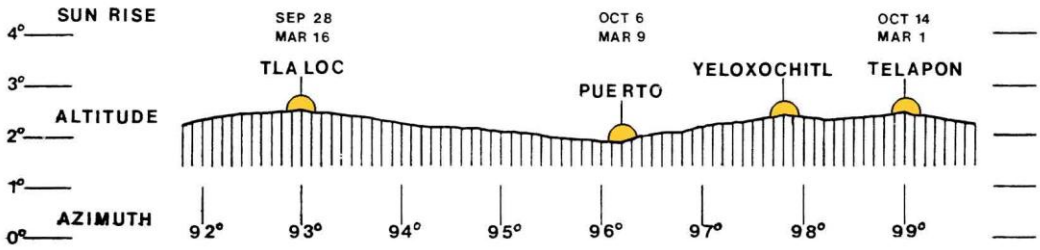


Figure 4.12. Horizon calendar of east as viewed from the Templo Mayor (Aveni, Calnek, Hartung 1988:Figure 5).

A system of codes was created within the living landscape. Isolated buildings, architectural assemblages and settlement patterns show particular alignments; in some cases, these alignments were coordinated with specific points of the landscape: mountains or other natural elements like springs and caves, as well as with artificial markers in the form of petroglyphs or buildings constructed deliberately. It is possible there even existed a complex structure of relating the political hierarchies of towns and villages to such an orientation scheme. These points on the horizon, or the orientation of temples to the rising or setting of the Sun and certain stars, were also coordinated with cult practice. The elaborate cult activities were kept in tune with agricultural cycles due to the fact that the basic structure of the festival calendar was the solar year and the main function of ritual was to regulate and control social and economic life (Broda 2000:253-254).

Besides the horizon calendars that tracked the rising or setting of the Sun along the local horizon, the mountain cult was also a fundamental aspect of Aztec cosmovision and religion. According to Sahagún, the Aztecs envisioned the space beneath the Earth filled with water, which came from Tlalocan, the paradise of the god of rain, Tlaloc, and from it issued the springs to form the rivers, the lakes and the sea (Figure 4.13). The purpose of the mountains was to retain the waters as "large vessels or houses full of water and release them when necessary to flood the Earth; that is why they call the villages *altepetl* which means mountain of water or mountain filled with water" (Broda 1982:49).

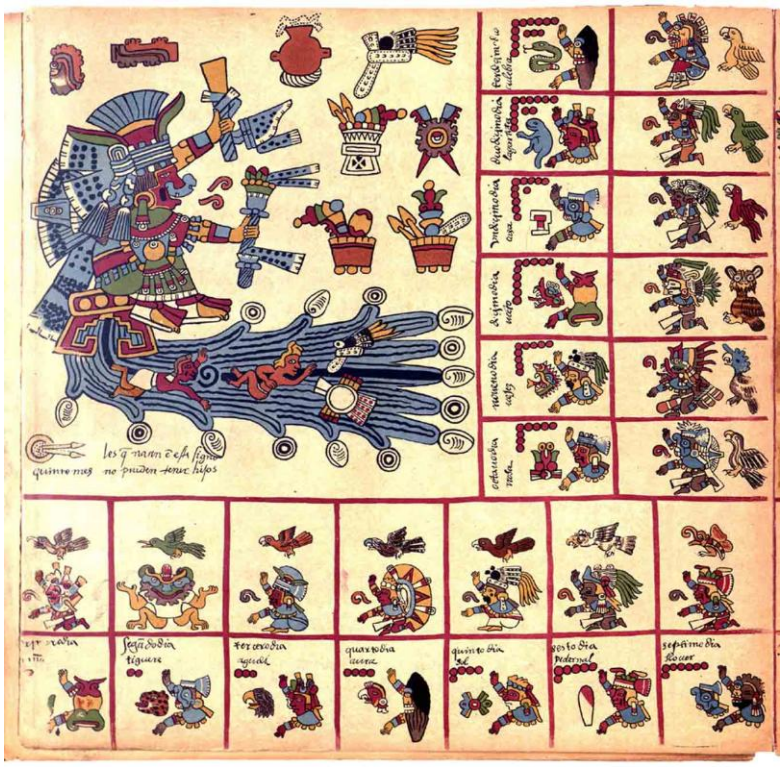


Figure 4.13. Depiction of Tlaloc in the Codex Borbonicus, folio 5 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0). [25]

The entrances to Tlalocan were the caves, hence they were also considered places of origin, or passages into the womb of the Earth (Figure 4.14 (a)). This conception of space inside the Earth filled with water, and of mountains as containers of that water, is also connected to rains and agriculture, a widespread belief in Mesoamerica (Broda 2000:252). For that reason, the teocallis were built to represent mountains, which were regarded as sources of water and fertility and the dwelling place of their ancestors (Figure 4.14 (b). Mountains were also the symbol of altepetl, "or the heart of the city filled with fertilizing water" (Aguilar 2007:220).

[25] In this depiction of Tlaloc, a water stream comes from his body carrying human beings, manifesting the power of water to be destructive as well as generative (Aguilar Moreno 327).

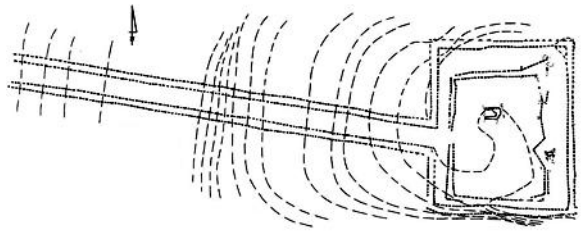
(a) (b)

Figure 4.14. (a) The caves of Chicomoztoc from which the Aztecs emerged, Historia Tolteca-Chichimeca, folio 16r (*Bibliothèque Nationale de France,* CC-BY-NC-SA 4.0); (b) Tlaloc seated on his mountain temple, Codex Borbonicus, folio 25 (*Bibliothèque Nationale de France,* CC-BY-NC-SA 4.0).

4.6 High-Mountain Archaeology

Even though the Aztecs venerated all mountains during the *Tepeihuitl* (celebration of the mountains) festival, the rituals to Tlaloc (god of rain, lighting and thunder) and Chalchiuhtlicuye (goddess of waters, rivers, and fountains) in other festivities guaranteed the arrival of the rainy season and the regeneration of nature. These rituals were performed in the tetzacualco (mountain shrine) on the summit of Cerro Tlaloc (Figure 4.5), a mountain located in Sierra de Rio Frío

mountain range on the east of the Valley of Mexico, and is also part of the binary volcanic system with Cerro Telapon (Montero 2004:4). Durán described Cerro Tlaloc as a mountain that was "so tall that clouds always surrounded it, and from it hail, lightning and thunder came out." Since the tetzacualco at Cerro Tlaloc "represented the womb of the Earth as the source of life's annual renewal" the purpose of these rituals "was to ensure the annual renewal of nature". According to Townsend when the Aztec kings performed the rituals to Tlaloc, they were legitimizing their power by assuring the "renewal of the Earth, the abundance of crops and the order and continuity of society". Besides these rituals in Cerro Tlaloc, other ceremonies were performed on teocallis, fields and other mountains since the Aztecs believed all mountains were related to Tlaloc (Townsend 1992:171-175).



(a) (b)

Figure 4.15. Tetzacualco mountain shrine on the summit of Cerro Tlaloc, (a) plan (Iwaniszewski 1994:Figure 3); (b) view towards the east where other mountains and volcanoes can be observed at a distance (Universidad Autónoma del Estado de Mexico 2010:Page 5).

In addition to Cerro Tlaloc, Montero has identified several archaeological remains on eleven important summits in Mexico (Table 4.1). These high mountain sites (4000 meters above sea level) were to the cult of water since pre-classic times and have continued to be a place where contemporary Mexicans perform ceremonies (Montero, 2000:97).

Table 4.1. Archeological remains of shrines located on high mountain shrines (Montero 2004)

Name	Latitude	Longitude	Mountain Shrines	Elevation	Nahuatl Name
Ajusco	19.2075	-99.2581	5 sites	3930	Axochco
Cofre de Perote	19.4920	-97.1500	3 sites	4220	Naucampatepetl
Iztaccihuatl	19.1789	-98.6417	32 sites	5230	Iztaccihuatl
Jocotitlan	19.7372	-99.7592	1 sites	3900	Jocotitlan
La Malinche	19.2303	-98.0318	22 sites	4430	Matlalcueye
Nevado de Toluca	19.1080	-99.7580	18 sites	4690	Chicnauhtecatl
Pico de Orizaba	19.0315	-97.2700	15 sites	5610	Citlaltepetl
Popocatepetl	19.0230	-98.6220	7 sites	5465	Popocatépetl
Volcán Sierra Negra	18.9873	-97.3144	1 sites	4585	Tliltépetl
Cerro Tlaloc - Cerro Telapon	19.4123	-98.7126	4 sites-	4125	Tlalocatepetl

Furthermore, the archaeological remains (Figure 4.16) found at these elevations have confirmed their ritual and astronomical function, particularly in regards to their horizon calendars, as solstices, equinoxes and ritual dates could easily be referred to this or that mountain peak. This knowledge was essential to synchronize agricultural cycles with the rainy seasons, the winds, and the cold and warm weather (Montero 2004:25).

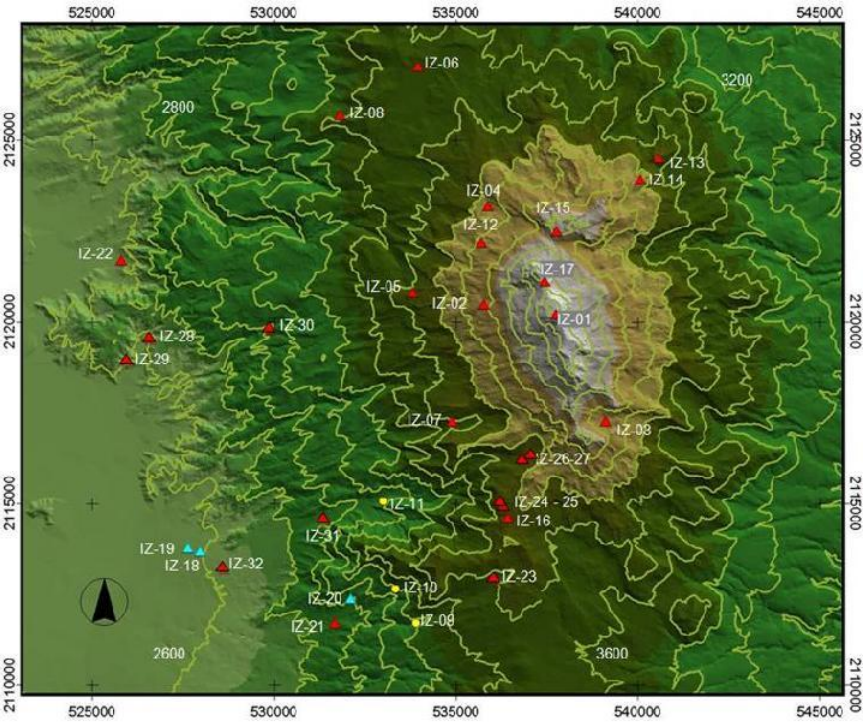


Figure 4.16. Register of the archaeological sites found on Volcán Iztaccihuatl (Montero: Figure 2004:75).

4.7 Chapter Summary

This chapter demonstrated the multilayered relationship between Aztec architecture and Aztec cosmovision in which the Huey Teocalli was the embodiment of their myths and religious beliefs. It presented the research carried out by archaeologists and historians who have corroborated the myth of Huitzilopochtli with the finding of the Coyolxauhqui stone discovered at the base of the Huey Teocalli along the axis of the temple dedicated to this deity. It also described the concept of the Aztec universe where space was conceived as a vast horizontal disk surrounded by water and intersected by a perpendicular disk organized in four quarters or directions. Each quarter was bounded by the solstice points of the rising and the setting Sun in its annual journey. This solar journey had a rectangular plan whose vertices delimited the four quadrants and where the four holders of heaven were located. Archaeoastronomical research in Central Mexico has established the importance of the space between solstitial points by confirming that post-conquest fields, villages and town have their urban axes skewed towards these directions. Furthermore, this chapter explained how the concepts of space and time were integrated in the Aztec calendar where a complex system of ritual and calendar rounds followed the cycles of the 365-day (73x5=365) Earth year and the 584-day (73x8=584) Venus year in periods of 52 years. This counting of the days was done through horizon calendars where the annual course of the Sun was tracked on the local topography; hence the concept of sacred landscape was introduced. The sacredness of topography was also a fundamental aspect of Aztec cosmovision and religion as the Aztecs envisioned the space beneath the Earth filled with water that emanated from Tlalocan, the paradise of the god of rain. Hence, the religious and cultural importance of Cerro Tlaloc and mountains was presented and explained through the findings of high mountain archaeology.

Consequently, this chapter contributed essential information for the analysis of Aztec architecture and urban planning that was utilized for the archaeoastronomical analyses of the pre-Aztec and Aztec sites selected for this research (Chapter 6), as it established the symbolic importance of the Huey Teocalli of Tenochtitlan, the understanding of the Aztec calendar, the utilization of horizon reference systems and the religious and cultural importance of Cerro Tlaloc.

Chapter 5: Aztec Concepts of Astronomy, Mathematics and Geometry

5.1 Introduction

The aim of this chapter is to provide an overview of Aztec astronomy, mathematics and geometry with the purpose of understanding how these disciplines were applied to Aztec architecture and urban planning. This knowledge was necessary to create the horizon reference system to track the Sun at calendrically significant intervals within the solstitial points as presented in Chapter 4 and to construct their cities and buildings. To this end, the first section includes an explanation of archaeoastronomy as well as its foundations and application in the study of archaeological sites; this explanation is followed by an overview of Aztec astronomy; and concludes with a technical explanation about charting the movement of the Sun. The second section introduces Aztec mathematics, including a discussion of numerical systems comprised of linear and angular measuring systems. The third section presents Aztec geometry by demonstrating the embedded design principles within monumental sculpture that were undoubtedly applied to architecture and urban planning. The last section presents an overview of Aztec building practice by describing the roles of the designers and tradesmen, the main construction materials and the construction tools recorded in historical and linguistic sources which conformed a sophisticated design and construction system that was required to lay out their urban centres and architectural structures.

5.2 Archaeoastronomy and Aztec Astronomy

Archaeoastronomy or "cultural astronomy"[26] studies the astronomy of ancient cultures. This interdisciplinary area of study requires accurate knowledge of mathematics and astronomy to determine the position of celestial phenomena. Furthermore, it must be based in anthropology, archaeology, ethnohistory, architecture and geography in order to make appropriate interpretations of the orientation of monuments and temples. Even though archaeoastronomy has

[26] "The interdisciplinary field of archaeoastronomy has already, by common consent, changed its name into 'astronomy in culture' or 'cultural astronomy.' This happened several years ago although it is still the case that the cultural aspect (cosmovision, or vision of the world) is not always taken sufficiently into account." (Broda 2011:407).

its antecedents in the last century, it started to develop as a discipline in the sixties when astronomer Gerald Hawkins hypothesized in his book, *Stonehenge Decoded*, that the megaliths of southern Great Britain constituted a calendar in stone (Aveni 2001:2).

In Mesoamerica, archaeoastronomy has been a particularly fruitful field of research as ethno-historical records strongly suggest that the positions of, and periods of, celestial bodies were recorded with precision in order to set dates in the ritual and solar calendars (Figure 5.1). The observational elements of pre-Hispanic religion not only included the observation of the annual course of the Sun, certain planets and constellations, but also the observation of geography and natural phenomena in a wider sense.

The detailed observation and accurate prediction of natural phenomena "were intimately fused with a magical attitude and an explanation of the cosmos in mythical terms" (Broda 2001:79). Broda broadens the concept of cosmovision by defining it as "notions about nature and society that were combined into a coherent structural whole and were characterized precisely by this intimate fusion between the exact observation of nature, on one hand, and myth, magic, and ritual on the other" (2001:79). This cosmovision was reflected in their calendrical systems, mathematical calculations, astronomical observations and architecture.

Figure 5.1. The Sun god in front of the solar disk, the sky (black band with small circles), the Moon (water-filled vessel with a rabbit), and the Earth (Earth monster below animal sacrificing a quail to the Sun) depicted within a *trecena* (13-day period) of the Tonalpohualli (260-day ritual calendar), Codex Borgia, folio 51 (*Biblioteca Apostolica Vaticana,* CC-BY-NC-SA 4.0). [27]

The understanding of this cosmovision in architecture and urban planning has been enhanced by archaeoastronomy, as scholars such as Aveni, Hartung, Tichy Galindo and Šprajc, among others, have carried out systematic studies of the orientation of buildings and ceremonial sites, correlated with certain dates of the solar course as they can be observed on the horizon. These reveal that:

> "… ancient Mesoamerican time and space were deliberately coordinated in the landscape by means of orientation of buildings and sites, an imposed order that was expressed in the terms of calendrical structure. Ancient Mesoamericans created a sacred landscape in which they tried to establish a harmonious, reciprocal structure among shrines, temples, settlements, and natural features such as mountains and water resources" (Broda 1991:80).

In several cases, the plans of ceremonial centres as well as certain buildings may have been adjusted in order to face a particular direction of astronomical significance (Aveni 2001:259).

[27] Interpretation of plate by Nowotny (2005:38).

The existence of the Mesoamerican calendar system itself implies astronomical observations maintained through many generations and centuries for its accuracy. Among the observations related to the calendar include the accurate determination of the tropical year, synodic months of the Moon, the cycles of Sun and Moon eclipses, the Venus cycle and the observation of the Pleiades. However, the importance of these phenomena is not evident in the ethno-historical sources; the sixteenth-century chroniclers barely wrote about these aspects of Aztec culture as they did not understand the meaning of the orientations of buildings and urban settlements and their relationship to astronomy. Consequently, in the absence of historical testimony about these aspects of Aztec culture, the archaeological remains have been key to its understanding (Broda 1991:8).

The cosmological relationship between time and space in the Mesoamerican worldview found its expression in architecture by orienting buildings and urban settlements. In most cases, these orientations can be associated with the dates of the rising or setting Sun on specific days of the solar cycle, but some are also related to stellar phenomena. Although several scholars began studying these orientations in particular sites during the early seventies, the decades-long work of Anthony F. Aveni, in collaboration with the architect Horst Hartung, deepened the understanding of these orientations, as they made systematic field measurements with precision instruments of a large number of the Mesoamerican archaeological sites. This data allowed them to make statistical conclusions about the Mesoamerican orientation systems (Broda 1991:9). Their work has been extended by other scholars, including Ivan Šprajc, who studied the astronomical orientations of pre-Hispanic architecture in Central Mexico in 2001.

Another valuable contribution to the study of the orientations was made by geographer Franz Tichy, who developed a specific methodology where he combined the measurement of pyramids and pre-Hispanic sites with the study of the contemporary cultural landscape in Central Mexico. By measuring the orientation of sixteenth-century churches, he was able to determine the dominant orientation system in this cultural area (Tichy 1988a:117).

The interest in the study of orientations of archaeological sites lies in the fact that the orientations represent a calendrical principle different from those represented in stelae and codices. This is

certainly a principle unfamiliar to Western thought, as the *"writing" is architecture and its relationship with the natural environment*: A code system is reflected in the landscape. In many cases, individual architectural elements, urban assemblages and whole settlements reveal some specific orientations. These sites, in turn, are related to specific points on the topographical landscape with mountains and other natural or artificial markers (Broda 1992:37).

5.2.1 Aztec Astronomy

Similar to other Mesoamerican cultures, astronomy had a prominent role in Aztec culture (Figure 5.2). Several pictorial manuscripts relate historical events with natural phenomena such as eclipses, meteor showers, comets and the aurora borealis. However, Aztec astronomers were mostly interested in following those celestial bodies whose cyclical movements were supposedly connected to the Sun (Aguilar 2007:304).

Figure 5.2. Aztec astronomers observing the sky (represented a black semi-sphere with small white and red eyes), Codex Mendoza, folio 63 (Bodleian Library, CC-BY-NC-SA 4.0).

The annual movement of the Sun was followed closely by astronomers who recorded solstices, equinoxes and zenith passage; these dates marked the ceremonies that were related to agricultural cycles and other important dates. The Sun is extensively depicted in both anthropomorphic and symbolic manner in pictorial manuscripts and associated with numerous rites, ceremonies and temples. It is also connected to the creation myth and the birth of

Huitzilopochtli, so it was revered every day and within different ceremonies (González 1975:51-83).

In the *Florentine Codex, Book II: The Ceremonies*, Sahagún describes in detail the elaborate festivals during each of the 18 months of the annual calendar or *Xiuhpohualli*, thus implying that priests followed with precision the movement of the Sun. Each festival was celebrated in the last day of the month, although some preparatory ceremonies started 20, 40, or 80 days before the main festival; and others lasted 20 or 40 days after the main festival (Figure 5.3).

Figure 5.3. The *Atamalqualiztli* Festival which was celebrated every eight years; during this time they only ate tamales made with water and salt, Primeros Memoriales, folio 254r (*Real Biblioteca de Madrid, CC*-BY-NC-SA 4.0).

Furthermore, in the *Florentine Codex, Book VII: The Sun, Moon and Stars, and the Binding of the Years,* Sahagún narrates, among other stories, the Legend of the Fifth Sun—the fifth era of a cycle or creation and destruction—and the rites during the annual Sun festival. Broda and Aveni have documented that the Atlcahualo ritual ceremonies dedicated to Tlaloc, the rain god, took

place in a diverse set of ceremonial landscapes which involved the sacrifice of many children on shrines in several mountaintops around Lake Texcoco (Aveni 1991:58).

The cycle of birth, growth, plenitude and decline of the Moon was also recorded by the astronomers, who associated it other natural phenomena with similar cycles such as plants, menstruation, fertility and reproduction. It was also represented in the codices and associated with the creation myth and the birth of Huitzilopochtli, as the disremembered body of Coyolxauhqui. Historical sources do not mention any ceremony or temple directly related to the Moon, however there were lunar rituals associated with other ceremonies (González 1975:51-83). For example, Sahagún describes how a pregnant woman placed a piece of maguey in her bosom in order that the child would not be born deformed during lunar eclipses (Figure 5.4).

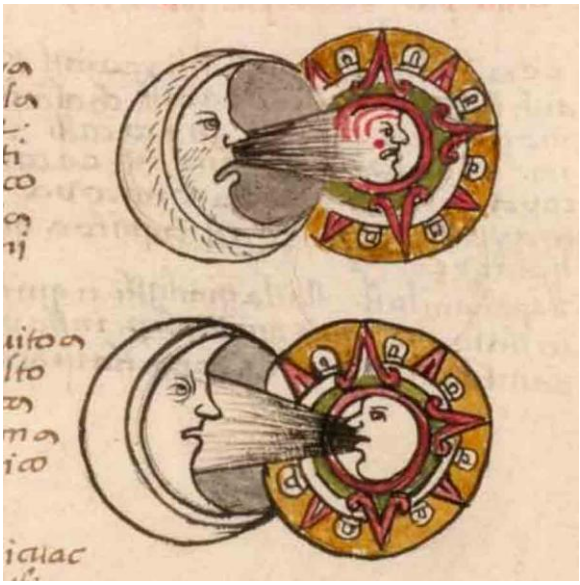


Figure 5.4. Eclipses of Moon and Sun, Primeros Memoriales, folio 282r (*Biblioteca Medicea Laurenziana, Firenze, CC-BY-NC-SA 4.0).*

After the Sun and the Moon, Venus is the brightest star in the sky, so Aztec astronomers also followed its synodic periods. Venus is depicted in both anthropomorphic and symbolic manner in pictorial manuscripts. Its aspects, Morning Star and Evening Star, were worshipped by the Aztecs (González 1975:103-107). Furthermore, they associated Venus with the god who guided the dead to the underworld (1975:117) since it is not visible for about 58 days when it is behind the Sun (50 days) or in front of the Sun (eight days).

Because of its synodic period of 584 days, it aided astronomers in the calibration of their calendar of 365 days. Five Venus cycles (5x584=2920), correspond to eight Earth cycles (8x365=2920) in a precise 8:5 ratio, so 65 Venus cycles were the equivalent of 104 Earth cycles. This 104-year cycle was called the *Huehueliztli*, which means "very long age." This cycle is also related to the calendar, because it was divided in two *Xiuhmolpilli* of 52 years, which were celebrated with a New Fire ceremony (Aveni 2001:148). However, the main importance of Venus was in soothsaying despite having a temple and ceremonies associated with it.

Celestial bodies and constellations were also venerated because many of the star groups had associated gods (Figure 5.5). One of the most astounding aspects of the *Florentine Codex, Book VII: The Sun, Moon and Stars, and the Binding of the Years* is that it gives a pictorial and written account of certain constellations by "representing the stars as circles connected by lines, which is reminiscent of the constellation patterns which can be seen inscribed around the periphery of the Aztec calendar stone" (Aveni 2001:32).

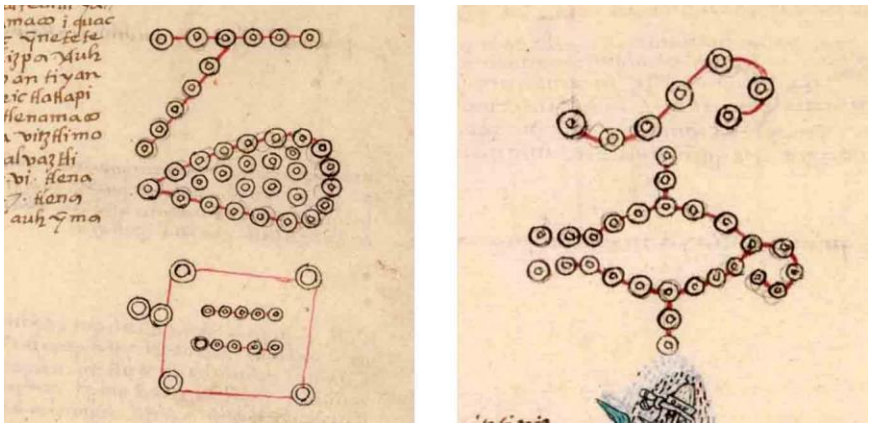


Figure 5.5. Aztec constellations, left (from top to bottom) Mamalhuaztli, Tianquiztli, Citlaltlachtli; right (from top to bottom Citlalxonecuilli, Citlalcolotl, Primeros Memoriales, folios 282 r y 282v (*Biblioteca Medicea Laurenziana, Firenze,* CC-BY-NC-SA 4.0).

Since astronomers needed to determine certain points on the horizon, pictographic evidence suggests that Mesoamerican astronomers utilized a pair of crossed-sticks as sighting devices (Figure 5.6). An astronomer could plot the position of an object near the horizon with precision by utilizing one crossed stick as a foresight and the other as a backsight. Even a distant point in

the landscape, such as mountain or a structure, could function as a foresight (Aveni 2001:65). This method could be used to calculate the synodical revolution of a celestial body as the astronomer only needed to count the days until it returned to its recorded position (Aguilar 2007:306).

(a) (b)

Figure 5.6. (a) Astronomer using a pair of crossed-sticks set up on top of a temple to determine a position of a celestial body; (b) An arrangement of two crossed-sticks through which an astronomer views a V-shaped arrangement in the distance, where a celestial body, probably the Sun, can be seen, Codex Bodley, plate 15 (Bodleian Library, CC-BY-NC-SA 4.0).

This astronomical knowledge, particularly the charting of the Sun, was used by the Aztec to lay out cities and buildings because ceremonial centres served as focal points in rituals. Aveni, Calnek and Hartung have thoroughly investigated the ethno-historical arguments about the orientation of the Tenochtitlan and found several circumstantial reasons for postulating an intentional astronomical orientation. One of the most compelling arguments is described by Motolinía who recounts how the Templo Mayor had to be rebuilt because it did not align with the equinox:

> Tlacaxipehualiztli. On this day they flayed all of the enemy prisoners, and dressed themselves in their skins; and they dedicated this festival to Tlatlauhqui Tezcatlipoca… This festival fell when the Sun was in the middle of [the temple of] Huitzilopochtli, which was the equinox, and because this was a little twisted Moctezuma wished it torn down and straightened (Aveni, Calnek and Hartung 1988:290).

Taking into account Motolinía's statement, Maudslay hypothesized that "the priest and worshippers doubtless faced to the east, to watch the Sun rise in the space between the two oratories." Maudslay's idea was further reinforced by a 1524 map of Tenochtitlan which shows a face representing the Sun flanked by twin temples on the top of the Templo Mayor (Aveni and Gibbs 1975:513) (Figure 5.7).

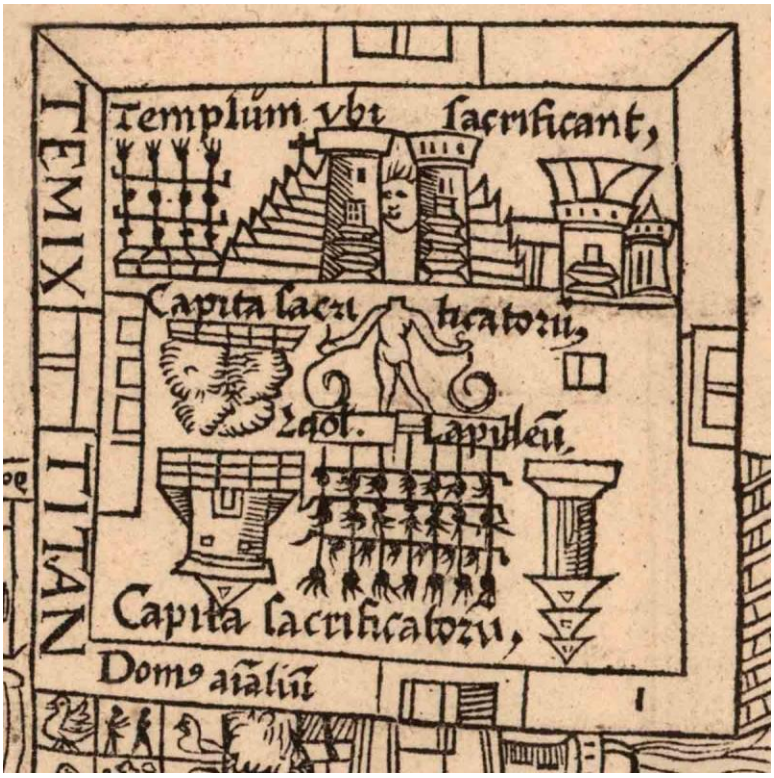


Figure 5.7. Ceremonial precinct depicted on the Map of Tenochtitlan included in the Second Letter of Cortes published printed in celebriciuitate Norimberga [Nuremberg] in 1524. Even though the ceremonial centre was rotated -90° from its real orientation, the face of the Sun is depicted as an animate being seen emerging between the twin temples of the Huey Teocalli (Newberry Library, Chicago, CC-BY-NC-SA 4.0).

Apparently, the archaeological record indicated that the Templo Mayor deviated 97.5° east of north, which indicated apparent conflict between historical and archaeological evidence. However, they concluded that this deviation was necessary because the Sun moved toward the southeast on a slanted path to an altitude of about 22 degrees above the astronomical horizon before it could effectively be seen between the temples during the equinox (Figure 5.8).

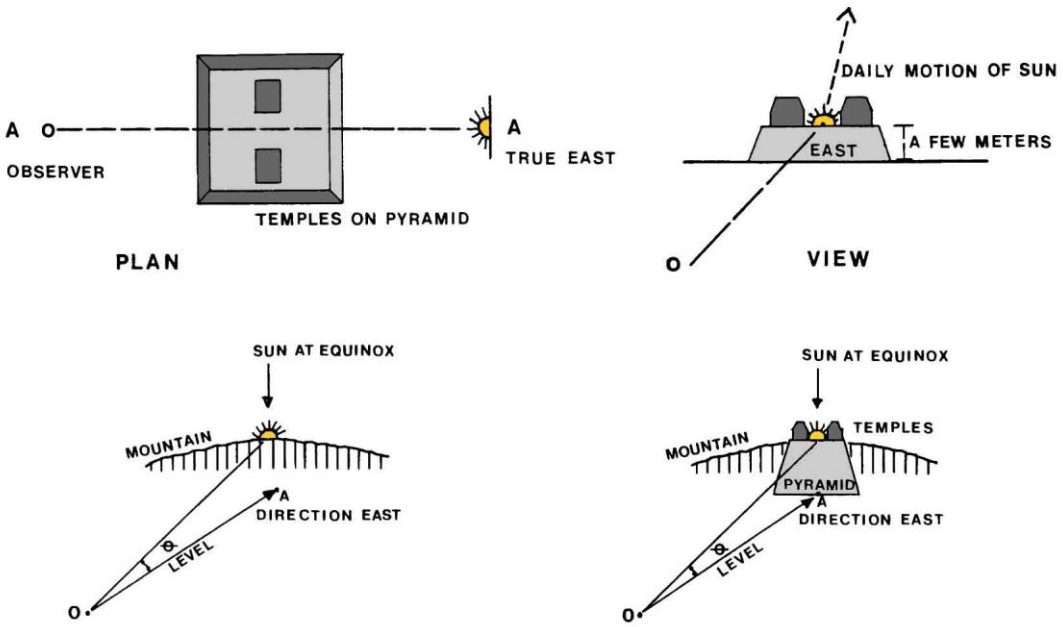


Figure 5.8. Orienting of a temple towards the Sun on the horizon and adjusting an orientation of Sun at horizon to Sun over temple (Aveni, Calnek and Hartung 1988:Figure1).

Other scholars, such as Sejourné, refute this theory and affirm that this orientation corresponded to the zenith passage, while Aveni and Hartung believe that orientation phenomena are the product of a tradition that began in Teotihuacan where the "equinox sunset is marked by a line passing from the top of the Pyramid of the Sun through a pair of petroglyphs at ranges of 6.5 and 7.5 km respectively that lie on the horizon precisely in line with the pyramid and at approximately the same elevation as its summit" (Aveni, Calnek and Hartung 1988:307).

In conclusion, no single explanation has been offered to explain the orientations of all known Aztec buildings and urban settlements in spite of the ubiquitous presence of these solar alignments in post-conquest churches, plazas and surrounding areas. This has led Tichy to posit the existence of three groups of axial orientations: a group near 7 degrees, a group near 17 degrees, and a group near 26 degrees east of north. This confirms a deliberate effort to orient Aztec buildings and urban settlements in these directions.

5.2.2 Charting the Movement of the Sun

Since the most important dates of the solar cycle—solstices, equinoxes and the path of the Sun through the zenith—were the most clearly expressed in architecture in Central Mexico (Šprajc 2001:411), a scientific understanding of orientations and the charting of the movement of the Sun is pertinent.

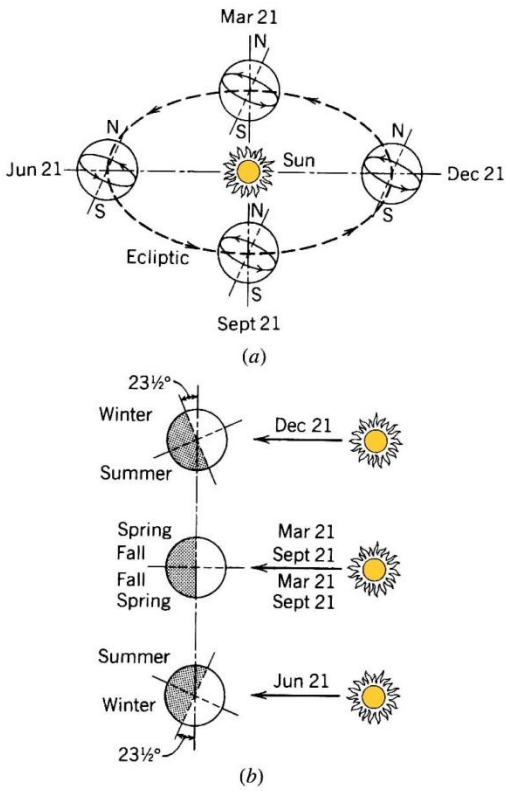


Figure 5.9. (a) The annual path of Earth around the Sun. (b) The tilt of the Earth's axis in the plane of the ecliptic results in the seasonal variations (Stein, et al. 2006:150).

The most obvious of the celestial motions is the path of the Earth around the Sun. Viewed from Earth, this trajectory has two directions: north-south and east-west. The east-west direction is indicated by the daily movement of the Sun across the sky; every day the Sun appears in the east and sets in the west. The Sun also moves annually for six months from north to south, then for the remaining six months of the year, from south to north. This north-south-north annual movement is easily visible on the horizon as the sunrise-point (*orto*) appears slightly offset from the point of departure the previous day. This apparent path of the Sun on the horizon has two extremes: around June21st on the Summer Solstice in the Northern Hemisphere when the Sun

reaches the peak on its way north, and around December 21st, on the Winter Solstice in the Northern Hemisphere when the Sun reaches its farthest point in its journey south (Figure 5.9). The apparent motion of the Sun on the horizon is due to the tilt between the axis of rotation of the Earth and the plane of the ecliptic (Aveni 2001:49-55).

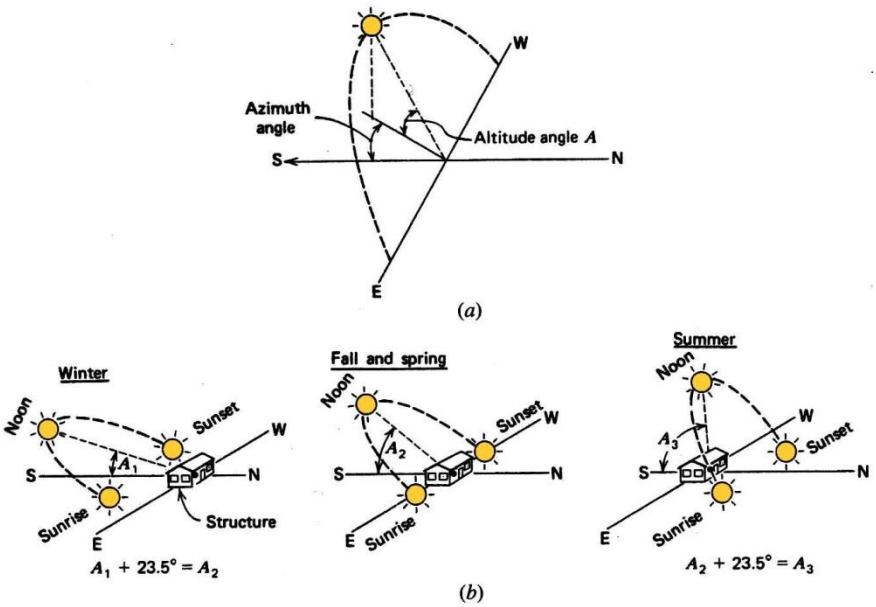


Figure 5.10. (a) The position of the Sun is expressed in terms of the vertical angle above the horizon (altitude) and the horizontal angle (azimuth). (b) Approximate position of the Sun in each of the seasons at a mid-northern latitude. Note that the altitude angle is maximum in the summer, minimum in the winter, and in between in spring and fall (Stein, et al. 2006:151).

The ecliptic is the apparent path of the Sun across the sky. The axis of rotation of the Earth forms, with the perpendicular to the plane of the ecliptic, an angle of 23.5 °. As a result of that inclination, during the Summer Solstice in the Northern Hemisphere, solar rays fall perpendicular to the Tropic of Cancer, located at 23.5 ° North of Equator. Conversely, during the Winter Solstice in the Northern Hemisphere, Sun rays fall perpendicular on the Tropic of Capricorn, located at 23.5 ° South of Equator. This variation in the inclination of the solar rays on the surface of the Earth causes the cyclic changes of season (Aveni 2001:55-58) (Figure 5.10).

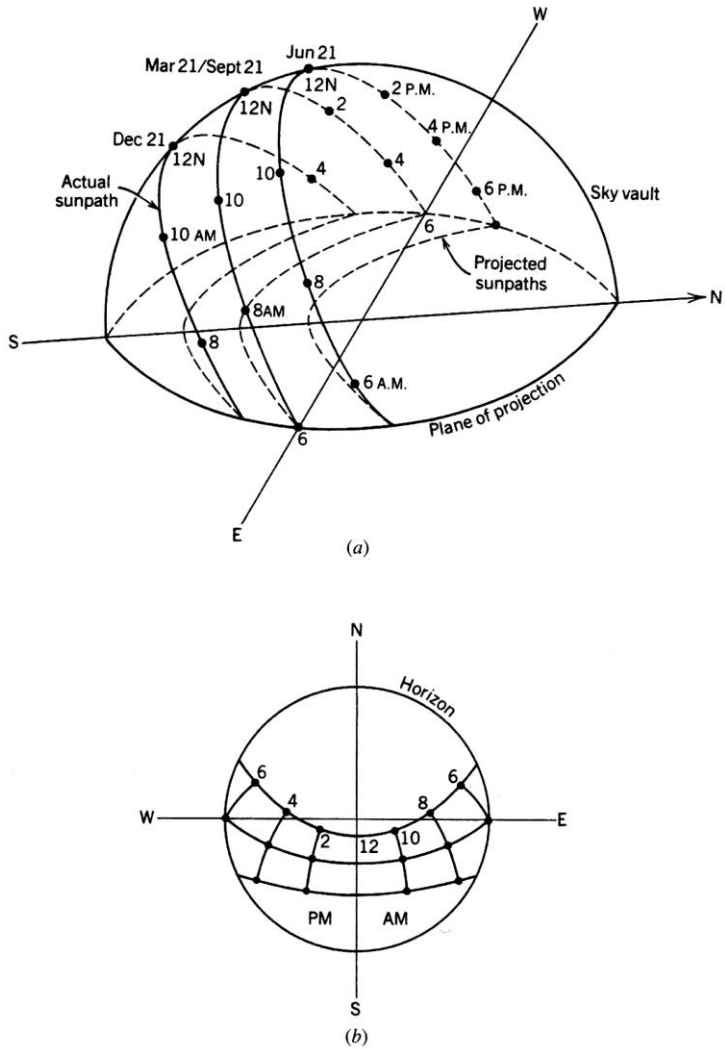


Figure 5.11. (a) The sky vault is represented as a hemisphere, which projects as a circle (b) on a projection plane. The exact shape of the Sun path chart depends upon the projection method. The hour points of the Sun path chart are connected to form hour lines that are useful for interpolation (Stein, et al. 2006:154).

Since there is historical and archaeological evidence that certain dates were considered in urban and architectural planning, charting the movement of the Sun during solstices, equinoxes and zenith passages is part of the study of Aztec architecture (Figure 5.11 This can be achieved through the utilization of Sun path calculations, Sun path charts (Figure 5.12) and topographical maps.

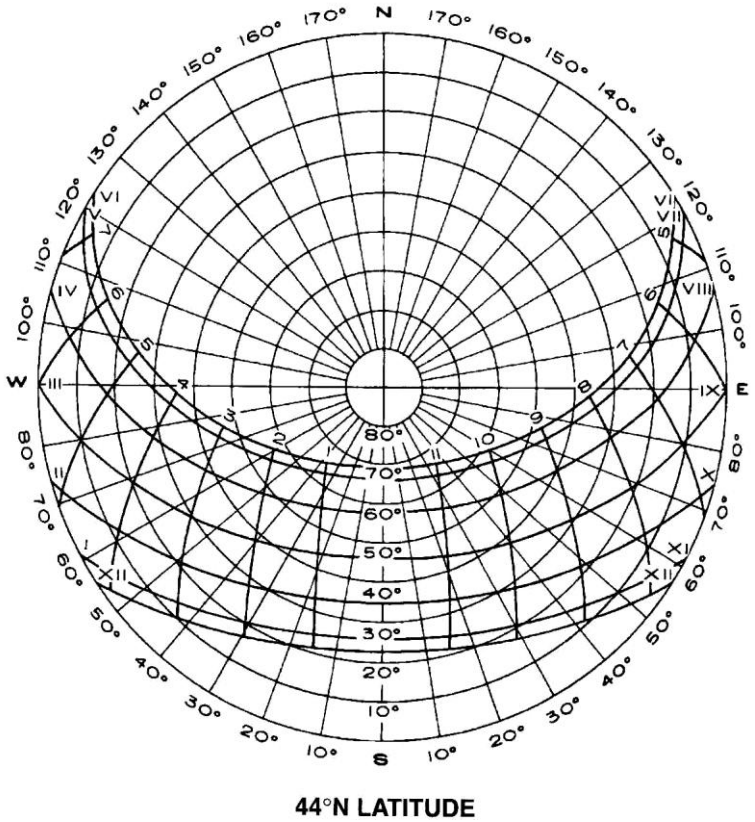


Figure 5.12. Equidistant (horizontal, polar) Sun path diagram for 44 degrees latitude (Stein, et al. 2006:156).

5.3 Aztec Mathematics

Ethno-historical records reveal that the Aztecs devised complex numerical systems that were not only utilized for calendrical and economic purposes (Payne and Closs 1986:214), but also for recording measurements and calculating the areas of houses, fields and streets (Harvey and Williams 1980:499; Williams and Jorge 2008:72). These systems used both picture symbols and lines and dots for numerical notation, incorporated a symbol for zero and used position to ascribe values.

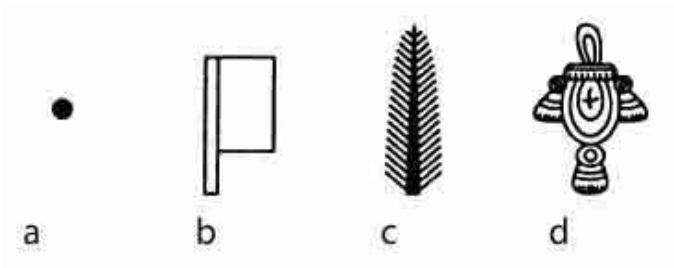


Figure 5.13. Aztec numerals(a) 1; (b) 20; (c) 400; (d) 8000 (Closs 2008:Figure1).

As elsewhere in Mesoamerica, the Aztec numerical system was base 20, *cem-poalli*, literally translated "one count." The next place in the system is 20^2 or 400 (*cen-tzontli*), literally translated "one hairs." The largest place denoted by a special term is 20^3 or 8000 (*ce-xiquipilli*), literally "one bag." (Harvey and Williams 1980:499) (Figure 5.13).

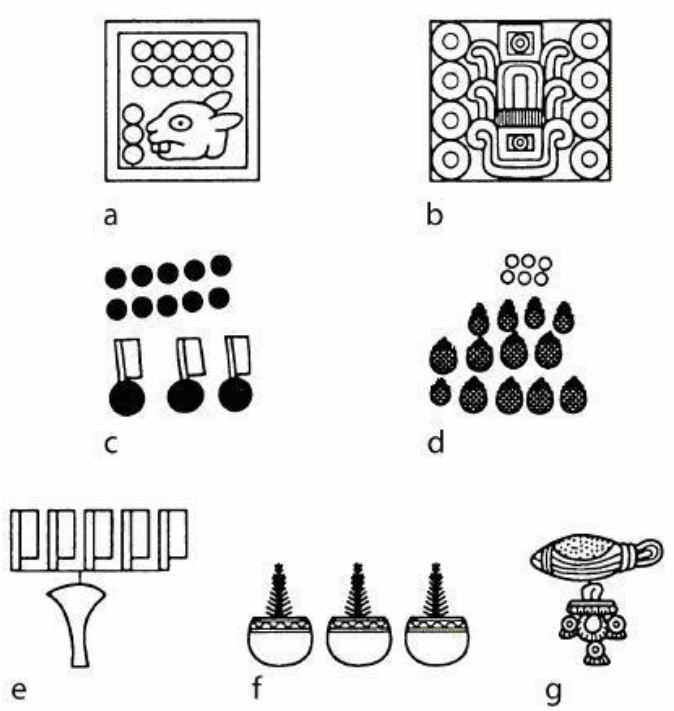


Figure 5.14. Contexts of Aztec numeral usage. Calendar dates: (a) 13 Rabbit; (b) 8 Reed. Chronological counts: (c) 70 years; (d) 5206 years. Tribute records: (e) 100 copper hatchets; (f) 1200 coarse clay pots; (g) 8000 balls of unrefined copal wrapped in palm leaves (Closs 2008:Figure2).

The integers between places are quantities to be added or multiplied. Thus, integers from 1 to 19 were represented by the appropriate number of dots or circles. The numeral 1 was represented by a single dot or a finger; 2, 3, and 4 were represented by two, three, and four dots, respectively; 5

was represented by five dots or a full bar; 6 through 9, by dots alone or a combination of dots and a bar; 10 was represented by ten dots, two bars or a rhombus. The integers between 10 and 20 were represented as a combination of dots, bars and a rhombus.

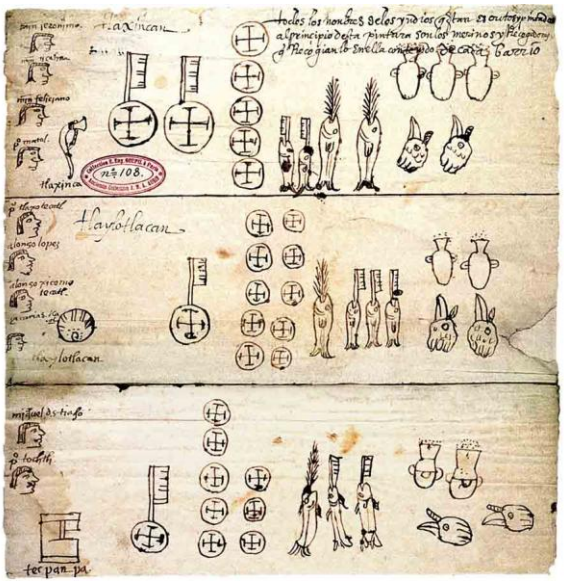


Figure 5.15. Tributes of Tlaxinican, Tlaylotlacan, Tecpanpa, etc. depicting number—represented by symbols on above objects—coins, fish, and waterfowl paid as tribute to Colonial authorities (*Archivo General de la Nación de México* ,CC-BY-NC-SA 4.0).

Similarly, multiples of 20 but less than 400 were represented by repeating the symbol of 20 as many times as necessary; integers between 400 and 8000 were repeated to form multiples of 400 and multiples of 8000 respectively (Closs 1368). This progression continued until the number 64000000 (8000 x 8000), a sufficient count to respond to the needs of the Aztec (Figure 5.14). The order of the terms followed a rigorous, logical and scientific progression which enabled them to compute large sums, especially when they were dealing with matters involving tribute pay (Aguilar 2007:314) (Figure 5.15).

Aztec numerals are found in several contexts, most commonly as coefficients in calendar dates, chronological counts and tribute records that consisted of lists in which the quantities of the various tribute items to be received from conquered towns were recorded (Closs 2008:1369). However, these numerals were found during the course of this research in several land titles and administrative documents as illustrated in Figure 5.16.

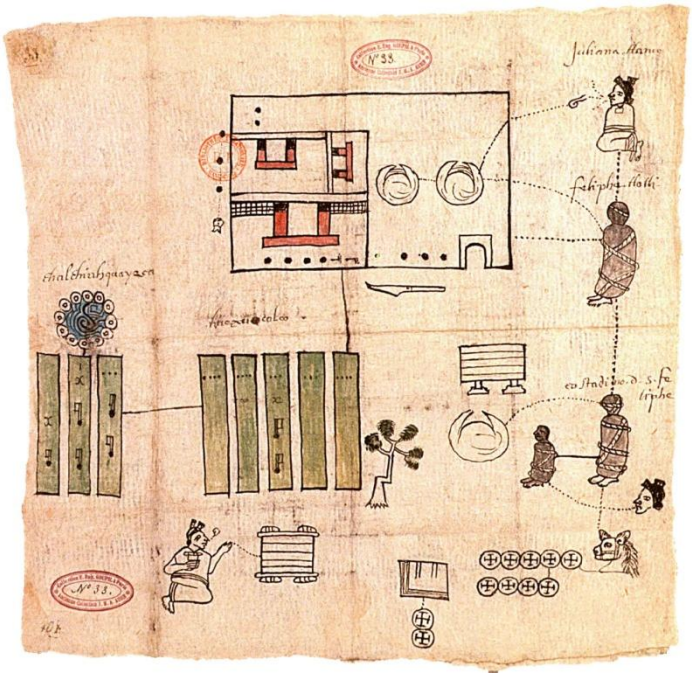


Figure 5.16. Plan and title of a property in Huexocolco, depicting measurements—represented by dots around the perimeter—of house and *chinampas* (*Archivo General de la Nación de México* ,CC-BY-NC-SA 4.0).

5.3.1 Linear Measuring System

In addition to picture-symbols, Aztecs used a positional line-and-dot system for recording the measurements of perimeters and areas of land holdings in at least two locations in the Valley of Mexico in Tepetlaoztoc. This system, contained in the Codex Santa Mara Asunción and the codex Vergara, employed only three symbols that were easy to draw: a vertical line, a bundle of five lines linked at the top and a corn glyph (*cintli*) with position indicating the value of the symbols (Figure 5.17). Harvey and Williams have noted that this system would seem to be more applicable and well-suited in general for arithmetic calculations (Harvey and Williams 1980:99).

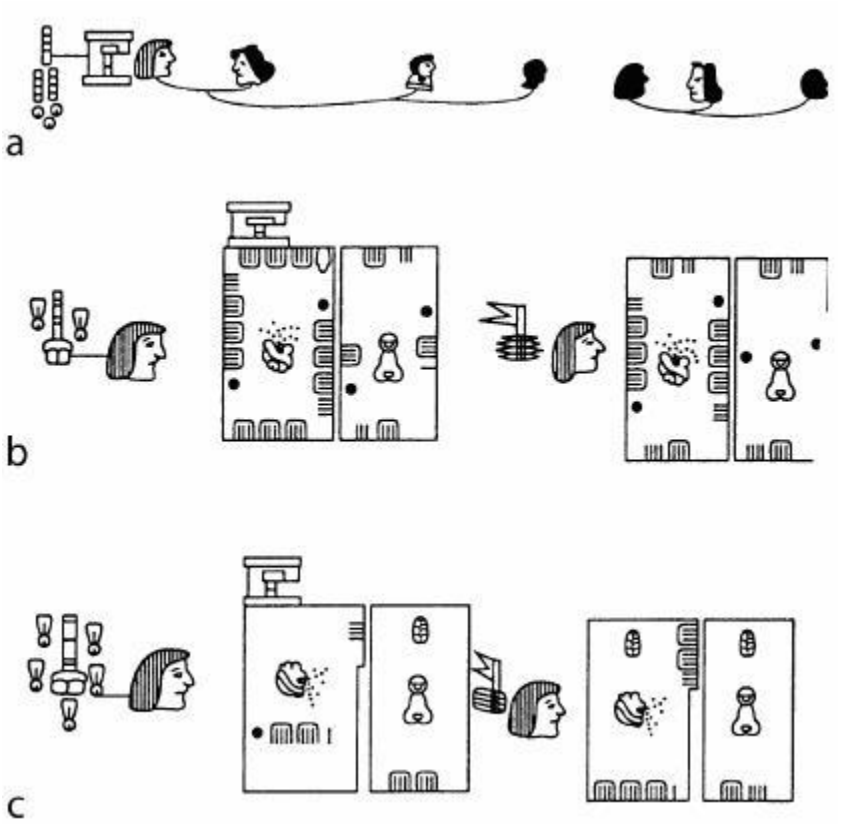


Figure 5.17. A land record from the codex Santa María Asunción (Harvey and Williams 1980:Figure 1).

Williams and Jorge revised the algorithms present in 408 quadrilateral fields of all five Codex Vergara localities and discovered "evidence for the use of congruence principles, based on proportions between the standard linear Acolhua measure and their units of shorter length" (Figure 5.18). This procedure substitutes for computation with fractions and is labeled "Acolhua congruence arithmetic." The findings also clarify variance between Acolhua and Tenochca linear units, long an issue in understanding Aztec metrology (Williams and Jorge 2008:72). An example of the application of these fractional units can be seen in the plan of the *House of Ana Justina, San Hipólito Teocatilan District*, where the measurements of the property are represented by hands, hearts and arrows glyphs (Figure 5.19).

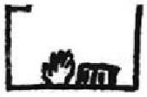
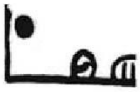
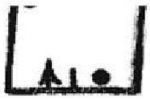
Monad glyphs in Acolhua land documents	Glosses Nahuatl	Proportion of monads to standard "land rods" (T)	Fractional equivalent of (T)	Metric equivalent (1T equals 2.5 m)
	Cemmatl one hand	5 : 3	3 / 5	1.5 m
	Cenyollotli one heart	5 : 2	2 / 5	1.0 m
	Cemomitl one bone	5 : 1	1 / 5	0.5 m
	Cemacolli one arm	3 : 1	1 / 3	0.83 m
	Cemmitl one arrow	2 : 1	1 / 2	1.25 m

Figure 5.18. Acolhua equivalences inferred from computation of Acolhua recorded areas. The hand, heart and arrow are referents for proportions 5:3, 5:2 and 2; the bone and arm are tentatively proposed glyphic referents for proportions 5:1 and 3:1 (Williams and Jorge 2008:Figure 2).

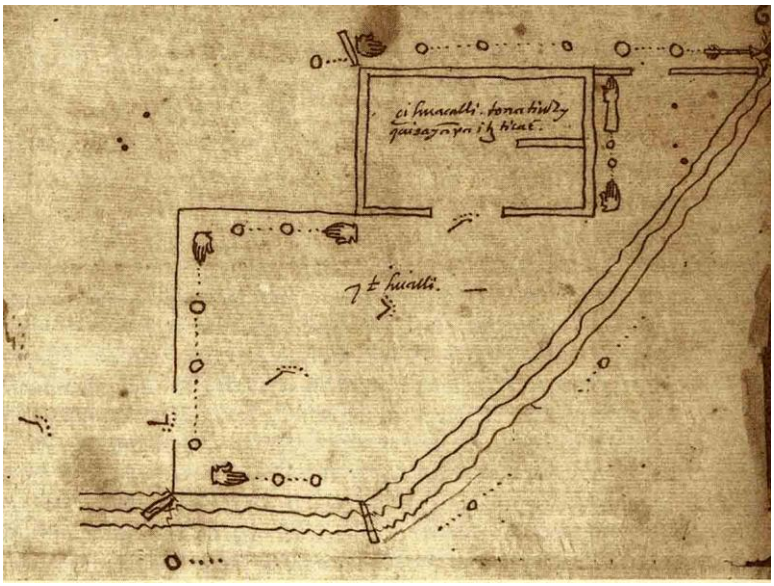


Figure 5.19. Measurements of property in hands, hearts and arrows, *House of Ana Justina, San Hipólito Teocatilan District,* 1593 (*Archivo General de la Nación de México* ,CC-BY-NC-SA 4.0).

In 2010, Clark refined and tested Aztec linear measurements in two Aztec palaces and applied them to the ceremonial precinct of Tenochtitlan. Similar to Sugiyama in Teotihuacan, he found

that the precinct was built according to the dimensions of sacred time that utilized Aztec linear measurement units. Based on research done by Castillo (1972), Molina (1977) and Williams and Harvey (1997), Clark affirms that Aztec linear measurements were calibrated to the human body (Figure 5.20). This is similar to the Spanish system as both utilized various arm measures.

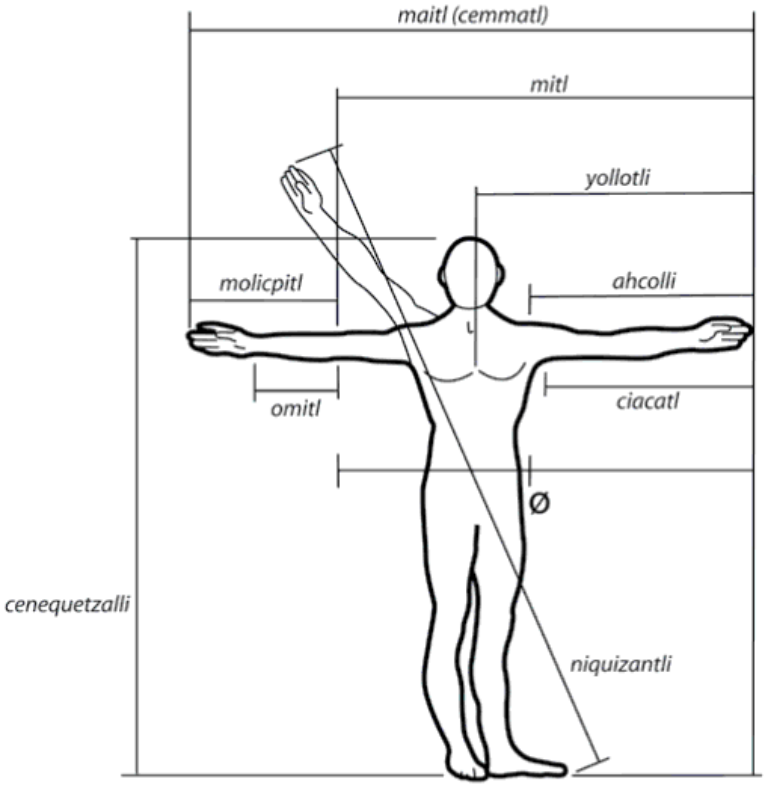


Figure 5.20. Aztec units of measure and their body referents (Clark 2010:Figure 12.1).

The *maitl* (hand) was the measure between the outstretched hands, the yollotli (heart) the measure from the centre of the chest to an outstretched hand. Utilizing the Aztec units, and correlating them to Spanish linear units (83.5905, the Castilian *vara* of Burgos), Clark developed a series of equivalencies between Aztec linear measures and their metric values (Figure 5.21).

Unit	Description*	Length
matlacicxitla	*maltacicxitlatamachiualoni* 'measure of 10 feet' (S:258)	2.786 m
maitlneuitzantli	3 varas	2.508 m
tlalquahuitl	'wooden measuring rod' (S:604), 3 varas	2.508 m
niquizantli	vertical braza, 2.5 varas	2.090 m
maitl	'hand' (S:250); horizontal braza, 2 varas	1.672 m
cenequeztzalli	'stature' (S:83), height of a man	1.60 m
mitl	'arrow, dart' (S:14, 80; M:57), 1.5 varas	1.254 m
yollotli	'heart' (S:199), 1 vara	83.59 cm
ahcolli	'shoulder' (S:14)	77.5 cm
ciacatl	'armpit' (S:109)	72.0 cm
tlacxitl	'step' (C:200, 201)	69.65 cm
molicpitl	'elbow' (S:285), ½ vara	41.80 cm
matzotzopaztli	'forearm' (S:263)	38.6 cm
omitl	'bone' (S:357)	33.44 cm
xocpalli	'foot print' (S:777), *tlacxitamachihualoni*, foot length (S:583)	27.86 cm
macpalli	'palm of the hand' (M:51), cuarta, 1/4 vara	20.90 cm
Cenmiztitl	'jeme' (C:220; M:118)	18.0 cm
centlacol icxitl	'half a foot' (S:85)	13.93 cm
mapilli	'finger of the hand' (M:37; S:255)	1.74 cm

Figure 5.21. Aztec linear measures and their metric values (Clark 2010:Table12.1).

An example of the utilization of different units for quantities (probably referring to the number of descendants as this document is a genealogy according to Elías Caracas) and for linear measurements indicating the perimeter of the house can be found the *Títulos de Propiedad de Mexico-Tenochtitlan* (Property titles of Mexico-Tenochtitlan) (Figure 5.22).

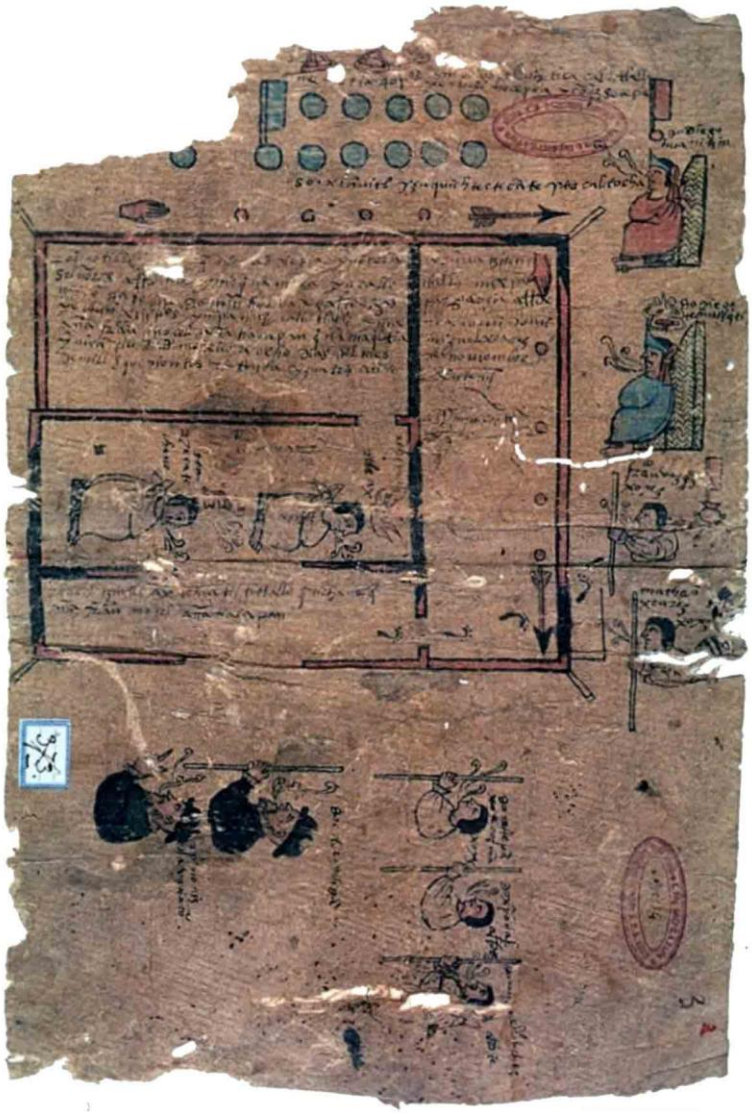


Figure 5.22. Property titles of Tenochtitlan utilizing two types of numeral, one for quantities (blue flag and dots on top) and measurements of house in hands, dots and arrows (*Archivo General de la Nación de México*, CC-BY-NC-SA 4.0).

5.3.2 Angular Measuring System

Tichy postulated an angular measurement unit that resulted from the statistical treatment of directional values in the basins of Central Mexico. He surveyed the axial directions of almost 300 churches, the colonial successors of the temples, and found that they were concentrated around astronomical east-to-south with the clockwise deviation 1-2, 11-12, 16, 20 and 25 degrees (Tichy 1988:106) (Figure 5.23).

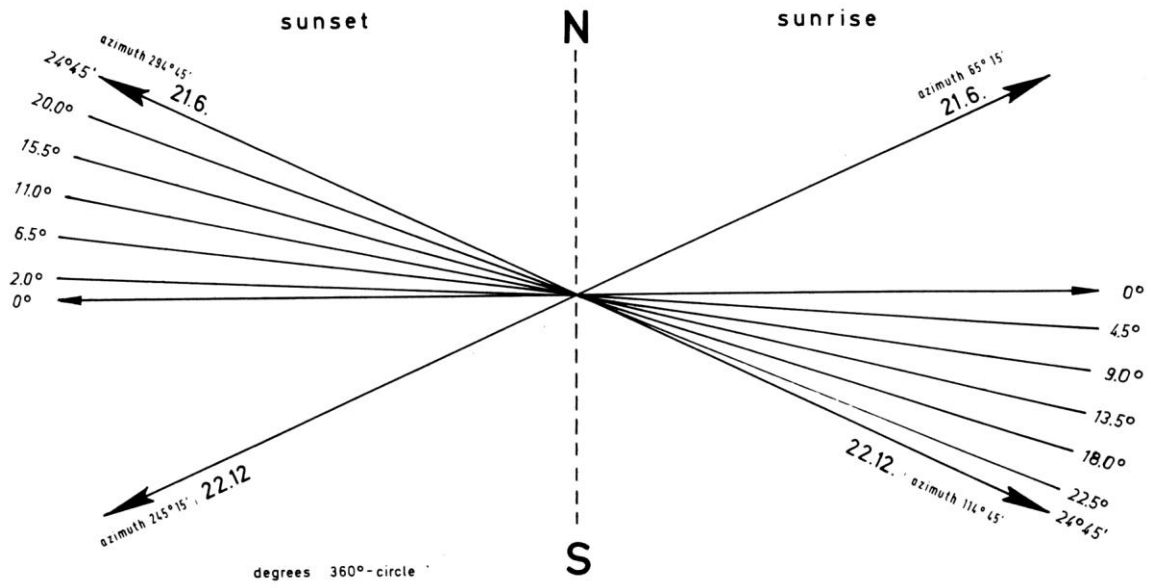


Figure 5.23. Diagram of the Mesoamerican Orientation System. The alignments are in accordance with the hypothetical solar orientation calendar with 13-day weeks. The clockwise deviations from east represent the "winter sunrise Maya type" and the deviations from West, the "Summer Sunset Central Mexico Type" (Tichy 1988:Figure7).

The correlation with the movement of the Sun can be observed in the direction of the solstice (25 degrees), the directions of the sunset on the days of the passage of the Sun through the zenith on 19 degrees N.L., and the midyear days near the equinoxes (1 degree). The 1, 7 and 16 degrees directions are explained by the first days of the periods of 20 days in a hypothetical fixed Sun calendar according to the description of Sahagún for 1564-67. According to Tichy, the basis of these orientations was not simply the calendar, but also a geometric system that consisted of arithmetical angular series with 4.5 degrees intervals (Tichy 1988a:107).

Tichy suggests that this angular measure was taken from the human body, as it was possible to indicate a distance on the horizon using the extended arm with spread fingers (Figure 5.24). With the width of five spread hands, one can cover a right angle, about 18 degrees per hand. In this way, with the outstretched arm, the horizon can be measured with a quarter of an open palm or a twentieth of the right angle, 4.5 degrees (Tichy 1988:106).

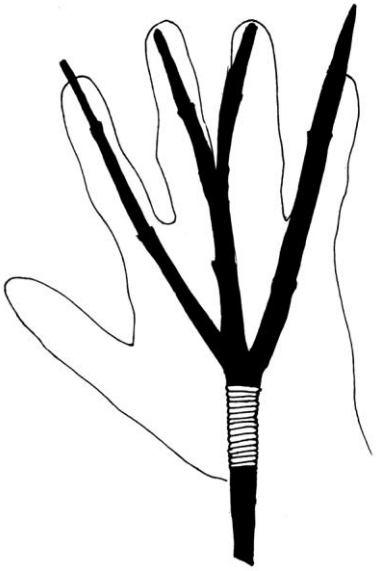


Figure 5.24. Reconstruction of an astronomical device based on an illustration in the Codex Selden that was probably used throughout Mesoamerica. It is the size of a hand with spread fingers and made of a bundle of twigs. When the hand is outstretched, the angle between the two tips, which are 4.3 cm apart, is 4.5 degrees or 1/20th of a right angle (Tichy 1988:Figure 9).

5.4 Aztec Geometry

The first attempt to study Aztec geometry in monumental sculpture was performed by Antonio León in Gama in 1792 when he utilized geometrical figures and measurements to analyze the Coatlicue and Aztec Sun Stone in his essay, *A Historical and Chronological Description of Two Stones which were found in 1790 in the Principal Square of Mexico During the Current Paving Project* (León y Gama 2010:65-76). More than a century later, in 1928 Alfonso Caso tried to investigate the module or unit that was utilized in its construction by measuring the Sun Stone, the Tizoc Stone, and the Quetzalcoatl temple in Xochicalco, and found several geometrical relationships among them. In 1953, Raúl Noriega analyzed the mathematical aspects of the Sun Stone and fifteen other solar monuments. These mathematical studies were continued in 1992 by Oliverio Sanchez, who deduced the construction methods of the geometric figures and the mathematic relationships embedded in the geometry of the Aztec Sun Stone (Ramirez 1995:50-56) (Figure 5.25). In 1995, Ramírez Bautista applied these methods in his analysis of the Sun Stone, the Stone of Tizoc and the Ex-archbishopric's Palace Stone, concluding that the presence of these geometrical principles among solar monuments demonstrated the existence of Aztec geometry (Ramírez 1995:108).

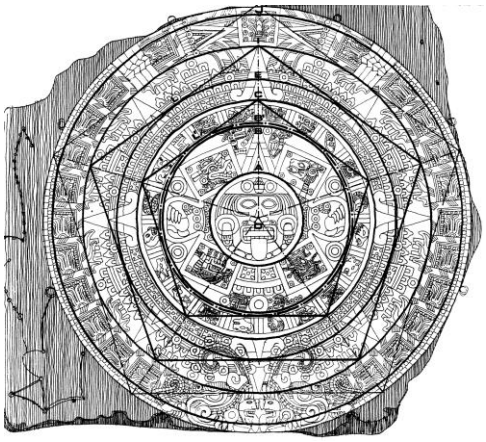


Figure 5.25. The geometric composition deduced by Oliverio Sánchez based in two interrelated pentagons (Ramirez 1995:Figure 16).

In 1996, Rivera applied geometrical and achaeoastronomical principles to the analysis of Aztec architecture. She demonstrated that both the Templo Mayor and the ceremonial precinct of Tenochtitlan had an embedded underlying geometry within their design. Later, in 2000, Martínez, analyzed several examples of Mesoamerican sculpture and architecture utilizing a more systematic geometric approach (Figure 5.26).

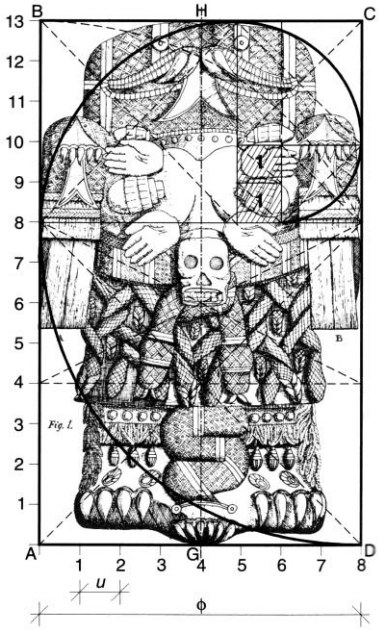


Figure 5.26. Geometric study of the Coatlicue (Martínez 2004:Figure 5.44).

In an urban scale, Sugiyama applied a geometric analysis methodology in his measurement study of Teotihuacan in the 2000s. He not only found direct relationships between the base ratios of the pyramids with the ritual and the solar calendars, but also inferred the measurement unit (Teotihuacan Measurement Unit, TMU=83.0 cm.) that was employed to build the city and its temples (Sugiyama 2010:134) (Figure 5.27).

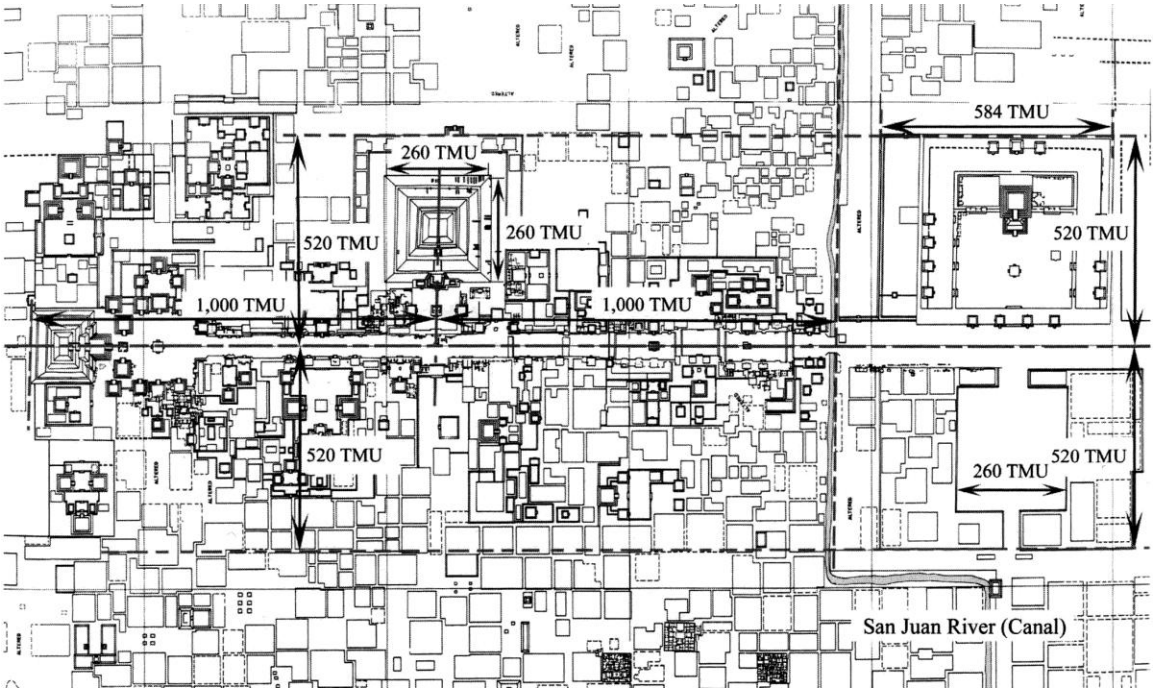


Figure 5.27. Plan of Teotihuacan with possible measured distances indicated in TMU (Sugiyama 2010:Figure 11.3).

Ramírez (1995), Rivera (1996) and Martinez (2010) have demonstrated that Aztec sculpture and architecture utilized several geometric figures either directly on their designs or underlying as regulating lines within their designs. These figures include: circles, triangles, squares, rectangles and several polygons.

5.4.1 Geometric Figures in Aztec Design

5.4.1.1 Circle

The circle, defined as "a plane curve consisting of all points at a given distance called the *radius* from a fixed point called the *centre*," is the geometric figure that contains all the possible regular polygons. It is a figure that does not have a beginning or an end, and with an infinite number of sides, it has been considered a symbol of unity, infinity and divinity in many cultures (Calter 2008:168). Its diameter, which corresponds to the diagonal of the maximum square that can be inscribed into the circle, represents the first division of the unit. Furthermore, the relationship between the circumference (the total length of the circle) and its diameter, generates one of the most important mathematical constants, Pi (π):

$$\pi = \frac{Circumference}{Diameter} = \frac{C}{d} \cong 3.1416\ldots$$

In Aztec culture, the circle represented a cycle as well as a unit in written numerals (Payne and Closs 1986:228). The circle was associated with the Sun, the Moon, Tlaloc and Aztlan, also called *Cemanahuac*, the place in a circle of water which was also in the middle of a lake (Figure 5.28). The Aztecs symbolically referred to the Valley of Mexico, and in general to the world, as *Cemanahuac* or Anahuac (Aguilar 2007:230).

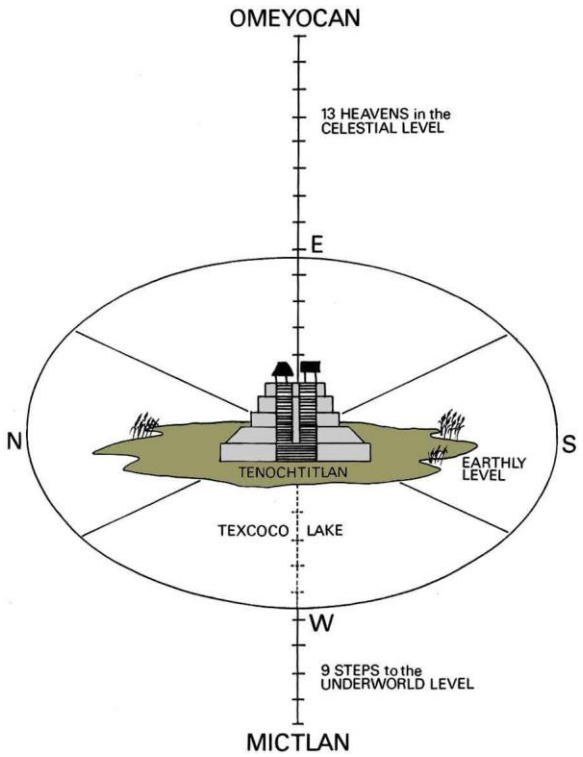


Figure 5.28. Schematic representation of the Aztec worldview (Matos 1988:Figure 107).

5.4.1.2 Polygons

A polygon defined as a "plane figure bounded by straight-line segments which are called the *sides* which intersect at points called the *vertices*," can be primarily classified by the number of sides. Ramírez meticulously identified several underlying polygons — including pentagons (5 sides), hexagons (6 sides), heptagons (7 sides), octagons (8 sides), nonagons (9 sides), hendecagons (11 sides), tridecagons (13 sides), pentadecagons (15 sides) and heptadecagons — on the Aztec Sun Stone, the Tizoc Stone and the ex-Archbishopric's Palace stone that required an advanced knowledge of geometry (Ramirez 1995:87-100) (Figure 5.29).

Figure 5.29. Underlying polygons in the Aztec Sun stone (Ramírez 1995:Figure 29).

5.4.1.3 Triangles

The triangle or trigon, defined as a "polygon with three vertices and three sides" (Calter 2008:67), is an integral part of the design in Aztec solar monuments. Isosceles triangles are always placed in on equidistant points along the main circle and an underlying octagon. Superimposed equilateral triangles are circumscribed within the circle to form the four segments of the ollin symbol on the Aztec Sun Stone (Ramírez 1995:96) (Figure 5.30).

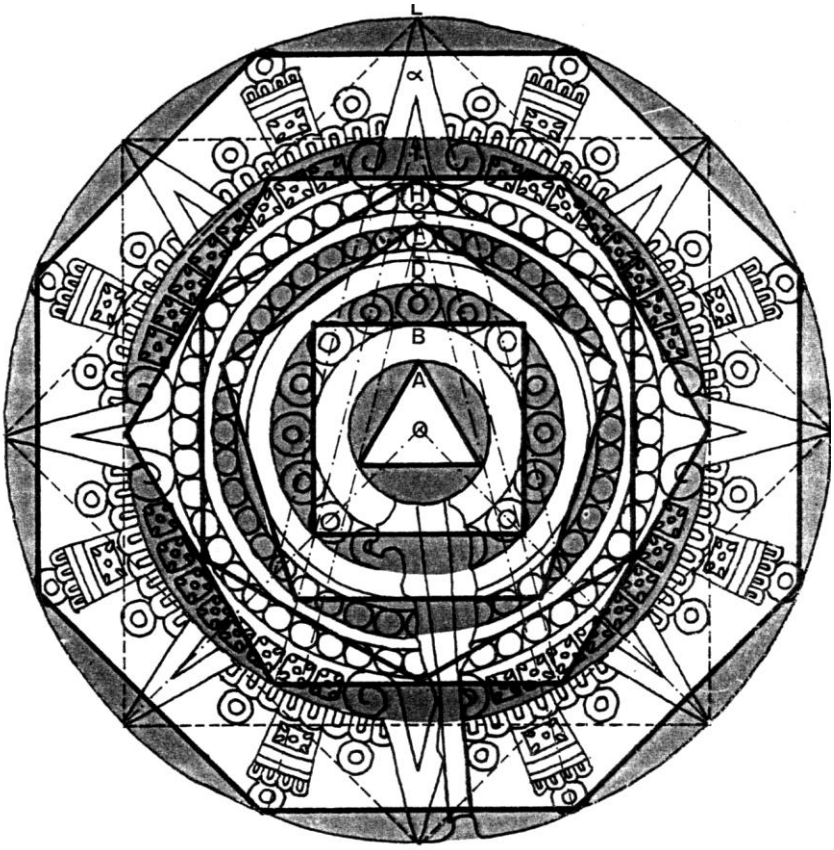


Figure 5.30. Superimposed isosceles triangles in the Tizoc Stone (Ramírez 1995: 95).

5.4.1.4 Square and Rectangles

The square defined as a "polygon with four equal right angles (90°) and four equal sides," derives directly from the circle when two of its perpendicular diameters turn into diagonals of the maximum square that can be inscribed within it. An infinite number of rectangles can be derived by the diagonal of the square, producing a root rectangle, defined as a rectangle with an irrational number as the ratio of length to width: $\sqrt{2}$, $\sqrt{3}$, $\sqrt{5}$, … (Calter 2008:98). Even though squares are present within the underlying geometries of Aztec solar monuments, Martínez argues that the most common figure utilized in architecture was the rectangle, that she has named the Σ rectangle 7x8 (2000:26-56).

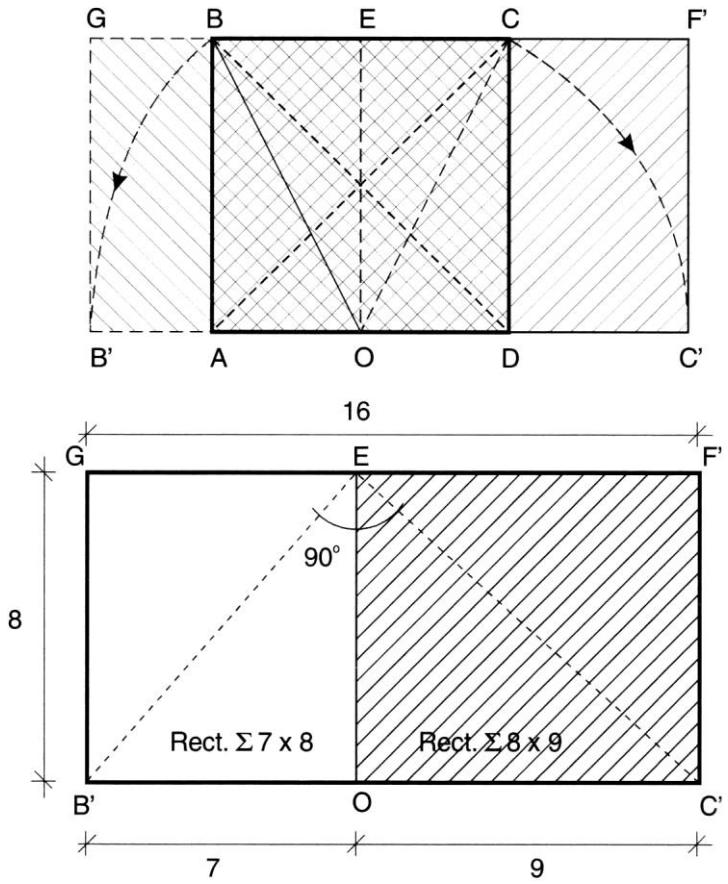


Figure 5.31. Σ rectangle 7 x 8 (Martinez 2000:Figures 2.6 and 2.7).

She defines a Σ rectangle as a square in which a unit has been added (or removed) to its two parallel sides, which is to say that the difference between a square and the Σ rectangle is another rectangle that has the unit as its base and the height of the square. The resulting rectangle is a unit-rectangle. Consequently, the *design unit* of the Σ rectangle is the difference between the lengths of its sides (Figure 5.31).

Martínez and Sugiyama have found the Σ rectangle in three pyramids in Teotihuacan (Sugiyama 2010:133) (Figure 5.32), Chichen Itzá and in the trapezoidal base represented on the first page of Codex Fejérváry Mayer.

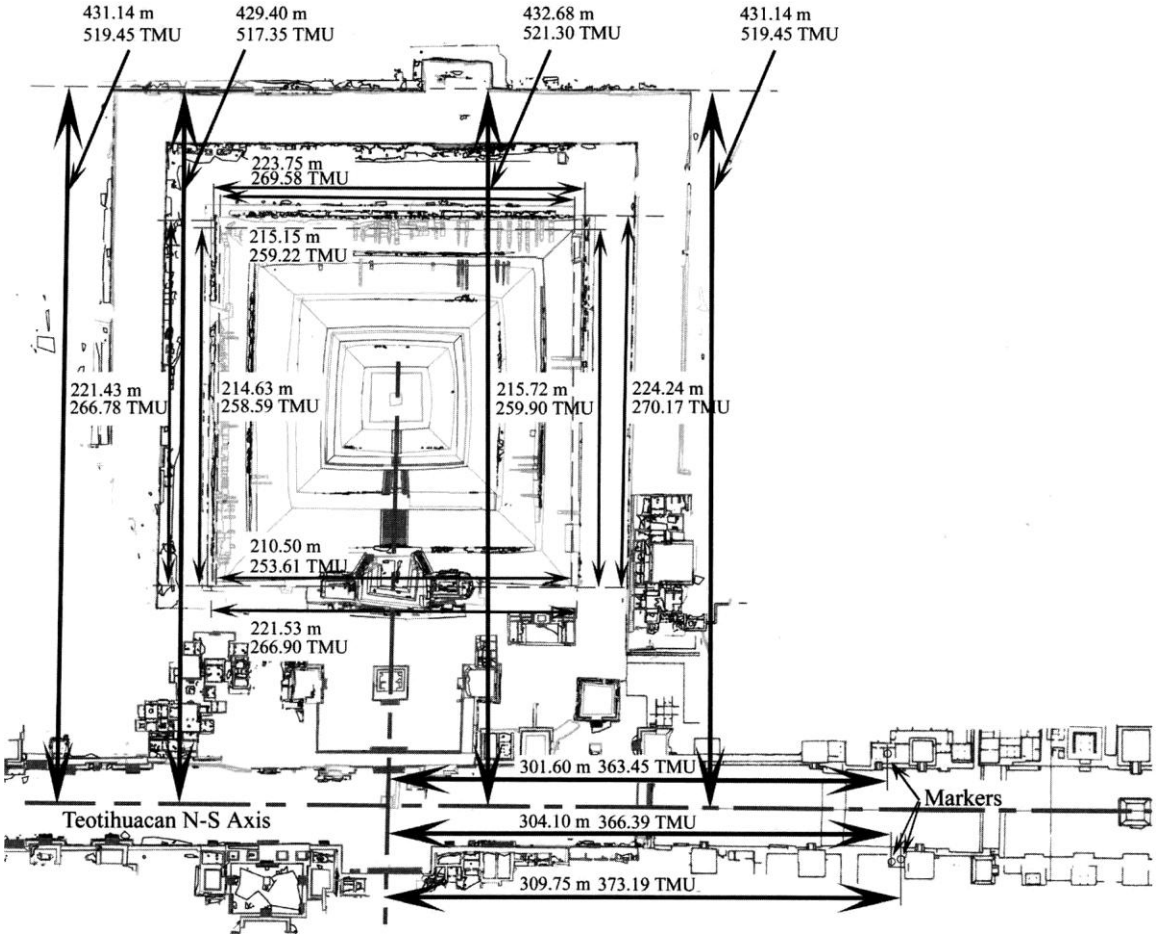
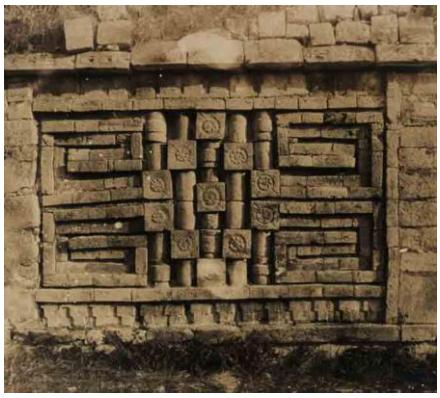
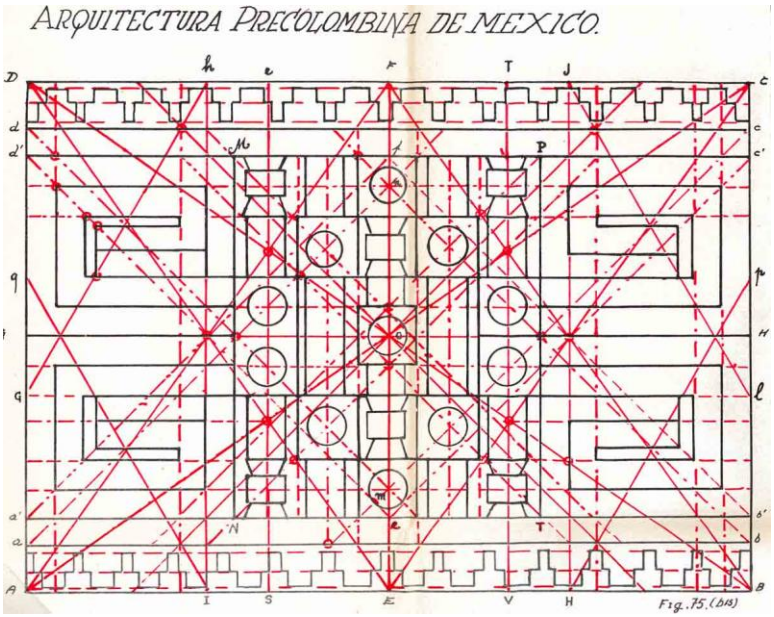


Figure 5.32. Plan of the Sun Pyramid complex with the Avenue of the Dead with measurements in meters and TMU (Sugiyama 2010:Figure 11.5).

In architecture, some architectural aspects and sculptural panels of pre-Columbian structures (particularly Mayan), were analyzed by Manuel Amábilis in 1929 (Figure 5.33). Despite the interest that his work aroused at that time, it is possible that his research was not widely publicized due to his strained relationship with Ignacio Marquina after Amábilis won the Gold Medal in the contest of the Royal Academy of Fine Arts of San Fernando in Madrid, in which Marquina had also participated with his work *Estudio Arquitectónico Comparativo de los Monumentos Arqueológicos de México*.



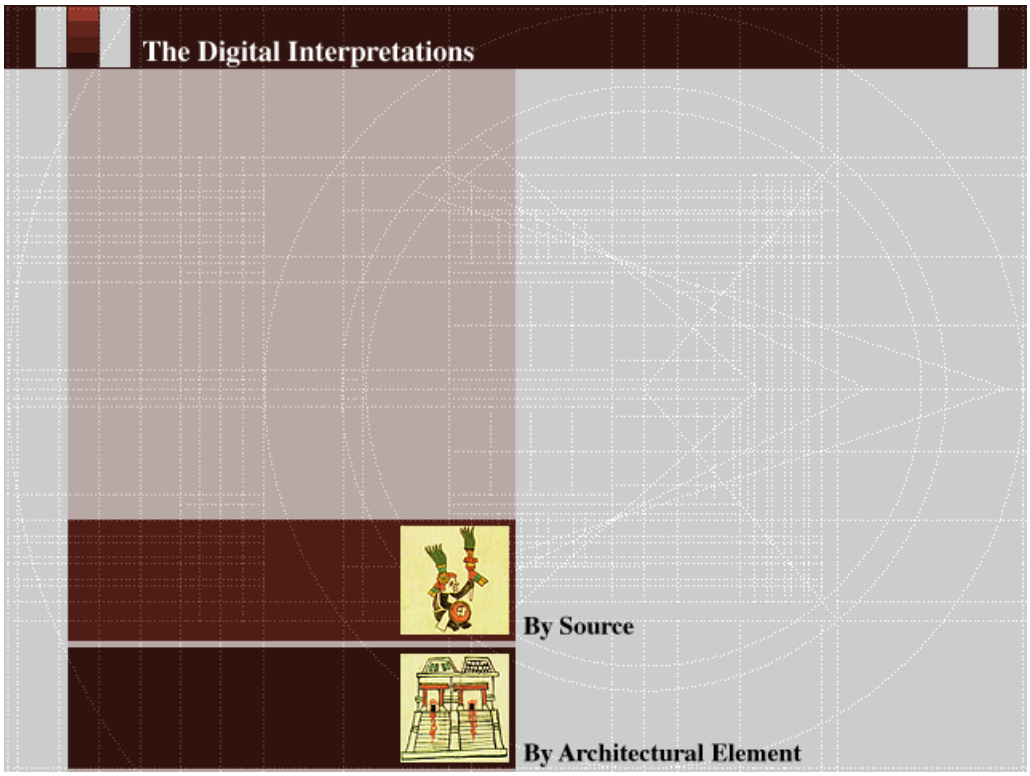


(a) (b)

Figure 5.33. (a) Stone panel on wall of the Monjas complex at Chichen Itza, (b) Geometric analysis of panel (Amábilis 1956:Figure 75).

Even though this mathematical and geometrical knowledge is not recorded in historical sources, its presence is evident in sculpture and architecture. Considering that it would not have been possible to sculpt precise designs on the Aztec Sun stone as Ramírez has demonstrated or layout Teotihuacan, a city of 125 000 people, as Sugiyama has discovered, without applying mathematics and geometry, it can be suggested that the Aztecs must have utilized this knowledge in architecture and urban planning

In 1996, Rivera examined the ceremonial precinct of Tenochtitlan utilizing geometrical in conjunction with achaeoastronomical principles from an architectural point of view. Her studies revealed an underlying geometry that established relationships of the main buildings and secondary precincts with the Great Temple (Figure 5.34).



(a)

(b)

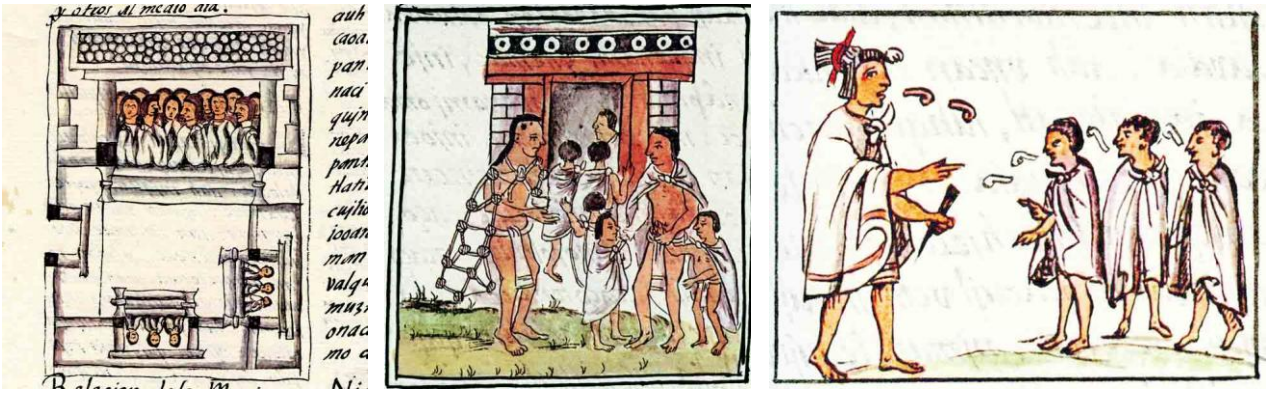
Figure 5.34. Digital interpretation of the ceremonial precinct of Tenochtitlan based on the geometric and archaeoastronomical analyses performed in the urban arrangement and each architectural type; (a) regulating lines of the Huey Teocalli; (b) digital interpretation with structures found in both ethno-historical sources and archaeological records (Rivera 1996).

After Rivera, Martínez has been the only scholar to address Mesoamerican geometry. However, Sobral has mostly concentrated on small scale sculpture and two buildings: the pyramid of the Sun in Teotihuacan and the Castillo in Chichen Itzá. Coupled with this, architectural design research is an emerging research field that began to be recognized in 1996 when Mario Salvadori presented his paper "Can There be any Relationships Between Architecture and Mathematics?" at the *Nexus-Architecture and Mathematics* conference in Fuceccio, Italy (Salvadori 1996:10).

Furthermore, the inclusion in these analyses of Mesoamerican measurement systems has only been explored by Rivera in the Huey Teocalli (1996), by Sugiyama in Teotihuacan (2005, 2010), and by Clark in the Oztoticpac palace and the precinct of Tenochtitlan (2010). These scholars have just opened a field of study within architectural design and archaeology that promises to be quite fertile due to the rich Mesoamerican built heritage.

5.5 Aztec Building Practice

In addition to possessing sophisticated astronomical, mathematical and geometric knowledge to layout urban centres and architectural forms, the Aztecs also had a complex building practice that involved highly skilled craftsmen, construction materials and specialized tools. These craftsmen were organized in *calpulli*, a basic structural unit of Aztec society composed of a group of commoners (usually kin groups) who held land in common and were also dedicated to the same socio-economic activity such as farming, practicing the same craft and trading (León Portilla 137). Each *calpulli* had a *Telpochcalli*, where sons of commoners were taught religion, military skills and a craft or trade, while sons of the nobility attended the *Calmecac*, where priests taught them religion, mythology, history, calendrics, writing, engineering and law, along with thorough military training (Figure 5.35). Students educated and disciplined in the calmecac were competent to fill leadership and important public posts (López Austin and López Lujan 2001:221-223).



(a) (b) (c)

Figure 5.35. (a) A calpulli, (b) Parents delivering their sons to the Calmecac, (c) Calmecac priest addressing students, Florentine Codex, Books 2, 3, and 2 respectively (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0).

Even though there is no direct mention in historical sources of a calpulli of builders, Sahagún describes several building types (Figure 5.36) as well as trades related to building practice such as carpenters, stonemasons and plasterers. These trades undoubtedly worked with painters and sculptors as architectural expression and sculptural work were related in their formal and spatial expression in many cultures throughout Mesoamerica, including Aztec.

This relationship between the Aztec architecture and cosmovision was reaffirmed in 1978 when the Coyolxauhqui stone was discovered accidentally while a group of workers opened a trench to place wires in the center of Mexico City. Matos recounts, "… from the moment when the sculpture was fully excavated, we realized that it was a dismembered female figure that could only match the Coyolxauhqui. This raised the possibility of finding what for nearly 200 years we had eagerly sought from the time that Coatlicue, mother of the gods, was discovered in 1790… the Great Temple of Tenochtitlan" (Matos 1981:106-107). This discovery marked a new era of Aztec scholarship and provided a fertile area for Aztec architectural research.

The Coyolxauhqui stone, snake heads attached to the balustrades of the stairs, and other sculptures found in several building stages of the Templo Mayor, strengthened the relationship between sculpture and architecture. Furthermore, the overall construction of the buildings excavated in the site, the foundations, vestiges of floors and other engineering and architectural details revealed how different trades like carpenters, stonemasons, bricklayers and painters had

to work together with "wise men" [architects and engineers] to build the ceremonial precinct of Tenochtitlan.

Figure 5.36. ***"De los diferentes edificios"*** **("About the different buildings"); a double teocalli depicted on the left, and a tradesman building the teocalli on the right, Florentine Codex, folios 240r and 241v** ***(Biblioteca Medicea Laurenziana, Firenze*****, CC-BY-NC-SA 4.0).**

5.5.1 Construction Trades and Architect

In Chapter 8, Book 10, "About other skilled workers such as carpenters and masons," Sahagún gave a detailed description of these trades, which are illustrated in some cases:

> ***Carpenter*** [28]
>
> The carpenter, his job is to do the following: cutting with ax, splitting beams, making pieces; sawing, cutting branches of trees, and splitting pieces from any tree. The good carpenter usually measures wood and lays it with a level; and adjusts it with the joiner so that it goes straight; he levels, matches, matches, fits it with other pieces, and put the beams in order across the walls; in short, he is skilled in his craft. The bad carpenter ruins what is right, and is neglectful, a cheat and damages the work he is given to do, and in everything he does, he is awkward and careless (Figure 5.37).

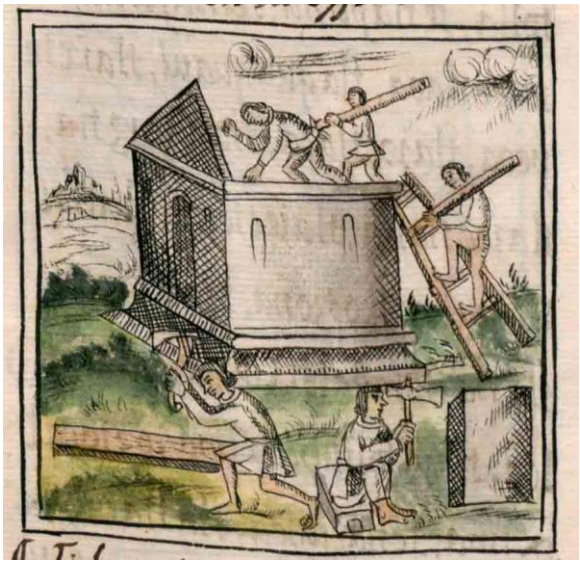


Figure 5.37. The carpenter, Florentine Codex, Book 10, folio 17r (*Biblioteca Medicea Laurenziana, Firenze,* CC-BY-NC-SA 4.0).

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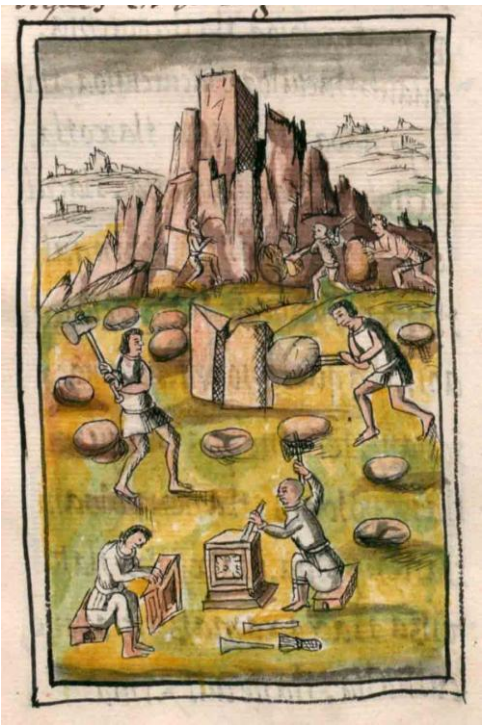
[28] **Carpintero**

El carpintero, es de su oficio hacer lo siguiente cortar con hacha, hender las vigas, y hacer trozos, y aserrar, cortar ramos de árboles, y hender concuñas cualquiera madero. El buen carpintero suele medir, y compasar la madera con nivel, y labrarla con la juntera para que vaya derecha, acepillar, emparejar, entarugar, encajar unas tablas con otras, y poner las vigas en concierto sobre las paredes, al fin ser diestro en su oficio. El mal carpintero desparpaja lo que está bien acepillado, y es descuida-do, tramposo y dañador de la obra que le dan para hacer, y en todo lo que él hace es torpe, y nada curioso. Translated by Rivera.

Stonemason [29]

The stonemason has strength, is vigorous, lightweight and clever, carving and shaping any stone. The good mason is a skilled worker, knowledgeable, proficient working the stone, adjusting corners; and splitting with wedge; making arches; sculpting; and carving the stone in great detail. It is also his job to trace a house;, make a good foundation; add corners; make roofs; well-made windows and partitions. The bad stonemason; is lazy; carves poorly; and does not let the walls harden; makes them crooked; and laying on a side and bulging (Figure 5.38 (a)).



(a)

(b)

Figure 5.38. (a) Several activities performed by stonemasons, Florentine Codex, folio 20v; (b) Mason and assistant preparing sand for plaster, folio 20r *(Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0).

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[29] **Cantero**

El cantero tiene fuerzas, es recio, ligero y diestro en labrar y aderezar cualquiera piedra. El buen cantero es buen oficial, entendido, hábil en labrar la piedra, en desbastar, esquinar, y hender con la cuña, hacer arcos, esculpir, y labrar la piedra artificiosamente. También es su oficio trazar una casa, hacer buenos cimientos, poner esquinas, hacer portadas, y ventanas bien hechas, y poner tabiques en su lugar. El mal cantero, es flojo, labra mal, y en el hacer de las paredes no las fragua: las hace torcidas, y acostadas a una parte, y corcovadas. Translated by Rivera.

Mason [30]

The work of the mason is making mixture well and plastering surfaces with lime; leveling and polishing them well. The bad craftsman is clumsy; his whitewash is reckless, not smooth; but with holes, rough and uneven (Figure 5.38 (b)).

Painter [31]

The work of the painter is using his craft to know colors and draw, or making drawings with coal; and making very good mix of colors; and knowing how to grind and mix them well. The good painter has good hand and grace in painting; and thinks about what he has to paint; mixes and blends the paint well; and knows how to make shadows and foliage. The bad painter has a wicked and silly wit; which makes him annoying; and does not fulfill the expectations of those who give him the work, does not give luster to his paintings, is confusing, disorganized and without proportion and done in a hurry (Figure 5.39).

Figure 5.39. Female painter, Codex Telleriano-Remensis, lower left corner of folio v (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0).

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[30] **Albañil**

El albañil tiene por oficio hacer mezcla mojándola bien, y echar tortas de cal, aplanarla y bruñirla bien. Él mal albañil por ser inhábil, lo que encala es atolondrado, ni es liso, sino hoyoso, áspero y tuerto. Translated by Rivera.

[31] **Pintor**

El pintor es de su oficio saber usar de colores y dibujar, o señalar las imágenes con carbón, y hacer muy buena mezcla de colores, y saberlas moler muy bien y mezclar. El buen pintor tiene buena mano y gracia en el pintar, y considera muy bien lo que ha de pintar, y matiza muy bien la pintura, y sabe hacer las sombras, y los lejos, y follajes. El mal pintor es de malo, y bobo ingenio, y por esto es penoso, enojoso, y no corresponde á la esperanza del que da la obra, ni da lustre a lo que pinta, y matiza mal, todo va confuso, ni lleva compás, ó proporción lo que pinta, por pintarlo de prisa. Translated by Rivera.

It should be noted that after giving an account of these trades, he describes "wise men" as skilled and knowledgeable, like a "path and guide for others" (Sahagún), characteristics that ideally describe an architect:

> ***Wise men [Architects and Engineers]*** [32]
>
> A wise man is like fire or a large ax, a gleaming mirror polished on both sides, a good example for others; skilled and knowledgeable, and is like a path and guide for others. The good wise man, as a good physician, remedies things well, and gives good advice and instruction, guides and enlightens others, because he is trustworthy and credible, and sensible and accurate in everything. So that things are done well, he gives order and coherence, which satisfies and pleases all; he responds to the desire of those who ask him; he encourages all and assists with his knowledge. The bad wise man is like bad doctor, foolish and lost, friend of the name "wise man" and vain glory; and, for being a fool, he is the cause of many evils and big mistakes, he is dangerous and shameless, deceiver or trickster.

These descriptions portray a complex building execution system that included talented craftsmen and "wise men" (Figure 5.40). Without these, it is difficult to imagine how they could have performed the many urban and architectural works that the Spanish found throughout the Aztec Empire. Moreover, without these indigenous hands, it would not have been possible to construct such a large number of buildings, churches and monasteries during the 16th century (Benítez 1992:20). The art and architecture performed with Indigenous hands and European ideas produced a style of art called *tequitqui*, which is the Indigenous redefinition and reinterpretation of European art and architecture (Aguilar 2007:389). This style found its greatest manifestations in façade reliefs, mural paintings, atrial crosses and sculptures.

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[32] **De los Sabios**

El sabio es como lumbre o hacha grande, espejo luciente y pulido de ambas partes, buen dechado de los otros, entendido y leído; también es como camino y guía para los demás. El buen sabio, como buen médico, remedia bien las cosas, y da buenos consejos y doctrina, conque guía y alumbra a los demás, por ser él de confianza y de crédito, y por ser cabal y fiel en todo; y para que se hagan bien las cosas, da orden y concierto, con lo cual satisface y contenta á todos; respondiendo al deseo esperanza de los que se llegan a él, a todos favorece y ayuda con su saber. El mal sabio es como mal médico, tonto y perdido, amigo del nombre de sabio y de vana gloria, y por ser necio es causa de muchos males y de grandes errores, peligroso y despenador, engañador o embaucador. Translated by Rivera.

(a)

(b)

(c)

Figure 5.40. (a) Strategizing for a battle with a plan of the building they intend to attack, folio 33r (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0); (b) Preparing colours for scribe seen writing on paper, (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0);(c) The people of Xochimilco building a causeway, depicted by several tradesmen, tools (including a measuring cord) and a group of three men receiving instructions from the emperor, Durán, plate 13, chapter 8 (*Biblioteca Nacional de España*, CC-BY-NC-SA 4.0).

"There is no doubt that the astounding craftsmanship that the Spaniards encountered in New Spain was rooted in a very ancient and rich artistic tradition, and thereafter it could never be fully suppressed. The friars, who made themselves responsible for the reconstruction of sacred spaces, therefore used Indian labour to build and adorn the churches and convents of the new Spanish colony (Aguilar 2007:390).

This system was accompanied by materials, tools and construction techniques that are still used today. Materials such as soil, rocks and wood, are still commonly employed, as are tools such as the plumb, water level, ruler, compass, square, trowel, wedge and the lever.

5.5.2 Construction Materials

Construction materials uncovered during the five seasons of Temple Mayor excavations are consistent with the data obtained from 16th-century historical sources. The type of rocks found at the archaeological site include volcanic, basalt andesite and limestone. They are found in widely varying shapes and sizes, meeting a variety of architectural functions (López Luján, Torres and Montúfar 2003:140) (Figure 5.41).

Soil was used primarily as a base material for construction fill of the religious buildings of Tenochtitlan. Whenever the temples were expanded, they required huge volumes of soil mixed with stone just to bury the previous stage. Soil was also used, although to a much lesser extent, as plaster for walls with murals (López Luján, Torres and Montúfar 2003:148).

Lime from limestone and volcanic sand were also essential in the construction the buildings. They were used in the preparation of the plaster and stucco covering the floors, stairs, walls, internal walls, sidewalks and drainage pipes (López Luján, Torres and Montúfar 2003:150).

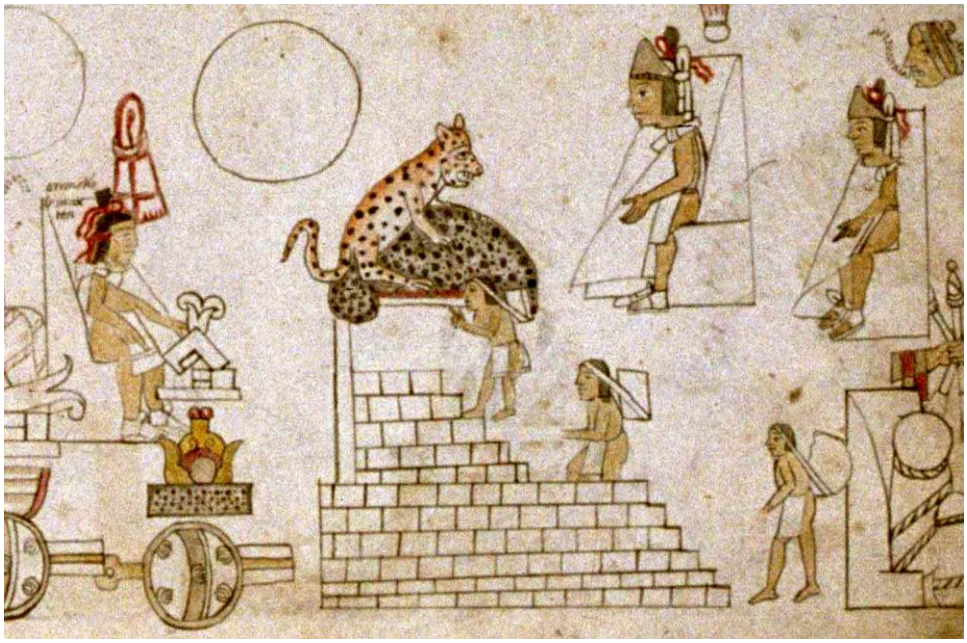


Figure 5.41. Enlargement of a temple in Tlatelolco utilizing several trades and construction materials, Codex Azcatitlan, folio 14 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

As for wood, archaeologists have unearthed numerous foundation pegs in Stage II of the Templo Mayor in the city of Tlatelolco. Other varied uses of wood in construction were recorded by Sahagún. He identifies, among other architectural elements, columns (*cuauhtlayahuallo*), lintels (*calíxcuatl, ilhuicatl*), stakes (*tlaxichtli*), jambs (*tlaquetzalli, tlaquetzamimilli, tlaxílotl*), the planks which are placed between the stone foundation and adobe wall (*cuauhtepánitl*), columns (*cuauhtectli, cuauhmimilli*), beams that rest on walls and support other beams (*cuauhtentli*), planks (*huapalli*), and boards (López Lujan , Torres y Montúfar 2003:152-154).

5.5.3 Construction Tools

Regarding construction tools, Guerra states:

> The Aztec mason (*tlahquilqui*) seems to have used most of the building instruments of the "Old World:" the plumb (*temetztepilolli*), water level (*aztecatl*), ruler (*tlahuahuanaloni*), compasses (*tlayolloanaloni*), square (*tlanacazanimi*), trowel (*tenexzasoloni*), wedge (*tlatilli*), and the lever (*quamniztli*). The stonecutter (*tetlapanqui*) used special axes made of extremely hard stone (Guerra 1969:43) (Figure 5.42).

(a)

(b)

Figure 5.42. (a) Carpenter tools, folio 17r; (b)Stonemason tools, folio 20r[33], (*Biblioteca Medicea Laurenziana, Firenze*, CC-BY-NC-SA 4.0).

These Nahuatl terms were also included in the *Vocabulario en lengua castellana y mexicana y mexicana y castellana* published by Alonso de Molina in 1571. For example, he defines:

> "*Quauhximaloyan*" as a carpenter shop, or a neighborhood [calpulli] of carpenters (Molina f. 87v. col. 2)
>
> "*Quammimilli* "as a round log or wooden column (f. 85r. col. 1.)
>
> "*Tenexzasoloni*" as a mason's trowel or bricklaying tool (f. 99r. col. 2).

[33] Even though metal tools, such as saws, were introduced by the Spanish, similar tools made of obsidian (utilizing the same technique used for weapons) might have been used.

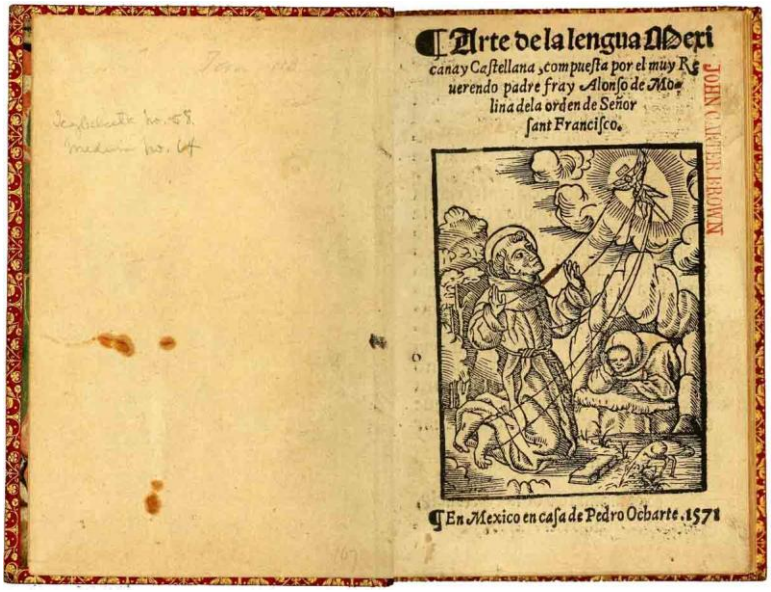
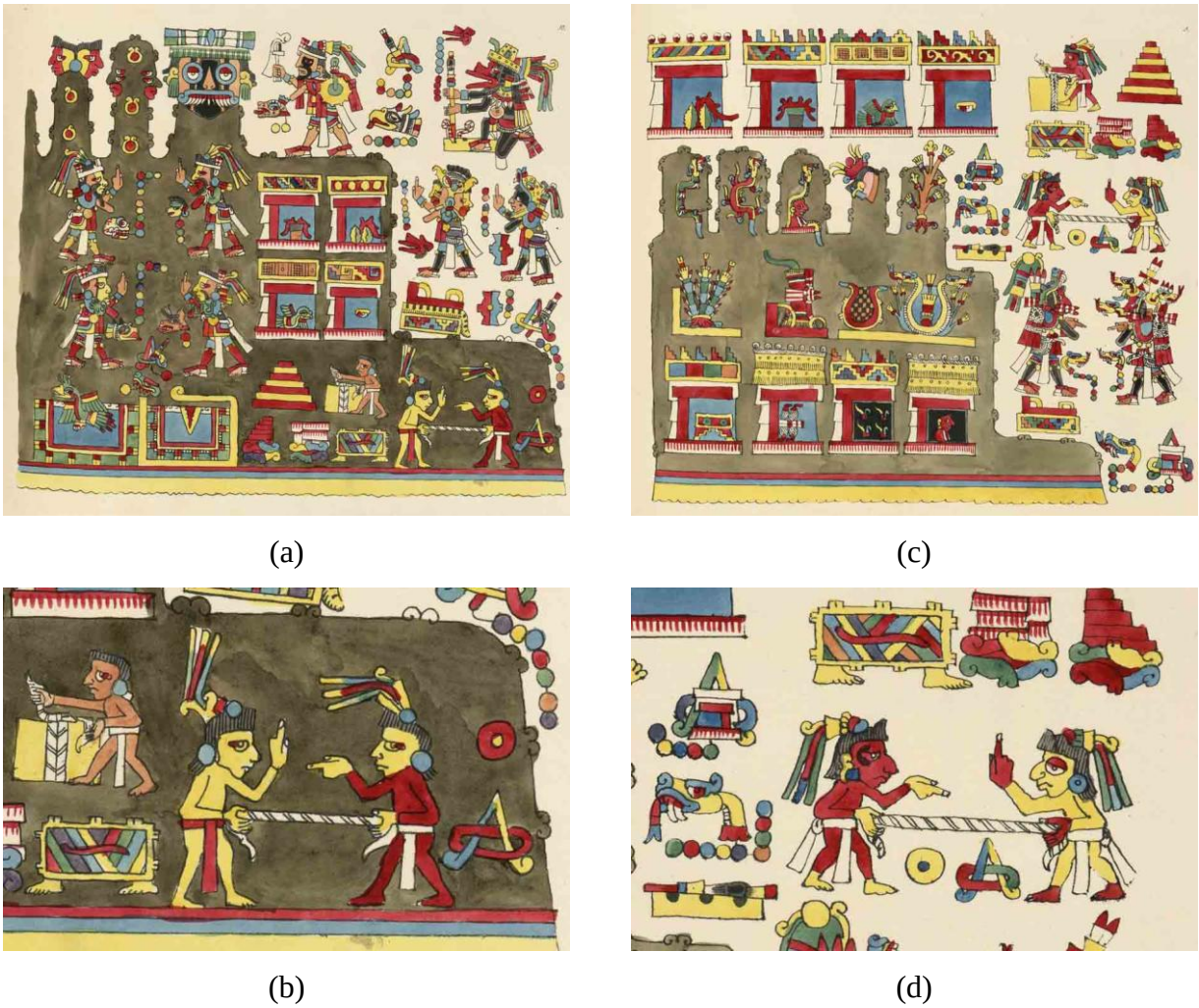


Figure 5.43. ***Arte de la lengua mexicana y castellana*** **published by Alonso de Molina in 1571 (Newberry Library, CC-BY-NC-SA 4.0).**

Finally, there is evidence of the use of a measuring cord before the Spanish arrival. Christopher Powell performed an analysis of the ethnohistoric and ethnographic descriptions of the uses of the measuring cord and interpreted their symbolic significance within architecture. He observed that first the measuring cord was repeatedly used to create sacred space in the ethnohistoric examples. For example, in *Codex Vindobonensis Mexicanus* 1,[34] the measuring cord is used in the creation stage at least ten times. Second, four of the ceremonies from the ethnohistoric accounts and all of the examples from the *Vindobonensis* involving the measuring cord were also depicted within architecture. "In the ethnohistoric accounts, these associations include: performance in courts in front of temples (creating a quincunx or sacred space in front of or near the temple); purification of temples; or refurbishing of temples." Based on these observations, he proposed that the two figures are utilizing the measuring cord to actually lay out sacred architecture (Powell n.d.:14-15) (Figure 5.44).

[34] Probably the codex belonged originally to Lord 4 Deer (Iya Quicuaa), the last pre-Hispanic ruler of Tilantongo, and was presented to the Spaniard conquistadores shortly after their arrival (1519). In 1521, it was already in Europe (Maarten E. R. G. N. Jansen 2006).



(a) (c)

(b) (d)

Figure 5.44. (a) Folio 10 displaying gods, mountains, buildings and figures with measuring cord on lower right; (b) detail of folio 10; (c) Folio 5 displaying gods, mountains, buildings and figures with measuring cord on middle right section; (d) detail of folio 5; all Facsimiles of the *Codex Vindobonensis Mexicanus 1*, Kingsborough Volume II (FAMSI CC-BY-NC-SA 4.0).

5.6 Chapter Summary

This chapter demonstrated how the Aztec knowledge of astronomy, mathematics and geometry was applied to create their horizon reference systems at calendrically significant intervals (Chapter 4) as well as to lay out their urban centres and architectural structures (Chapter 3), since a set of design principles had to be followed to achieve the relationship between the buildings and the landscape. These principles involved charting the movement of the Sun, calculating linear distances, measuring angles and utilizing geometric principles in their designs.

Even though this design knowledge was not specifically described in the ethno-historical sources that survived the Conquest, this information can be inferred from several sources including: pictorial administrative manuscripts (Chapter 2) that have been studied by mathematicians; measurements of the direction of the urban axes of a large number of churches —the colonial successors of temples— that have been surveyed by archaeoastronomers in Central Mexico; and underlying regulating lines in both monumental sculpture and architecture deduced by architects.

Furthermore, a sophisticated design and construction system can also be extracted from ethnohistorical and linguistic sources (Chapter 2). Similar to the contemporary architectural and building practice of contemporary Western civilizations, this building execution system required skilled tradesmen, "wise men" [architects and engineers], materials and tools that allowed them to construct buildings and cities throughout their empire.

Consequently, this chapter contributed essential information for the analysis of Aztec architecture and urban planning that was utilized for the archaeoastronomical analyses of the pre-Aztec and Aztec sites selected for this research (Chapter 6), as it established the role of astronomy, the symbolic importance of the Sun rising between the temples of the Huey Teocalli of Tenochtitlan, the role of precise measurements and the application of geometric design principles.

Chapter 6: Archaeoastronomical Analyses of Selected Pre-Aztec and Aztec Sites

6.1 Introduction

Research carried out in the previous chapters demonstrated that cultural aspects such as religion, geography, astronomy, mathematics and geometry were embedded in the design of their urban centres and architectural structures. Each of these chapters provided the cultural information that needed to be taken into account for the archaeoastronomical analyses. The ethnohistoric sources contributed the architectural and urban information contained in manuscripts, sculpture and oral history (Chapter 2); the typological analysis highlighted the main double temple teocalli as a distinct Aztec architectural type in Central Mexico (Chapter 3); the explanation of Aztec cosmovision provided an understanding of the significance of mountains, caves and bodies of water; the findings of high mountain archaeology demonstrated the relevance of certain topographic features within the sacred landscape and Cerro Tlaloc (Chapter 4); astronomy outlined the role of the heavenly bodies, including the cyclical movement of the Sun and Venus and their role in Aztec calendric systems; mathematics demonstrated the utilization of measurement units and angular systems; and geometry validated the use of axes and regulating lines (Chapter 5). Consequently, the aim of this chapter is to demonstrate how the cultural information extracted from traditional and non-traditional ethnohistoric sources converged and overlapped with the archaeoastronomical analyses—the core of the radial methodology — in order to understand the design principles of Aztec architecture and urban planning.

This chapter is divided in two main sections. The first section illustrates with a case study the methodology that was applied in the archaeoastronomical analyses through a series of images and detailed explanations. Since this methodology considered information ranging from religious, mathematic and geometric cultural knowledge to site-specific topographic and solar information, the analyses followed the same format even though the amount of cultural information varied from site to site. In spite of this unbalance, the topographic and solar information of each site always included: the seasonal-and-hourly positional changes of the Sun throughout the year; the rising and setting times of the Sun during the solstices, equinoxes and

alignment dates; the altitude and azimuth of the Sun on these dates; and, finally, the topographic features in the local horizon of each site such as mountains, caves and springs.

The second section is a summary of the archaeoastronomical-topographic analyses of two pre-Aztec sites, Teotihuacan and Tula, and five Aztec sites with surviving archaeological remains of a double temple teocalli: Tenochtitlan, Tlatelolco, Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. The analyses of each of these sites includes four subsections: a historical background; a summary of previous archaeoastronomical research and theories that have been proposed to explain its orientation; a discussion of the digital archaeoastronomical analyses and research findings; and a selection of images to illustrate the analyses at the end of each section to allow a continuous reading flow.

The archaeoastronomical-topographic analyses of each site consisted of: identifying the site in the context of the Valley of Mexico, defining the major alignment of the site, calculating the visibility of major topographic features, exploring with precision each significant direction (site alignment, solstices and equinoxes), building an horizon calendar based on identified alignments and summarizing the findings of each site. These summaries contain the same type of information that allows the comparison among sites and the identification of their similarities and differences.

Chapter 6 concludes with a discussion of the main urban and architectural design principles deduced from the archaeoastronomical-topographic analyses and how they were applied in main Aztec cities and their respective Huey Teocallis.

6.2 Methodology

As a means to understand each archaeological site from an architectural and urban design point of view, a consistent methodological approach was developed that would allow a systematic, and importantly, a precise analysis of the astronomical and topographic aspects of each site. Archaeoastronomical research carried out in the last four decades had already revealed that Mesoamerican civil and ceremonial buildings were mostly oriented towards the position of the

rising or setting Sun on the local horizon on certain dates of the tropical year (Aveni and Hartung 1986, 2000; Aveni 2001, 2003; Tichy 1990; Galindo 1994; Šprajc 2001a, b, 2008) (Figure 4.7). These dates have been interpreted in relation to the cultivation cycle and the counting of the days in the calendrical system. There is historical and anthropological evidence that these dates marked four crucial moments in the cultivation cycle of maize corresponding to the preparation of farmland in February, the start of the rainy season and the time of planting at the beginning of May, ripening of the first ear August and the end of the rainy season and the beginning of the harvest at the beginning of November. One of the characteristics of these dates is that they are separated in intervals of 260 days (Chapter 4:132), the duration of the ritual cycle in the Tonalpohualli calendar (Šprajc 2008:237). Based on these significant dates, several archaeoastronomers have reconstructed possible horizon calendars utilizing prominent peaks on the horizon as natural markers of sunrises and sunsets in calendrical significant intervals of 13 or 20 days (Aveni and Hartung 1986; Tichy 1990; Aveni 2003; Šprajc 2001a, b, 2008) (Chapter 4:136). Since the average length of a year is 365.2422 days, these horizon calendars were necessary to adjust to the 20-day months (*veintenas*) of the *cempoallapohualli* (Johansson 2005:149).

The digital archaeoastronomical analyses for this research built upon the observational calendar concepts developed by these archaeoastronomers. However, it expanded these concepts by exploring the relationship between architecture and local topography in addition to the position of the Sun on certain dates within the local horizon (Chapter 4:136). Furthermore, it also considered a very dissimilar corpus for each site, from religious myths to site-specific astronomical information to topographic features.

Precise solar positions were also calculated, given that the Sun is not a point but a circular disk with an angular diameter of 32' of arc. The edge is called the limb; sunrise and sunset respectively occur with the first and last appearances of the upper limb of the solar disk (Kaler 2002:193). Hence, sunrise/sunset solar data —azimuth, altitude, date and time— can be calculated either for the astronomical horizon or for the local horizon where local topography must be taken into account (Kaler 2002:200). Consequently, this research had to calculate both sets of data due to the complexity of the topography in the Basin of Mexico (Chapter 4:139).

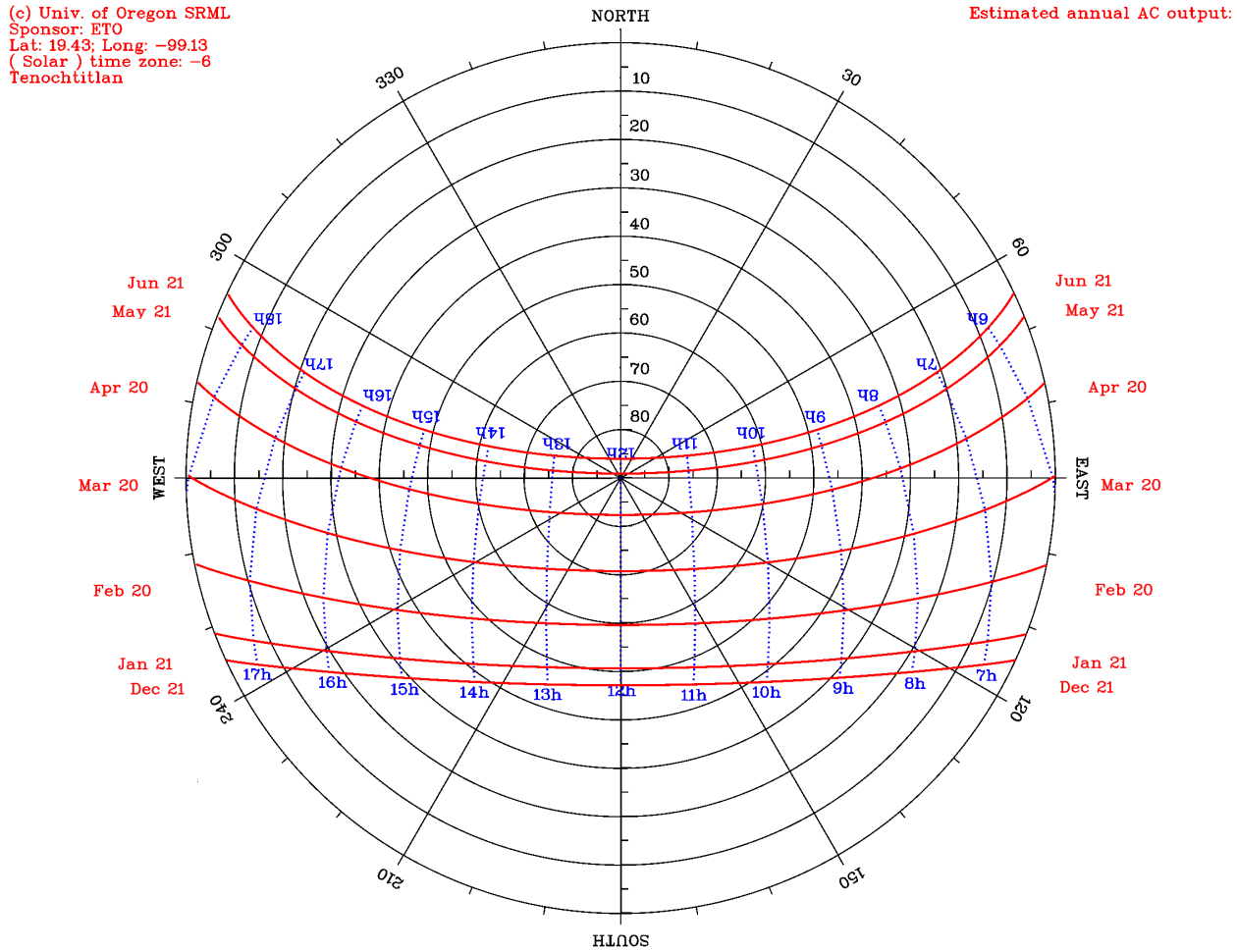


Figure 6.1. Sun path polar chart of Tenochtitlan, LAT 19.434921, LON -99.131362 on the astronomical horizon indicating the apparent seasonal-and-hourly positional changes of the Sun as the Earth rotates and orbits around the Sun. Azimuth angles run around the edge of the diagram; altitude angles are represented as concentric circular lines that run from the center of the diagram out; date lines start on the eastern side of the graph and run to the western side and represent the path of the Sun on one particular day of the year; hour lines are shown as dotted blue lines that intersect the date lines and represent the position of the Sun at a specific hour of the day. The intersection points between date and hour lines give the position of the Sun (Polar chart by the University of Oregon, Solar Radiation Monitoring Laboratory).

Table 6.1. Rising and setting times for the Sun in Tenochtitlan, LAT 19.434921, LON -99.131362 on the astronomical horizon from January to June (2012). Cells in columns indicate the time when the first and last appearances of the upper limb of the solar disk occur during sunrise and sunset respectively. (Table by the Astronomical Applications Department of the U.S. Naval Observatory Data Services).

	Jan.		Feb.		Mar.		Apr.		May		June	
Day	**Rise**	**Set**	**Rise**	**Set**	**Rise**	**Set**	**Rise**	**Set**	**Rise**	**Set**	**Rise**	**Set**
	h m	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**	**h m**
1	710	1810	711	1829	656	1842	630	1851	608	1900	558	1911
2	711	1810	711	1830	655	1842	629	1851	607	1900	558	1912
3	711	1811	711	1830	654	1843	628	1851	607	1900	557	1912
4	711	1811	710	1831	653	1843	627	1852	606	1901	557	1913
5	712	1812	710	1831	653	1843	627	1852	606	1901	557	1913
6	712	1813	710	1832	652	1844	626	1852	605	1901	557	1913
7	712	1813	709	1832	651	1844	625	1852	605	1902	557	1914
8	712	1814	709	1833	650	1844	624	1853	604	1902	558	1914
9	713	1815	708	1833	649	1845	623	1853	604	1902	558	1914
10	713	1815	708	1834	649	1845	622	1853	603	1903	558	1915
11	713	1816	707	1834	648	1845	622	1853	603	1903	558	1915
12	713	1817	707	1835	647	1846	621	1854	602	1904	558	1915
13	713	1817	706	1835	646	1846	620	1854	602	1904	558	1916
14	713	1818	706	1836	645	1846	619	1854	602	1904	558	1916
15	713	1818	705	1836	644	1846	619	1854	601	1905	558	1916
16	713	1819	705	1837	644	1847	618	1855	601	1905	558	1916
17	713	1820	704	1837	643	1847	617	1855	600	1906	559	1917
18	713	1820	704	1838	642	1847	616	1855	600	1906	559	1917
19	713	1821	703	1838	641	1847	616	1856	600	1906	559	1917
20	713	1822	702	1838	640	1848	615	1856	600	1907	559	1917
21	713	1822	702	1839	639	1848	614	1856	559	1907	**559**	**1918**
22	713	1823	701	1839	638	1848	613	1857	559	1908	600	1918
23	713	1824	700	1840	638	1848	613	1857	559	1908	600	1918
24	713	1824	700	1840	637	1849	612	1857	559	1908	600	1918
25	713	1825	659	1840	636	1849	611	1858	558	1909	600	1918
26	713	1825	658	1841	635	1849	611	1858	558	1909	601	1918
27	713	1826	658	1841	634	1849	610	1858	558	1910	601	1919
28	712	1827	657	1841	633	1850	610	1859	558	1910	601	1919
29	712	1827	656	1842	632	1850	609	1859	558	1910	601	1919
30	712	1828			632	1850	608	1859	558	1911	602	1919
31	712	1828			631	1850			558	1911		

Note: Hours in bold indicate rising (559) and setting (1918) times on June 21, 2012.

Table 6.2. Altitude and azimuth for the Sun in Tenochtitlan, LAT 19.434921, LON -99.131362 on the astronomical horizon on June 21st, 2012. *Sunrise occurs between 6:00 and 6:10 when the Sun rises from the horizon at an azimuth between 64.8 and 65.6.* (Table by the Astronomical Applications Department of the U.S. Naval Observatory Data Services).

h m	Altitude	Azimuth	h m	Altitude	Azimuth	h m	Altitude	Azimuth
5:10	-11.1	60	**10:10**	55.3	76.6	**15:10**	54.6	283.4
5:20	-9.1	61.1	**10:20**	57.6	76.6	**15:20**	52.3	283.5
5:30	-7	62.1	**10:30**	59.9	76.6	**15:30**	50	283.6
5:40	-4.9	63	**10:40**	62.2	76.4	**15:40**	47.8	283.8
5:50	-2.8	63.9	**10:50**	64.5	76.1	**15:50**	45.5	284.1
6:00	**-0.1**	**64.8**	**11:00**	66.8	75.7	**16:00**	43.2	284.3
6:10	**1.8**	**65.6**	**11:10**	69.1	75	**16:10**	40.9	284.6
6:20	3.8	66.4	**11:20**	71.3	74.1	**16:20**	38.6	285
6:30	5.9	67.2	**11:30**	73.6	72.8	**16:30**	36.3	285.3
6:40	8.1	67.9	**11:40**	75.8	71	**16:40**	34.1	285.7
6:50	10.2	68.6	**11:50**	78	68.3	**16:50**	31.8	286.1
7:00	12.4	69.2	**12:00**	80.2	64.2	**17:00**	29.6	286.5
7:10	14.6	69.9	**12:10**	82.3	57.6	**17:10**	27.3	287
7:20	16.8	70.5	**12:20**	84.1	46.2	**17:20**	25.1	287.5
7:30	19	71.1	**12:30**	85.5	25.8	**17:30**	22.8	288
7:40	21.3	71.6	**12:40**	86	354.9	**17:40**	20.6	288.6
7:50	23.5	72.1	**12:50**	85.2	326.7	**17:50**	18.4	289.1
8:00	25.7	72.6	**13:00**	83.6	309.6	**18:00**	16.1	289.7
8:10	28	73.1	**13:10**	81.6	300	**18:10**	13.9	290.3
8:20	30.3	73.6	**13:20**	79.5	294.3	**18:20**	11.7	291
8:30	32.5	74	**13:30**	77.4	290.7	**18:30**	9.6	291.6
8:40	34.8	74.4	**13:40**	75.1	288.4	**18:40**	7.4	292.3
8:50	37	74.8	**13:50**	72.9	286.7	**18:50**	5.3	293.1
9:00	39.3	75.2	**14:00**	70.6	285.6	**19:00**	3.2	293.8
9:10	41.6	75.5	**14:10**	68.4	284.7	**19:10**	1.2	294.6
9:20	43.9	75.8	**14:20**	66.1	284.2	**19:20**	-1.3	295.5
9:30	46.2	76	**14:30**	63.8	283.8	**19:30**	-3.5	296.3
9:40	48.5	76.2	**14:40**	61.5	283.5	**19:40**	-5.6	297.3
9:50	50.7	76.4	**14:50**	59.2	283.4	**19:50**	-7.7	298.2
10:00	53	76.5	**15:00**	56.9	283.4	**20:00**	-9.7	299.2

Note: Altitude is the angle up from the horizon. Azimuth is the angle along the horizon with respect to true north, with zero degrees corresponding to north, and increasing in a clockwise fashion. The apparent position of the Sun at a given time is defined by these two angles.

If sites were in a flat location, this information could have been enough for the analyses, but they were situated within geographic areas filled with very distinct topographic features specific to the Trans-Mexican Volcanic Belt (TMVB). Few regions in the world exhibit such a variety of volcanic landforms as the TMVB, which include binary volcanic systems, volcanic fields and lava caves. An example of these landforms are the Popocatepetl-Iztaccihuatl, the Ajusco–Xitle and the Sierra Negra–Pico de Orizaba binary systems in which one volcano is active and the other is inactive (Figure 6.2). Despite their proximity, these binary volcanoes are in different states of preservation because they were formed during different geological periods; some are small and perfect as the young cone Xitle (2400 years old), while others are eroded by the impact of several glaciations such as the Iztaccihuatl (30 million years old). The mountains that delimit the Basin of Mexico to the west and the mountain ranges of Las Cruces and Río Frío (Cerro Tlaloc (also known as Mount Tlaloc, Figure 4.15), Cerro Telapon and Cerro Papayo) to the east, are also volcanoes that lost their craters, original conical shapes and all eruptive systems through time (Chapter 4:139) (Montero 2004:2-4).

Figure 6.2. View of the binary volcanic system composed by the Volcán Iztaccihuatl and the Volcán Popocatepetl—with a fumarole coming out from its cone—seen from the tetzacualco located on the summit of Cerro Tlaloc. The closer mountain to the right is Cerro Telapon (Photograph by José Luis – CC:BY).

This complex landscape has been a challenge to archaeoastronomers as there is an abundance of topographic features that are not easy to identify due to the thick layer of smog that frequently covers the basin of Mexico or due to their underground location, for example caves or water springs. Furthermore, most sites are situated in areas that have been engulfed by the exorbitant

growth of Mexico City in the 20th century and are often in "peripheral" hard-to-reach places, dangerous due to their economically and socially marginalized population. Fieldwork is therefore extremely difficult (Broda 1991b:81). Archaeoastronomers have also been limited by the inherent constraints of printed topographic maps which might have covered some areas and not others, might have been in a smaller scale, or might not have contained the required information relevant to their analyses. In addition to these challenges, some buildings, such as the double teocallis, were built in several construction stages (Chapter 3:87). For example, in the Great Teocalli of Tenochtitlan, the remains of these stages have also subsided unevenly because of the difference in the solidifying of the subsoil clays, which have lead to different azimuth measurements. These slight variations (±1° from average azimuth) have resulted in diverse interpretations of the orientation of the Great Teocalli (Šprajc 2001: 384-390). Despite these variations, there is a widespread agreement that the location and orientation of the Great Teocalli was determined by astronomical and topographic considerations. However scholars differ in the interpretation of these variations, as they disagree on the observational techniques the Aztecs utilized to observe the Sun rise between the double teocallis described by Motolinía, but because we do not know from which location they were observed, or the exact height of these buildings, some archaeoastronomers had to make estimates (Figure 6.3 and Figure 5.8).

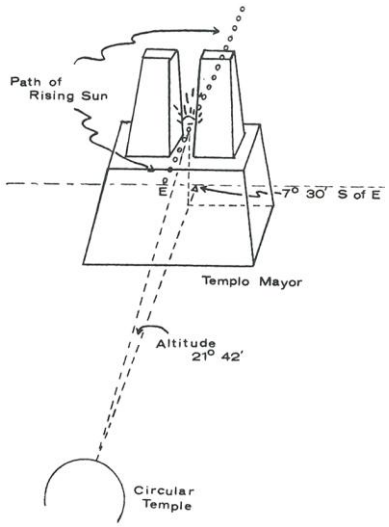


Figure 6.3. Interpretation of the Sun rising in the notch of the Great Temple on March 21st by Aveni which presupposes the height of the Templo Mayor and the existence — at a certain distance and height — of a circular temple where this event was viewed (Aveni and Gibbs 1978: Figure 4).

In order to overcome most of these challenges —and utilize as a basis for further exploration the archaeoastronomical studies carried out by scholars such as Aveni (1975, 2001), Aveni and Hartung (1986), Broda (1993), Galindo (1994), Šprajc (2001a, b, 2008), Tichy (1990) and Montero (2004), among others— an interdisciplinary methodology was developed for this digitally-based research that combined the vast corpus of research on Aztec culture with digital mapping, solar charting, viewshed calculating, geo-tagging and collaborative mapping applications. These applications provided the accuracy this research required, for they are based on high-resolution superimposed images of Earth obtained from satellite imagery, aerial photography and the GIS 3D globe. Google Earth, the virtual globe, and the map and geographical information applications use the digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM); its internal coordinate system employs the geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 (WGS84) datum, the same datum used by GPS (Zomrawi et al. 2013:7). Besides utilizing the information supplied by Google Earth, the solar charting and viewshed calculating applications also take into consideration the curvature of the Earth and the average refraction of a certain area so as to obtain results closer to reality. The obliquity (angle between the ecliptic and the equator that has been steadily decreasing by approximately 40 seconds of arc per century) was disregarded as it has barely shifted since A.D. 1500 (Aveni 2001:103). In addition, the dates utilized in the solar charting applications for this research correspond to the year 2014, so ±1 day variations can be expected in the calculations of dates. In conjunction, these applications offer unparalleled precision and information compared to printed maps, as sites can be analyzed at different scales; relationships between sites, other sites and nearby or distant topographical features can be explored; and a variety of locally relevant information can be accessed for any given site.

Although there is a wide diversity of research performed by archaeoastronomers on several sites —particularly in Teotihuacan and Tenochtitlan— this digitally-based independent exploration did not reference horizon calendars published by archaeoastronomers to prevent inadvertently influencing findings of this research (Tichy 1990, Šprajc 2001a). It also did not utilize any of the publicly available plans of the archaeological sites, since they are frequently inaccurate, confuse true magnetic north with true north or vice versa, and sometimes draw structures as if they had

already been excavated; hence, they are not accurate enough for digital astronomical and topographic analyses.

The digital archaeoastronomical analyses of this research only focused on the orientation of the main structure of the site, as ethno-historical sources indicate that the foundation of a city was followed by the construction of the temple to the patron deity(s) of the ethnic group, as well as by the respective consecration ceremonies (Florescano 2006). This temple served as central point of the axis mundi (Chapter 4:Figure 4.5) that divided the physical space in quadrants bounded by the solstice points of the rising and setting Sun (Chapter 4:Figure 4.6).

In Aztec sites, this temple is the double teocalli, but in Pre-Aztec sites, this temple corresponds to the main teocalli on the urban east-south axis of the site. Since the main axes of sites in Central Mexico exhibit an easterly deviation from the true north (Aveni 2001:233) (Chapter 4:Figure 4.7), this research introduced the utilization of the concept of *"urban axes"* to refer to this azimuthal deviation and clearly distinguish it from true, magnetic or grid directions. Furthermore, since the same structure can exhibit slight variations on each of its sides —either due to pre-Hispanic construction methods (Chapter 5:178) or due to restoration or reconstruction work—the mean alignment present on both the main structure and the site was selected for the analyses.

Regarding the digital topographic analyses, this research considered not only the visible prominent peaks on the horizon as calculated by the viewshed applications, but also other topographic features such as mountains, valleys, caves, lakes, rivers and springs (Chapter 4:Figure 4.13 and Figure 4.14). It also kept the names of volcanoes, mountains and caves in Nahuatl or Spanish to facilitate their identification.

Since the objective of this research was to gain an understanding of Aztec architecture and urban planning, both Pre-Aztec and Aztec sites were analyzed. The pre-Aztec sites of Teotihuacan and Tula were chosen due to their historical and symbolic relation to the cultures in Central Mexico as archaeologists, archaeoastronomers, ethnographers, and historians have demonstrated (Carrasco et al. 2000:12) (Chapter 3:121) The Aztec archaeological sites of Tenochtitlan,

Tlatelolco, Tenayuca, Santa Cecilia Acatitlan, and Teopanzolco (Chapter 2:68) were selected based on the following criteria:

1. They must have some uncovered archaeological remains.
2. They should lie within an archaeological zone of the Instituto Nacional de Antropología e Historia (INAH).
3. They should be identified by scholars as Aztec sites.
4. They should have a teocalli, since it is a unique Aztec building type (Chapter 3:87).

In order to perform the complex analyses that each site required, an application capable of performing geometric, solar and topographic analyses *at the same time* was developed for this dissertation. Even though Google Earth had the capability of making some of these analyses, it lacked the precision and interactivity required for this purpose.

Eventually, the analyses required the utilization of several applications: Google Earth, a solar charting application (SCA), a topographic application (TA), an open-content collaborative application (Wikimapia), a geo-location-oriented photo sharing site (Panoramio) and a custom geometric application (CGA) that could run over all of them. Google Earth located with precision sites and topographic features. The solar application provided solar information that could be controlled with exactitude by the minute. The topographic application gave altitude, distance and visibility of topographic features from a certain location. The custom geometric application (CGA) allowed to view the relationships between the site, its topography and the movement of the Sun as it could zoom in and out, draw reference lines, measure and graphically annotate the site being analyzed at a given moment without affecting the underlying application. This custom application also provided the capability to work *in the same scale* between digital maps and applications which was critical for obtaining the most precise information. Wikimapia, Panoramio and Google aided with the identification of sites and provided contextual information of topographic features, as many of these applications rely on databases which might not have complete —or culturally relevant— data.

Since the aim of the analyses was to acquire consistent data that could be utilized for comparison among sites, a detailed step-by-step systematic and replicable methodology was developed. Consequently, each site was taken through a series of steps, data was recorded and findings were documented for each site.

6.3 Methodological Steps for the Digital Topographic and Archaeoastronomical Analyses

In order to demonstrate this methodology, a summary of the steps that correspond to the analysis of Tenochtitlan are further described in the next section. For the purpose of clarity, they are presented in a linear form, even though the inherent process of the radial methodology involved continuous cross-referencing solar, topographic, cultural and ethnohistorical information. Since these steps focus on the explanation of the methodology, a further discussion about the site of Tenochtitlan was included in its corresponding section later in this chapter.

1. Define precise latitude, longitude and azimuth of the major east-west axis of the main teocalli of site ± 0.5° (Figure 6.4).

This step involved drawing reference lines with the custom geometric application (CGA) on identifiable walls or platforms of the archaeological remains of the Great Teocalli displayed on Google Maps. This resulted in the values of 19.434921° latitude (LAT) and -99.131362° longitude (LON).

The process for determining the major east-west axis alignment of the Great Teocalli was more complex since its azimuths varied from 95.71° to 97.38° among its different construction stages, resulting in a mean value of 96.54°. These calculations were consistent with the measurements taken by Šprajc, who calculated a mean of 96.5° ± 0.5° on Stage II and 96.67° ± 0.5° on subsequent stages (2001a:388). It was also similar to the 96.7° mean calculated by Aveni, Calnek and Hartung in 1988 (294). Therefore, the azimuth of the major east-west of the Great Teocalli was rounded to 96.5° ± 0.5°, thus defining the urban east west axis for the digital analyses.

Figure 6.4. Archaeological remains of the Great Teocalli of Tenochtitlan, scale 1:200. The streets of present day Mexico City follow the same azimuthal direction of 96.5° ± 0.5° of the Great Teocalli (Map data: Google Earth).

2. Identify prominent peaks around site, (Figure 6.5), and calculate azimuth, apparent altitude and distance of the prominent peaks on the horizon viewed from site (Table 6.3).

Table 6.3. Prominent peaks on the horizon viewed from Tenochtitlan

Azimuth/Apparent Altitude	Topography	Distance
5°/2.37°	Pico Tres Padres	17 km
131°/2.3°	Volcán Popocatepetl	70 km
140°/0.74°	Sierra de Santa Catarina	17 km
141°/0.6°	Cerro Xaltepetl	17 km
164°/2.03°	Volcán Tlaloc	38 km
186°/1.6°	Cerro Acopiaxco	35 km
196°/2.27°	Volcán Pelado	33 km
208°/3.24°	Volcán Ajusco	29 km
252°/2.1°	Cerro La Campana	30 km
319°/0.46°	Cerros Los Baños	59 km

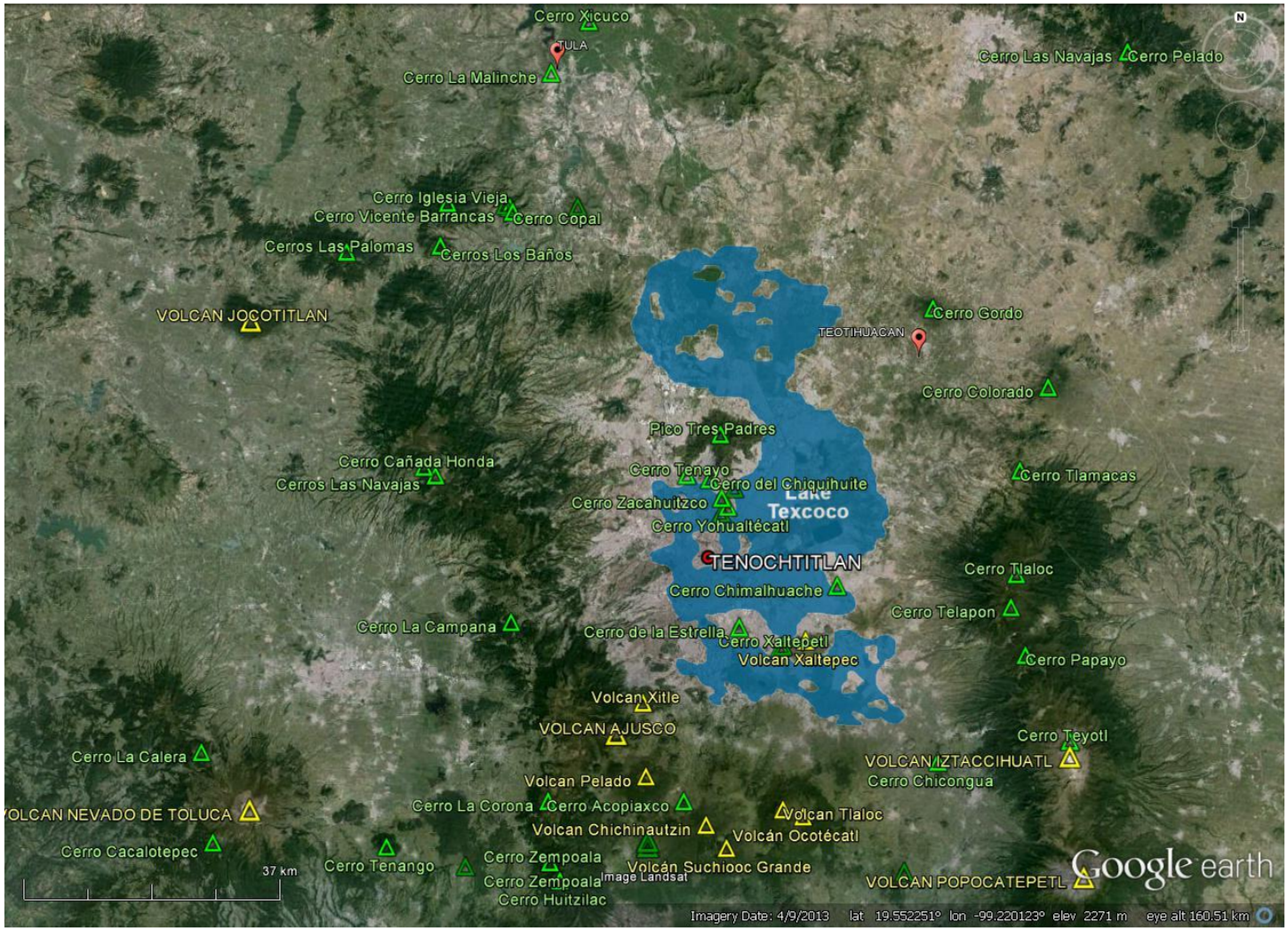


Figure 6.5. Prominent peaks around Tenochtitlan, scale 1:10,000 Yellow triangles, which indicate larger peaks, are identified as "volcán" (volcano), while green triangles, which indicate smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

3. Calculate viewshed of site (Figure 6.6).

This viewshed calculation was necessary because not all prominent peaks might be visible from the site (Tenochtitlan) due to the presence of local topographic features that might obstruct the view to a prominent peak or due to the curvature of the Earth. Likewise, prominent peaks located farther from local viewshed might be visible in clear atmospheric conditions.

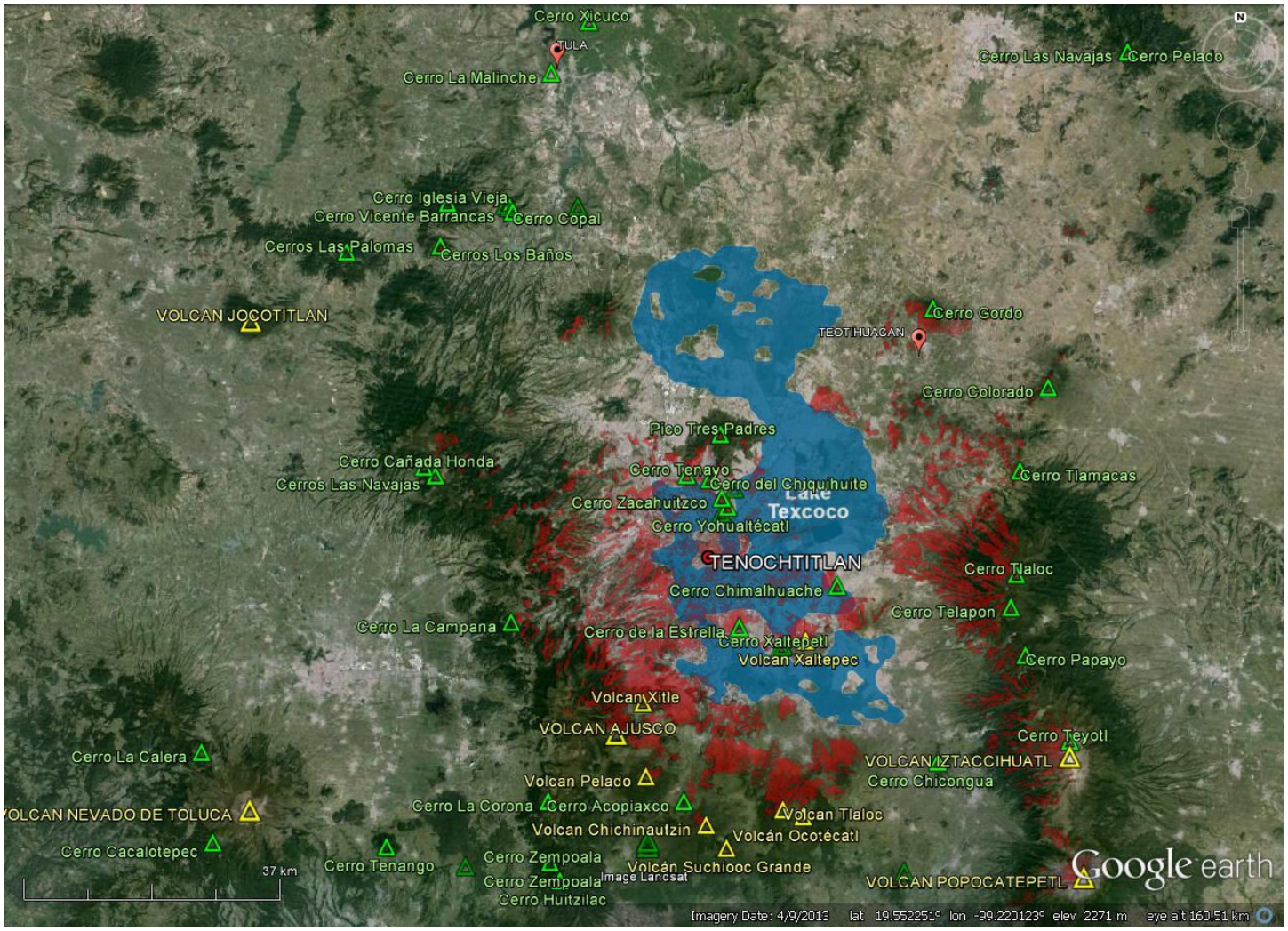


Figure 6.6. Viewshed of Tenochtitlan shown as red shaded areas and prominent peaks on the horizon, scale 1:10,000 (Map data: Google Earth and TA).

4. Create a 6.5° alignment reference diagram of the site (indicating true north-south-east-west axes, solstitial/equinoctial axes and urban north-south-east-west axes) and superimpose it on topographic landscape around site (Figure 6.7). Repeat the same steps for a 7.0° alignment reference diagram.

This step involved creating an alignment reference diagram of the site (Tenochtitlan) in AutoCAD that was later utilized in the custom geometric application (CGA) so it could be superimposed on Google Earth (with the viewshed data imported from the TA) concurrently on the same screen. While CGA kept the size and resolution of the diagram, Google Earth was able to increase or decrease its scale as a result of zooming in or out. The results of these analyses only served as a guideline for further exploration as this reference diagram is only a geometric reference that did not consider the topographic altitude and the curvature of the Earth.

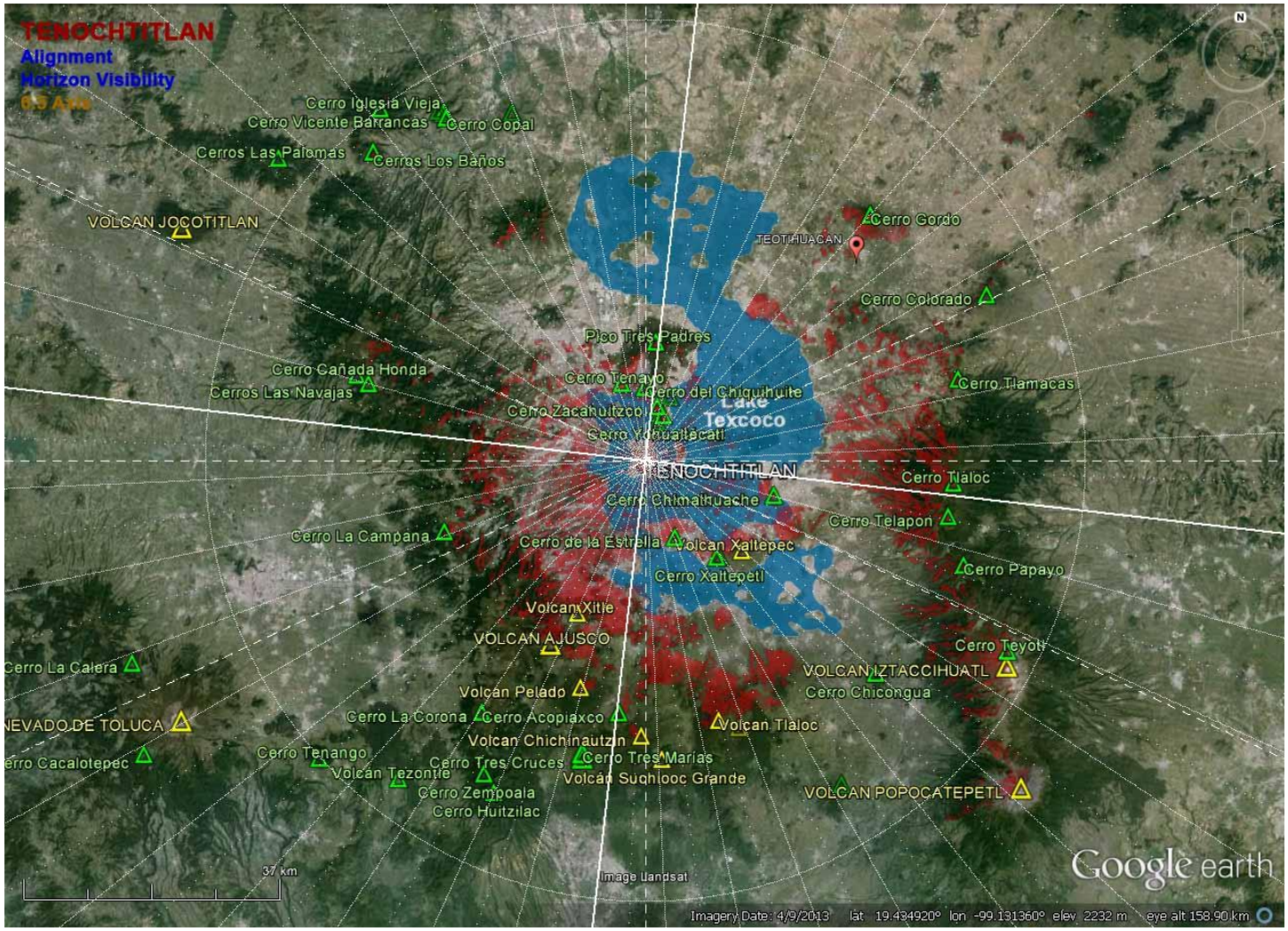


Figure 6.7 Alignment reference diagram superimposed on topographic landscape of Tenochtitlan. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

5. Calculate solar elevation and azimuth angles for the dates when the 96.5° urban east-west axis aligns to the position of the rising Sun (instant when the upper limb of the solar disk touches the horizon) on the eastern horizon taking into consideration astronomical and local horizons (Figure 6.8). Repeat the same steps for a 97.0° urban east-west axis.

Considering that the astronomical horizon is the imaginary horizontal plane at a 90° angle from the observer's zenith (the point directly above the observer) and that the local horizon is the visible boundary between the Earth and sky, both sets of solar data needed to be calculated for the site (Tenochtitlan) with the SCA since they are different due to the topography of the Valley of Mexico (Figure 2.29). These calculations revealed that the Sun appeared in the intermediate point (19.391519°, -98.716064°) between the binary volcanic system of Cerro Tlaloc (also known as Mount Tlaloc) and Cerro Telapon on March 6 and October 7 utilizing the mean value of 96.5° and on March 4 and October 9 utilizing the value of 97° (calculations based on the year 2014).

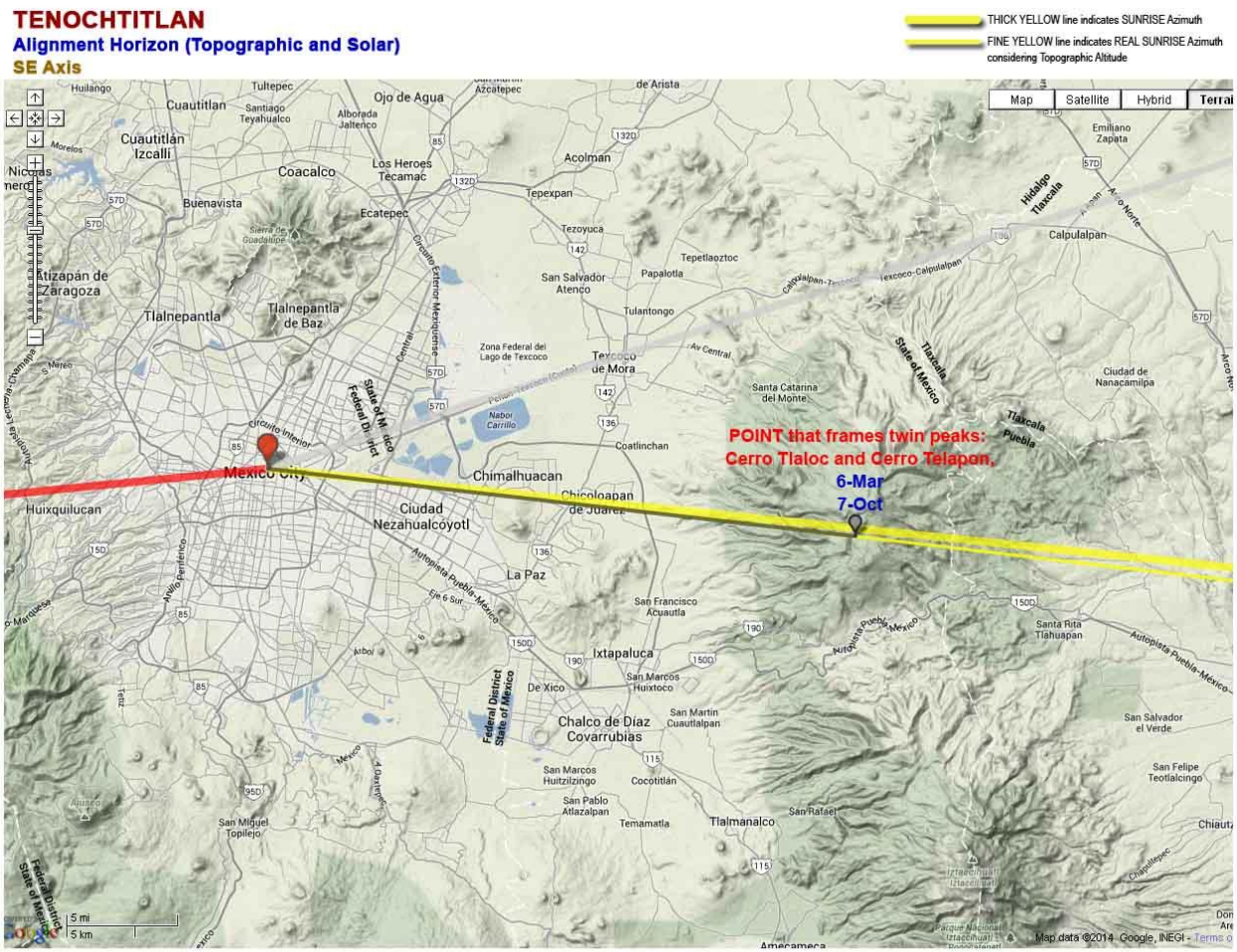


Figure 6.8. Position of the rising Sun between Cerro Tlaloc (also known as Mount Tlaloc) and Cerro Telapon along the 96.5° urban east-west axis of Tenochtitlan considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

6. Calculate solar elevation and azimuth angles for the dates when the 96.5° urban east-west axis aligns to the position of the setting Sun (instant when the upper limb of the solar disk touches the horizon) on the western horizon taking into consideration astronomical and local horizons (Figure 6.9). Repeat the same steps for a 97.0° urban east-west axis.

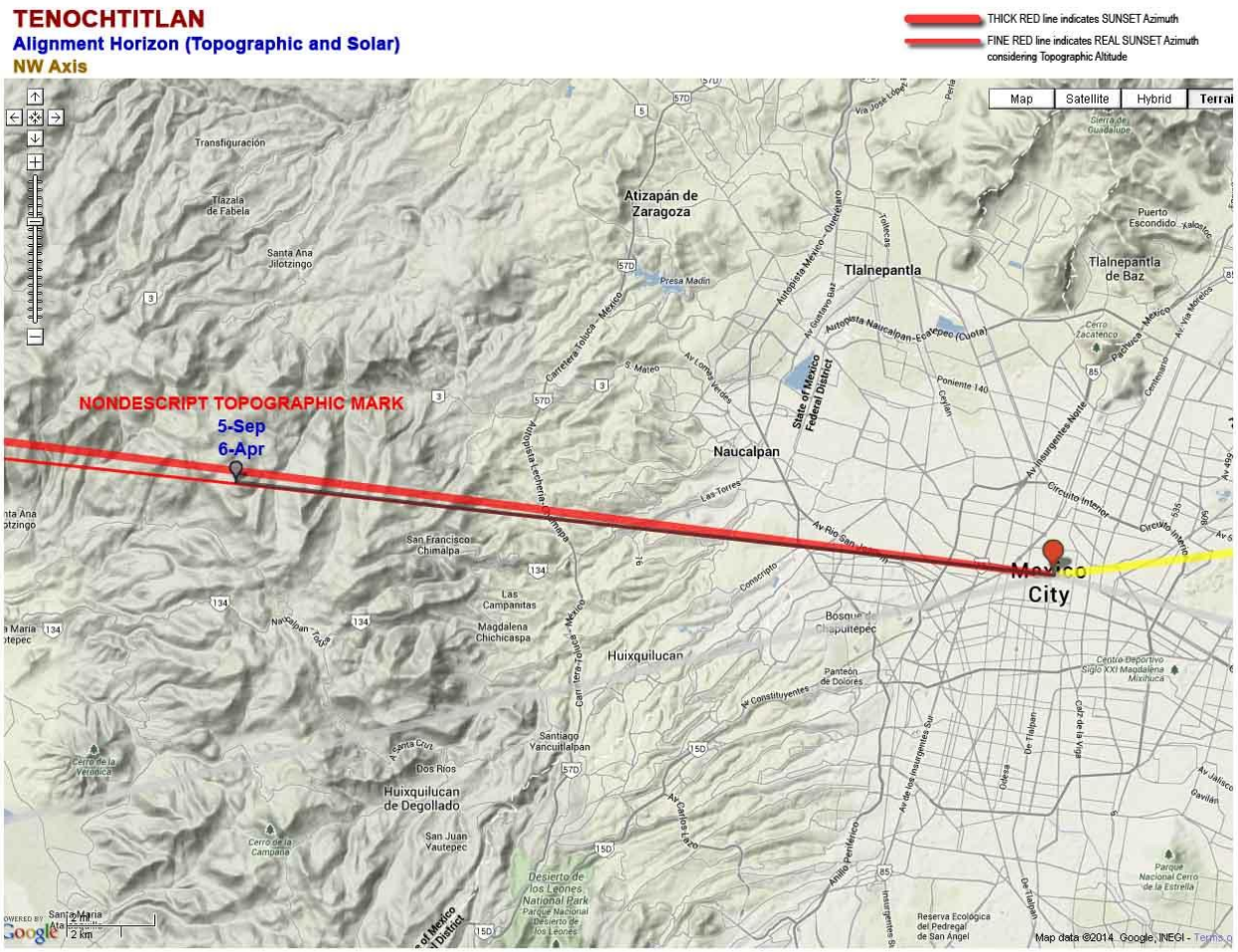


Figure 6.9. Position of the setting Sun on nondescript topographic feature along the 96.5° urban east-west axis of Tenochtitlan considering topographic altitude and the curvature of the Earth. The thick red line indicates the sunset azimuth in the astronomical horizon. The fine red line indicates the sunset azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

7. Locate the topographic feature where the 6.5° urban north axis of the site intersects with the northern local horizon by calculating its altitude and distance (Figure 6.10). Repeat the same steps for a 7.0° urban north axis.

This step involved calculating the distance and altitude of the topographic feature along the urban north axis of Tenochtitlan, taking into account the local viewshed, curvature of the Earth and refraction. This analysis revealed that the urban north axis of Tenochtitlan was the most prominent peak on the local horizon to the north, the highest peak of Pico Tres Padres, the same topographic-urban relationship that Teotihuacan has along its urban north axis with Cerro Gordo.

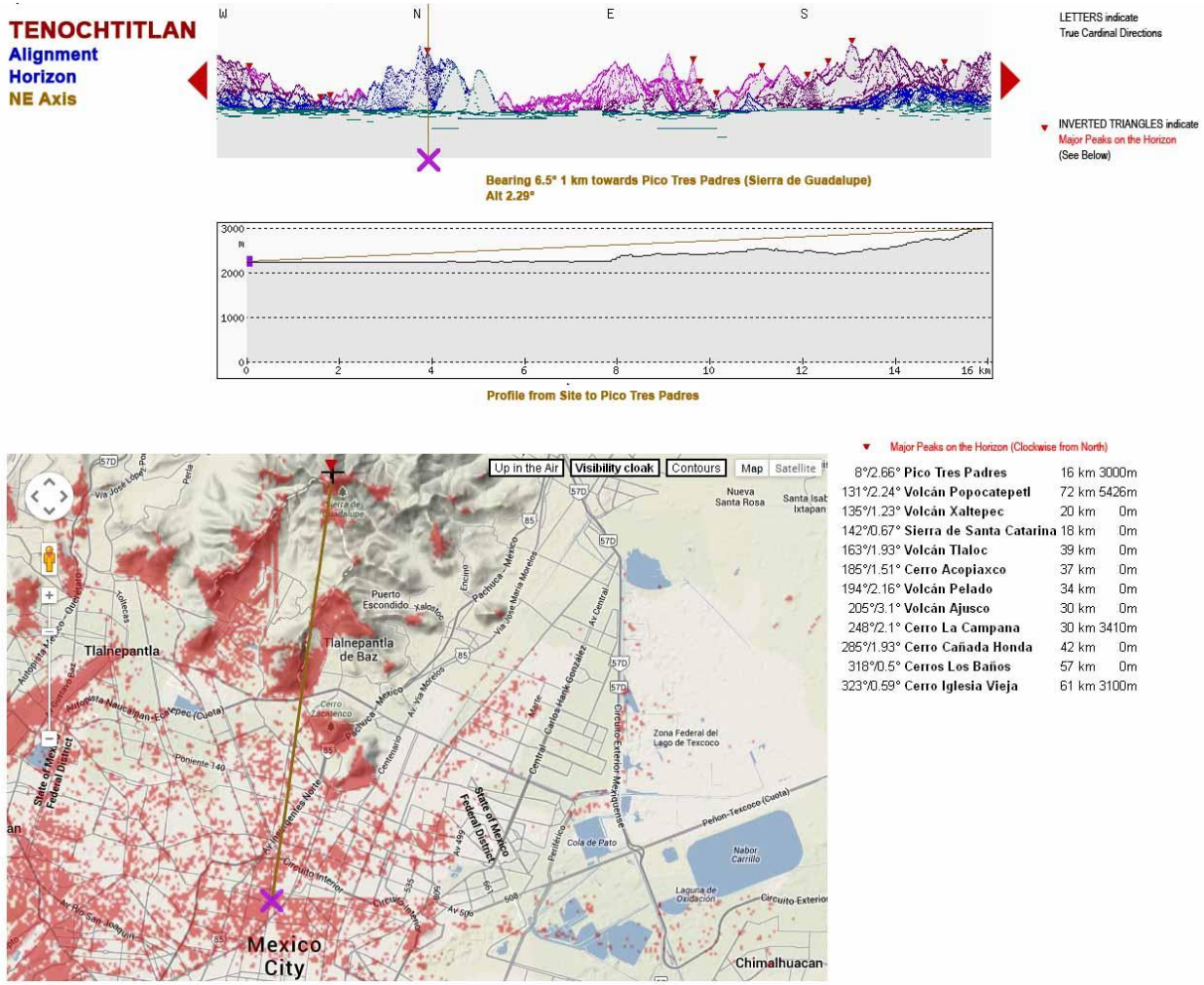


Figure 6.10. Alignment of Tenochtitlan to the highest peak of Pico Tres Padres (within the Sierra of Guadalupe) along its the urban north axis (marked on diagram as NE axis). This diagram contains three views from Tenochtitlan to the highest point of Pico Tres Padres: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view (Map data: Google Maps and TA).

8. Locate the topographic feature where the 96.5° urban east-west axis of the site intersects with the local eastern horizon by calculating its altitude and distance (Figure 6.11). Repeat the same steps for a 97.0° urban east-west axis.

This step involved calculating the distance and altitude of the topographic feature along the urban east of Tenochtitlan taking into account the local viewshed, curvature of the Earth and refraction. This analysis confirmed that the urban east axis of Tenochtitlan was to the intermediate point (19.391519°, -98.716064°) that marked the concave space between the binary volcanic system of Cerro Tlaloc and Cerro Telapon, thus framing the rising of the Sun on March 6 and October 7 (96.5°) or on March 4 and October 9 (97°). There is ethnohistorical and archaeological evidence that these two prominent peaks were an integral part of Aztec religion, as Cerro Tlaloc was called "Tlalocan" —house of the rain god— which was believed to be the origin of rain, mist, clouds and snow (Aveni, Calnek and Hartung 1988:298) (Chapter 4 Figure 4.14 and Figure 4.15).

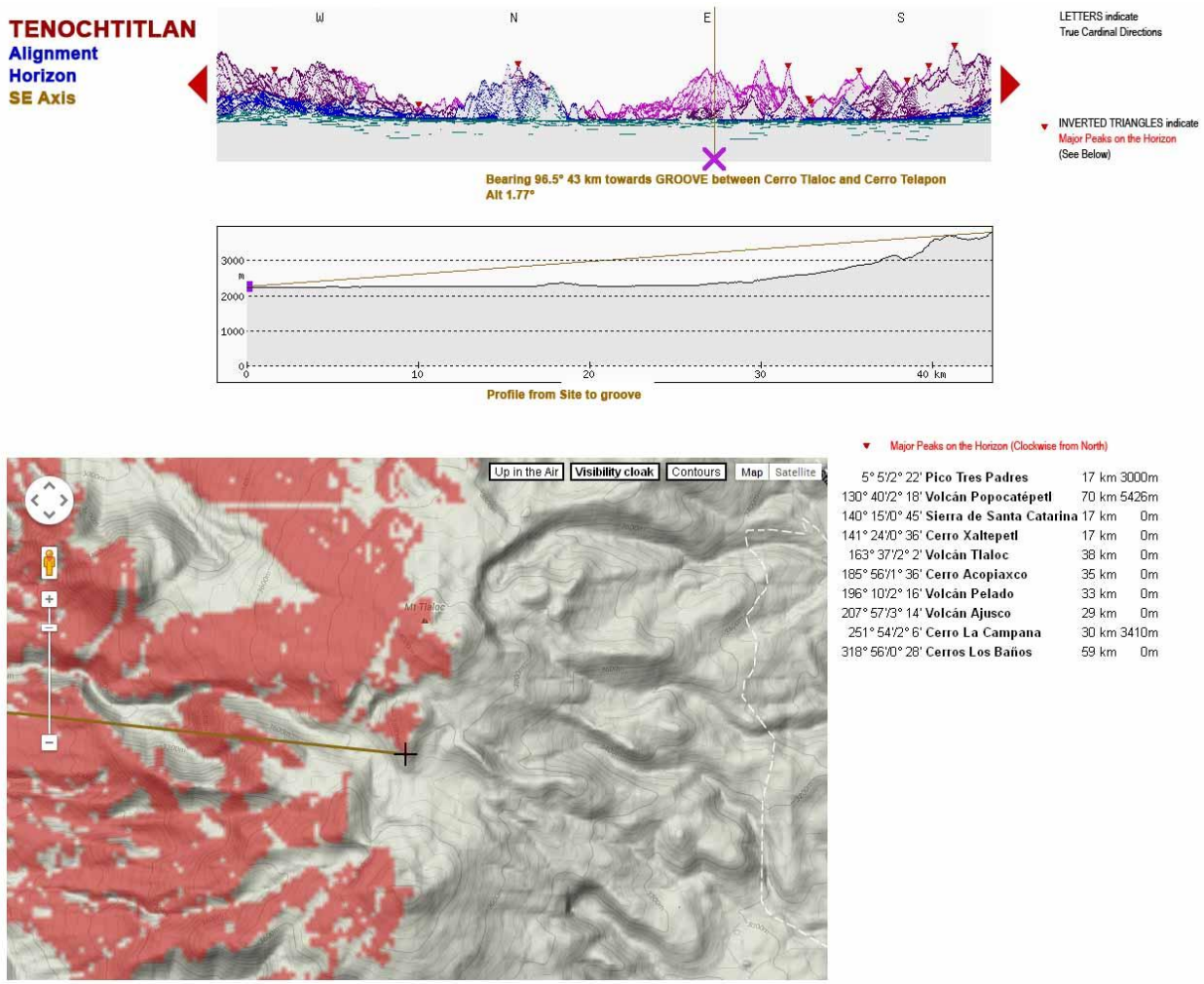


Figure 6.11. Alignment of Tenochtitlan to the intermediate point (19.391519°, -98.716064°) between the binary volcanic system of Cerro Tlaloc and Cerro Telapon along its the urban east axis (marked on diagram as SE axis). This diagram contains three views from Tenochtitlan to Cerro Tlaloc and Cerro Telapon: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view (Map data: Google Maps and TA).

9. Locate the topographic feature where the 186.5° urban south axis of the site intersects with the southern local horizon by calculating its altitude and distance (Figure 6.12). Repeat the same steps for a 187.0° urban south axis.

This step involved calculating the distance and altitude of the topographic feature towards the urban south of Tenochtitlan taking into account the local viewshed, curvature of the Earth and refraction. This analysis revealed that the urban south axis of Tenochtitlan was to Cerro Acopiaxco, an inconspicuous cinder cone located on the massive Chichinautzin volcanic field, specifically on an area characterized by multiple caves of great extension, the same topographic-urban relationship that Teotihuacan has along its urban south axis to the Xometla caves.

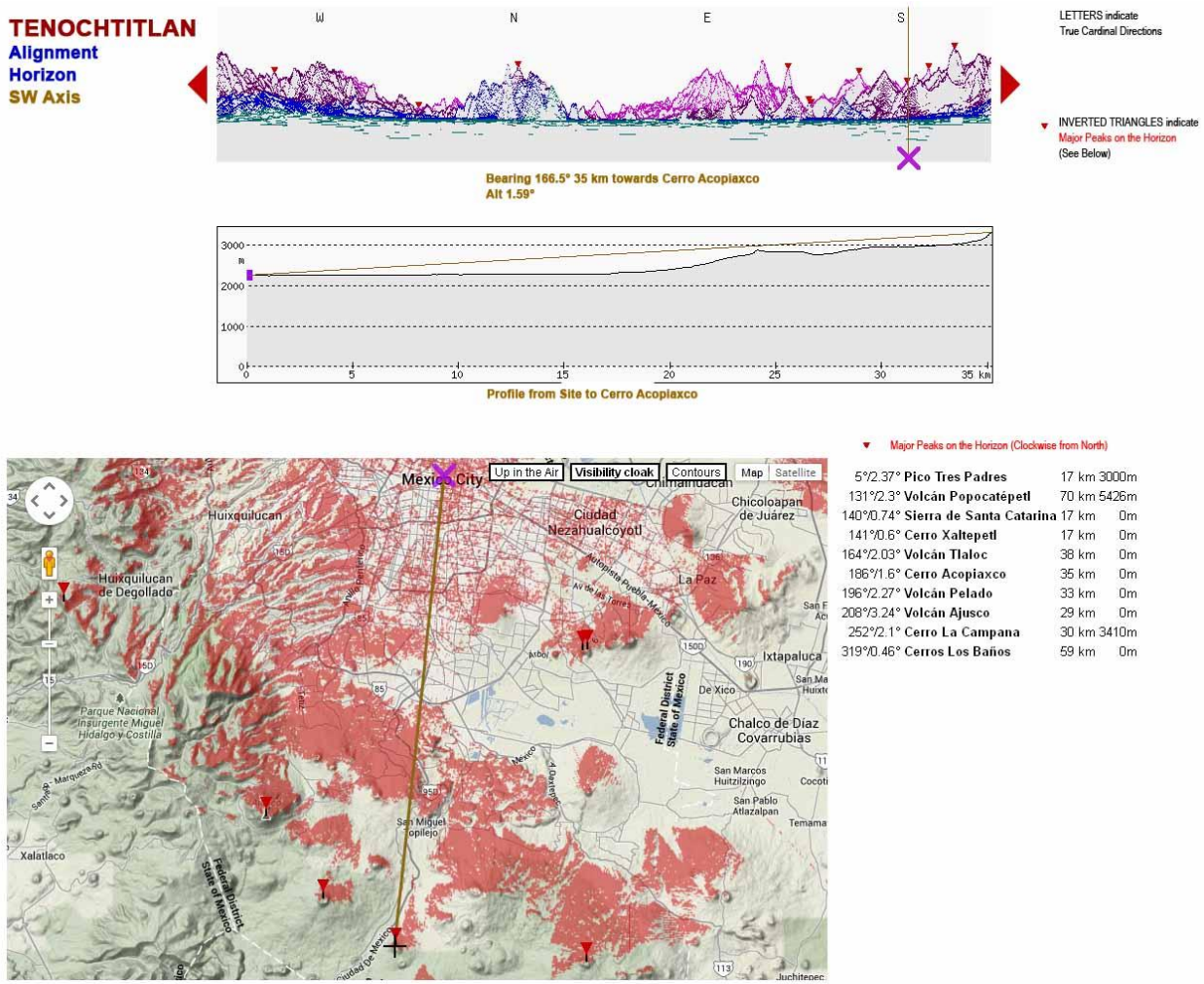


Figure 6.12. Alignment of Tenochtitlan to Cerro Acopiaxco (within the Chichinautzin volcanic field and lava caves) along its the urban south axis (marked on diagram as SW axis). This diagram contains three views from Tenochtitlan to Cerro Acopiaxco: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view (Map data: Google Maps and TA).

10. Locate the topographic feature where the 276.5° urban west axis of the site intersects with the local western horizon by calculating its altitude and distance (Figure 6.13). Repeat the same steps for the 7.0° urban west axis.

This step involved calculating the distance and altitude of the topographic feature towards the urban west of Tenochtitlan taking into account the local viewshed, curvature of the Earth and refraction. This analysis confirmed that the urban west axis of Tenochtitlan was to a nondescript topographic feature between Cerro La Malinche and Cerro Geishto, thus making this location a difficult reference point for a horizon calendar. Even though this area has been inhabited by an otomí population since pre-Aztec times, it is neither mentioned in ethnohistoric sources nor has it any reported archaeological remains (Galindo 166). Even supposing a horizon calendar could have been built towards this direction, it is unlikely that this location served as a reference point because it is hard to distinguish it from other peaks within the mountain range. However, a Google Earth exploration with a three-dimensional model of the Great Teocalli by Blake and Rivera revealed that during sunset, the Sun illuminates with a spotlight effect the Great Teocalli, thus making it standout as in a theatrical stage with the Valley of Mexico as a background on April 6 and September 5 (96.5°) or on April 9 and September 3 (97°), an imposing view that Bernal Diaz del Castillo described when they entered Tenochtitlan (Chapter 2:61).

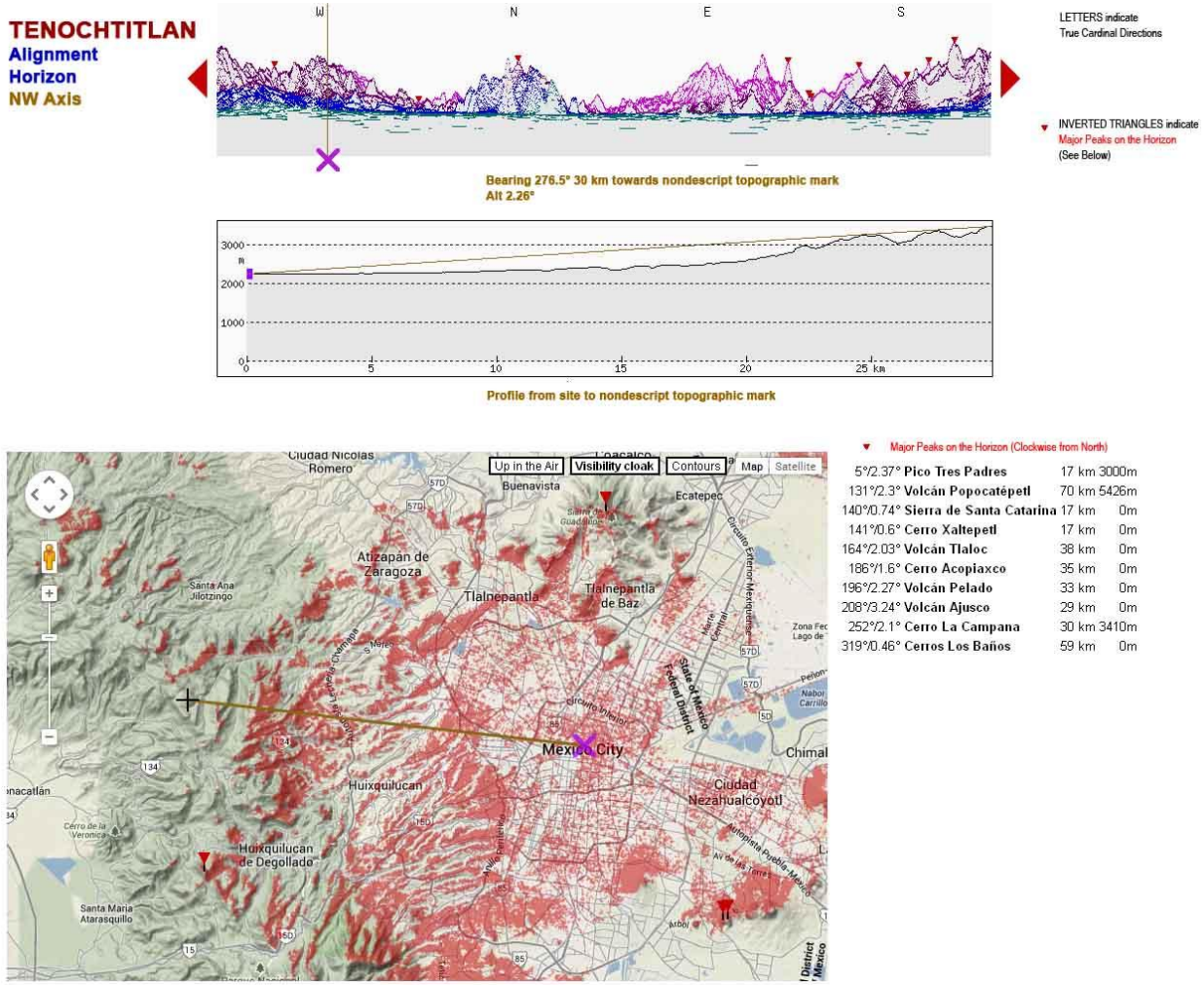


Figure 6.13. Alignment of Tenochtitlan to a nondescript topographic feature along its the urban west axis (marked on diagram as NW axis). This diagram contains three views from Tenochtitlan to Cerro Tlaloc and Cerro Telapon: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view (Map data: Google Maps and TA).

11. Locate the topographic features where the Sun rises during the solstices and equinoxes on the true eastern horizon from site, and plot these reference points along with main site alignment point in a 360° topographic panorama (Figure 6.14). Perform the corresponding calculations for the true western horizon.

This step involved calculating the distance and altitude of the topographic feature towards the true east during the equinox of Tenochtitlan taking into account the local viewshed, curvature of the Earth and refraction. This analysis suggests that the base of Cerro Tlaloc was also an important reference point for the horizon calendar on March 22 and September 22, with respect to the main reference point of the urban east-west axis of Tenochtitlan on March 6 and October 7 (96.5°) or on March 4 and October 9 (97°).

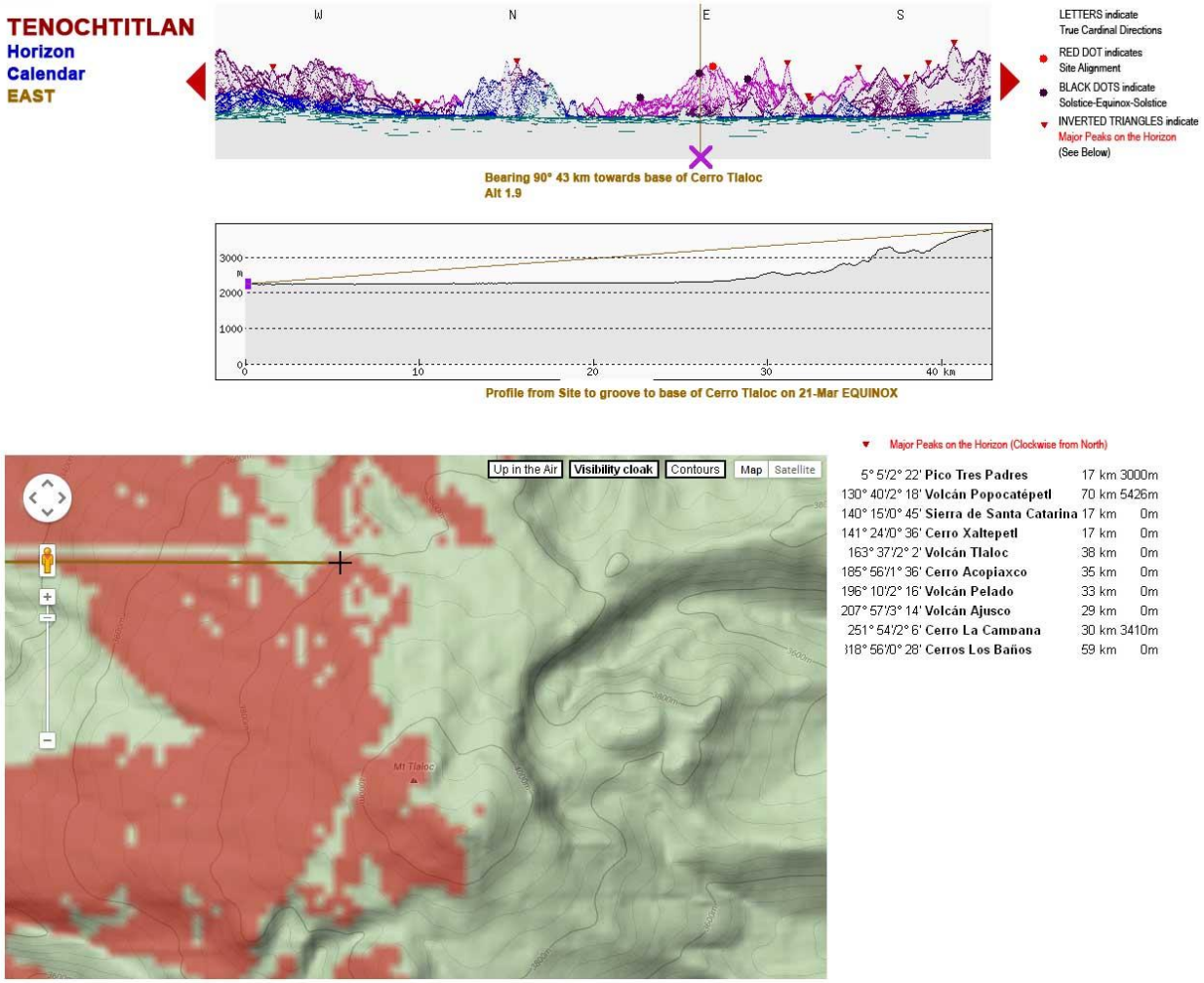


Figure 6.14. Position of the rising Sun during the equinox on the true eastern horizon. This diagram contains three views from Tenochtitlan to the base of Cerro Tlaloc: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view. The solstitial/equinoctial points are marked as black dots and the site alignment (urban east) is marked as a red dot in the panorama (Map data: Google Maps and TA).

12. Summarize site alignments towards the eastern horizon (true north-south-east-west and urban north-south-east-west axes) and solar position on local horizon and transfer this information on an eastern horizon table (Table 6.4**). Repeat the same steps for the western horizon and summarize and transfer the corresponding calculations on a western horizon table.**

Due to the large amount of information for each site, the results of the topographic and solar analyses had to be summarized in a table in order to understand the urban design principles of Tenochtitlan. These results confirmed that the urban north-south axis of Tenochtitlan was determined by the highest point of Pico Tres Padres (within the Sierra de Guadalupe) to the northern horizon and Cerro Acopiaxco (within the Chichinautzin volcanic field and lava caves) to the southern horizon.

The information compiled on Table 6.4 includes site alignments (true north-south-east-west and urban north-south-east-west axes) and solar positions on local eastern horizon. Urban axes are indicated as NE (urban north), SE (urban east), SW (urban south) and NW (urban east). Topographic features (mountain-caves) determined orientation to the urban north-south axis, whereas solar position determined the orientation of urban east-west axis. These alignments are summarized graphically on Figure 6.15 (horizon calendar) and Figure 6.17 (main alignments).

Table 6.4. Main topographic and solar references of Tenochtitlan on the eastern horizon (96.5° axis).

SITE ALIGNMENTS ON LOCAL EASTERN HORIZON						
URBAN Axis	**Topographic Alignment**	**Azimuth**	**Distance**	**Altitude**	**Date**	**Date**
NE Axis	Highest point of Pico Tres Padres	6.5	18	2.29		
SE Axis	Cerro Tlaloc and Cerro Telapon	96.5	43	1.77	6-Mar	7-Oct
SW Axis	Cerro Acopiaxco (volcanic field and lava caves)	186.5	35	1.59		
NW Axis	Nondescript topographic feature	276.5	30	2.26	6-Apr	5-Sep
CARDINAL Axis	**Topographic Alignment**	**Azimuth**	**Distance**	**Altitude**	**Date**	
North Axis	Las Lumbreras-Sierra Guadalupe-Cerro Chiquihuite	0	66-18-11	0.25-1.5 - 2.39	N/A	
East Axis	Base of Cerro Tlaloc	90	43	1.9	20-Mar	
South Axis	Cerro Chichinautzin	180	38	1.6	N/A	
West Axis	Nondescript topographic feature	270	25	2.4	22-Sep	
SOLAR POSITION ON LOCAL EASTERN HORIZON						
SUNRISE	**Topographic Alignment**	**Azimuth**	**Distance**	**Altitude**	**Date**	
Spring Equinox	Base of Cerro Tlaloc	90	43	1.9	20-Mar	
Summer Solstice	Nondescript topographic feature	64.8	50	0.61	21-Jun	
Autumn Equinox	Base of Cerro Tlaloc	90	43	1.9	22-Sep	
Winter Solstice	Ixtapaluca - base of Volcán Iztaccihuatl	114.7	59	1.87	21-Dec	
MAIN SOLAR REFERENCES ON THE EASTERN HORIZON CALENDAR OF TENOCHTILAN						
SUNRISE	**Topographic Alignment**	**Azimuth**	**Distance**	**Altitude**	**Date**	
Summer Solstice	Nondescript topographic feature	64.8	50	0.61	21-Jun	
Autumn Equinox	Base of Cerro Tlaloc	90	43	1.9	22-Sep	
SE Axis	Cerro Tlaloc and Cerro Telapon	96.5	43	1.77	6-Mar	
Winter Solstice	Ixtapaluca - base of Volcán Iztaccihuatl	114.7	59	1.87	21-Dec	
SE Axis	Cerro Tlaloc and Cerro Telapon	96.5	43	1.77	7-Oct	
Spring Equinox	Base of Cerro Tlaloc	90	43	1.9	20-Mar	

13. Plot main solar references on the 96.5° eastern horizon calendar of site on a 60° panorama (Figure 6.15) and calculate days between alignments and solstitial and equinoctial dates. Plot the corresponding references on the 276.5° western horizon calendar. Repeat the same steps for the 97.0° eastern horizon calendar (Figure 6.16).

As discussed in Chapter 4, time and space converged in the landscape as the annual course of the Sun was tracked on the local topography through a horizon reference system. (Figure 4.12), Consequently, the positions of the Sun on the solstices, equinoxes and on the date in which Tenochtitlan aligned to the rising of the Sun between Cerro Tlaloc (also known as Mount Tlaloc) and Cerro Telapon on March 6 and October 7 (96.5°) or on March 4 and October 9 (97°), served as main references for the horizon calendar. These references allowed the Aztecs to calculate the dates for the monthly festivals in the 365-day Xiuhpohualli calendar. Since this solar calendar consisted of 18 months of 20 days (plus five nemontemi days), additional references for each month could be added to the main reference points even though the topographic features would not be as distinct as the prominent peaks on the horizon every Aztec month of 20 days. Hence, the main reference points divided the year in three intervals:

- Horizon calendar (Figure 6.15) on the eastern horizon (96.5° urban E-W axis):
  March 6 > ***215 days*** > October 7 > ***75 days*** > December 21 > ***75 days*** > March 6

- Horizon calendar (Figure 6.16) on the eastern horizon (97.0° urban E-W axis):
  March 4 > ***219 days*** > October 9 > ***73 days*** > December 21 > ***73 days*** > March 4

It should be noted that 219 is a multiple of ***73***, a number related to the Xiuhpohualli calendar (***73*** days x 5 = 365), Tonalpohualli calendar (260 days x ***73*** years = 18 980 days = 52 years "calendar round" when both calendars coincided), and the Venusian year (584 days = ***73*** Earth days x 8) (Chapter4:132). Since Sahagún mentions ("*Por sus ruedas aquí antepuestas cuentan los Indios sus días, semanas, meses, y años,* ***olimpiadas*** *. . . "*) that every four years an additional day was added at the end of the last nemontemi days of the last year of the four years (***73*** days x 5) x 4 years = 1460 days + 1 day), the main points on the horizon every ***73*** days could have served to recalibrate the calendar when needed, as the real length of the solar year is 365.24219 days.

Furthermore, these dates at the beginning of March —March 4 (97.0°), March 5 (96.75°), or March 6 (96.5°)— marked the beginning of the Tlacaxipehualiztli Aztec month (Figure 2.26) which honoured the god Xipe Totec, god of vegetation and of the east and the rising Sun (Aguilar 2007:295). Since the feast of the 20-day Aztec months took place at the end of the month according to Sahagún, it is likely that the Tlacaxipehualiztli festival happened around the equinox. Hence, during this Aztec month the Sun began its journey in the concave space between Cerro Tlaloc and Cerro Telapon on March 5±1 day, traveled along the silhouette of Cerro Tlaloc during the month, and ended its passage at the base of Cerro Tlaloc around the equinox on March 21±1 day. This date validates the information recorded by Motolinía, who wrote:

> Tlacaxipehualiztli. On this day they flayed all of the enemy prisoners, and dressed themselves in their skins; and they dedicated this festival to Tlatlauhqui Tezcatlipoca … This festival fell when the Sun was in the middle of [the temple of] Huitzilopochtli, which was the equinox (Aveni, Calnek and Hartung 1988:290).

Reinforcing this date is the image of the Sun rising between the twin temples of Tlaloc and Huitzilopochtli of the Great Teocalli within the ceremonial precinct of Tenochtitlan depicted in the Nuremberg Map published along with a Latin version of the letters of Hernán Cortés on 1524 (Figure 5.7). Consequently, the results of this research suggest that the Aztecs intentionally designed their urban east axis (96.5° ±0.5° east of true north) with the purpose of aligning their Great Teocalli and their city to the sacred space where the Sun began its journey around Cerro Tlaloc before it landed on its base 20 days later on the equinox.

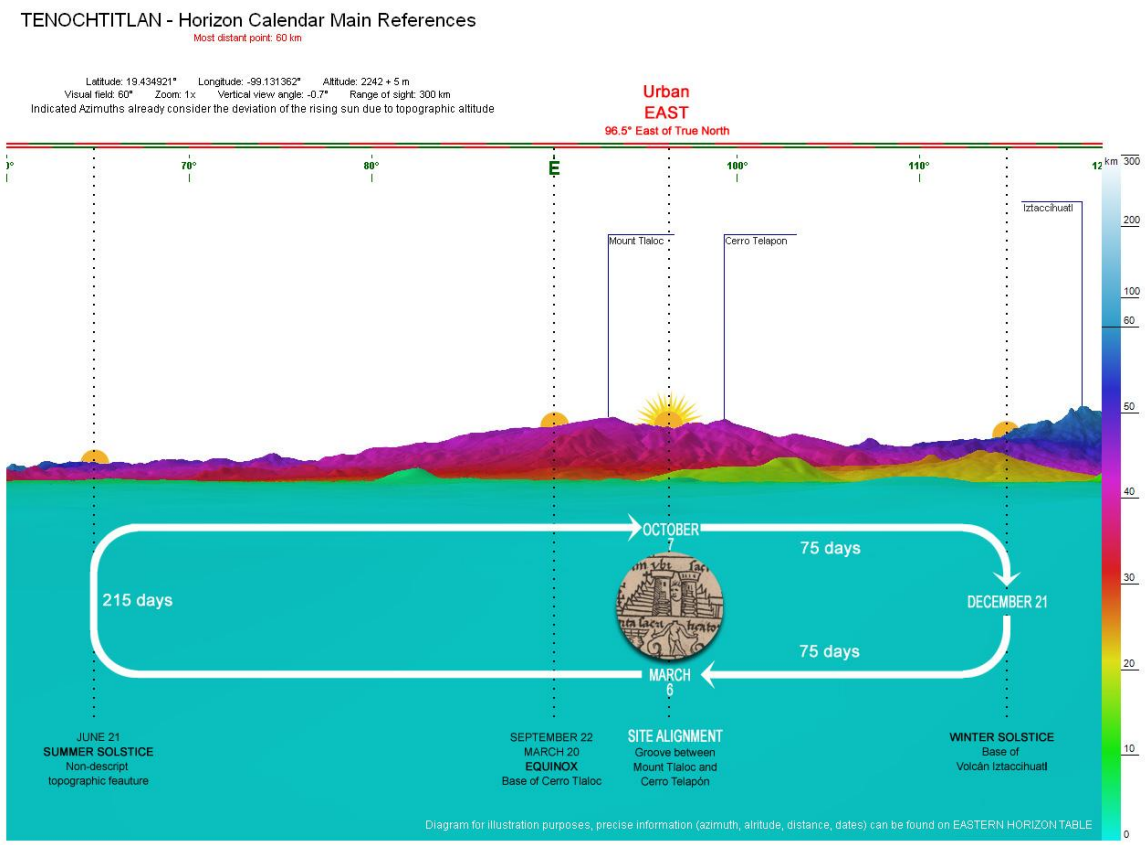


Figure 6.15. Main solar references on the 96.5° eastern horizon calendar of Tenochtitlan where the Sun rises between Cerro Tlaloc and Cerro Telapon on March 6 and October 7. The coloured bar on the right indicates the distance to the topographic features; the red and green line indicate azimuthal directions; and the dotted lines indicate the positions of the Sun on the solstices, equinoxes and the alignment date. The white line shows how this horizon calendar was utilized to count the days between these events so as to calculate the months in the Aztec calendar. The circular image on the urban east axis is a detail of the Great Teocalli taken from the Nuremberg Map where the Sun (depicted as a face) can be seen rising between the twin temples of Tlaloc and Huitzilopochtli. This event was recreated on a sacred landscape when the Sun came out between Cerro Tlaloc and Cerro Telapon (Map data: Google and INEGI).

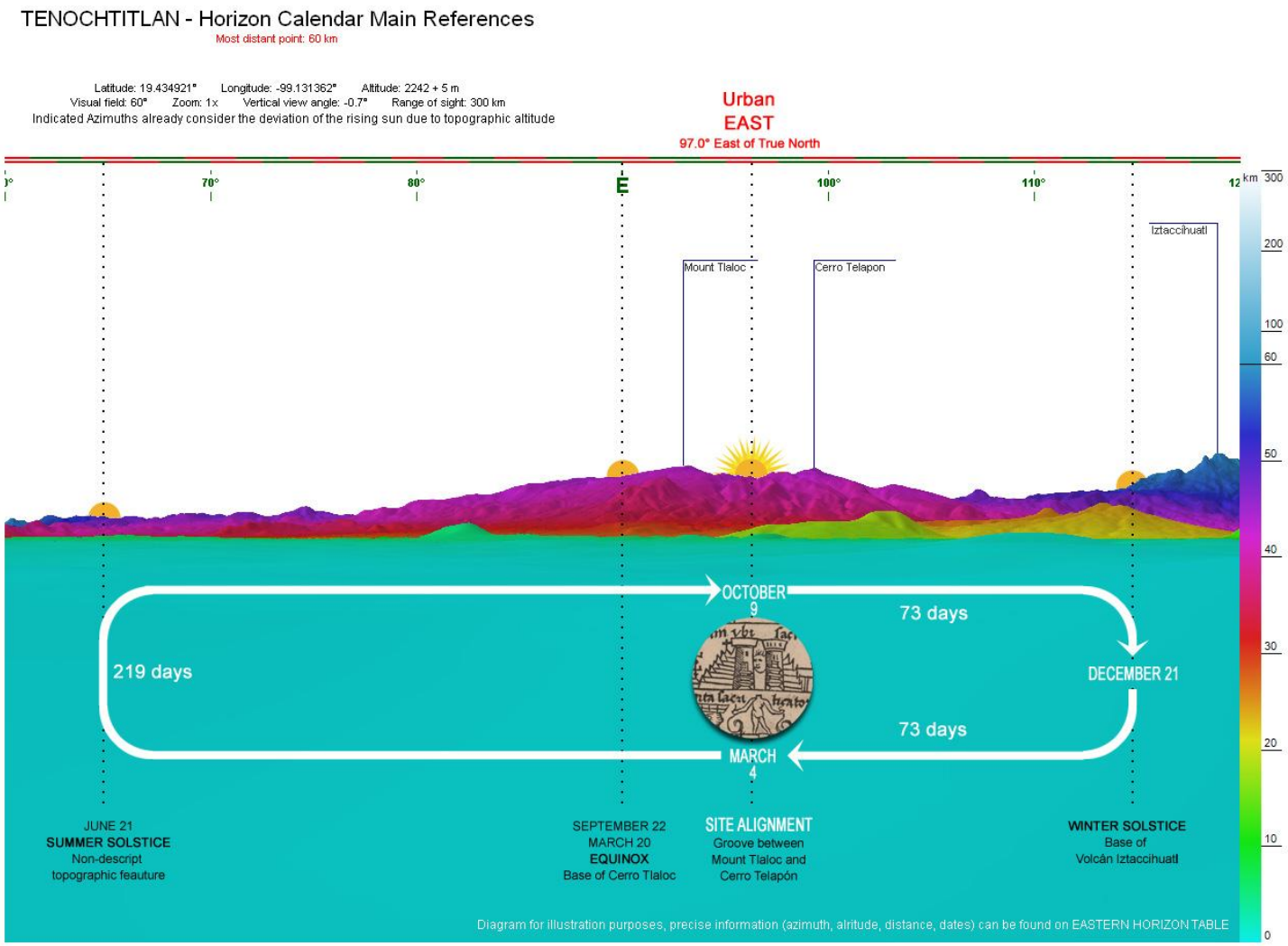


Figure 6.16. Main solar references on the 97.0° eastern horizon calendar of Tenochtitlan where the Sun rises between Cerro Tlaloc and Cerro Telapon on March 4 and October 9 in 73-days intervals related to Venus (Map data: Google and INEGI).

14. Create diagram of main eastern alignments of site (Figure 6.17). Create the corresponding diagram of main western alignments of site.

The aim of this diagram was to create a graphical synthesis of the solar and topographic analyses, applying the concept of the sacred landscape articulated by Broda, where the "extreme complexity in the relations among settlements, natural features, alignments, interactions and symbolic forms, constitute a "grand design" derived from an ancient tradition" (1991b:74). The findings of this research validated this "grand design" concept, as it revealed that the location of Tenochtitlan was the result of a complex interaction between a topographic alignment to Pico Tres Padres, the most prominent peak on the local northern horizon, and the multiple lava caves with the extensive volcanic field of Sierra Chichinautzin on the local southern horizon, and a solar alignment to the position of the rising Sun between Cerro Tlaloc and Cerro Telapon. In addition to these alignments, the location of Tenochtitlan was determined along a line (azimuth 18° west of north) from Cerro de la Estrella to Tula, thus connecting geographic space with cultural space.

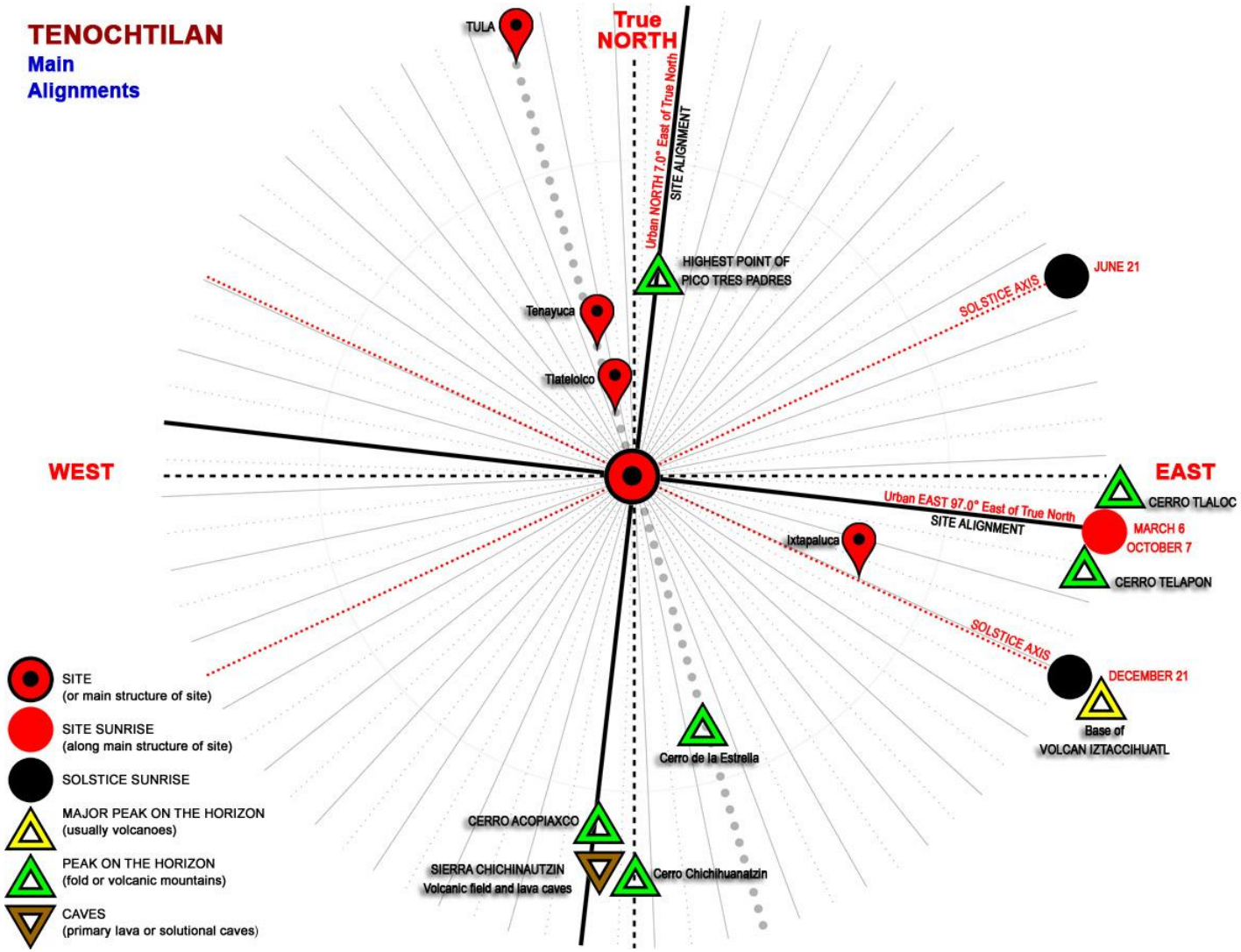


Figure 6.17. Main eastern alignments of Tenochtitlan. True cardinal directions are indicated as black dotted lines; the main urban axes of Tenochtitlan are indicated as black lines. The interactions between the urban north-south-east-west axes with the topography reveal the urban design principles of Tenochtitlan. Furthermore, the direction of the urban east axis reveals the architectural design principles of the Great Teocalli, the unique Aztec architectural form characterized by double temples.

15. Summarize findings.

Given that the digital archaeoastronomical analyses for this research were done concurrently with several digital mapping, solar charting, viewshed calculating, geo-tagging, collaborative mapping, drafting, image processing and custom geometric applications, it would only be possible to completely show the research findings in the same multi-dimensional format. However, due to the inherent constraints of the traditional format of a dissertation, an effort has been made to summarize most of the research findings in a limited number of two-dimensional images in spite of the multi-dimensional nature of topographic, solar and cultural analyses. Even though most of the research material is not contained within each dossier, the most representative information has been chosen to aid in the understanding of the research findings in order to relate them to other findings in other pre-Aztec or Aztec sites.

Consequently, the section that follows is a discussion of the archaeoastronomical digital analyses conducted in each selected pre-Aztec and Aztec sites, complemented by aerial views, topographic maps, diagrams, codices and relevant cultural information. The dossier for each site is composed of a brief description from an urban-archeological view, a recapitulation of the theories that have been suggested to explain the orientation of its main urban axes, the digital archaeoastronomical analyses and a proposal of additional theories to explain the orientation of the site and its relationship to other sites. To avoid interrupting the reading flow, all images have been placed at the end of their corresponding section.

As mentioned at the beginning of this section, a further discussion of the analyses of Tenochtitlan has been included in its corresponding section later in this chapter.

6.4 Archaeoastronomical Analyses of Selected Pre-Aztec Sites

6.4.1 TEOTIHUACAN

6.4.1.1 Historical Background

The site of Teotihuacan is located in the state of Mexico, 40 km northeast of Mexico City (Figure 6.18). Covering an area of about 21 square kilometers, the city is widely considered the first true urban centre in Mesoamerica due to its dense urban concentration and its grand urban design that integrates monumental and residential architecture (Cowgill 1997:129).

Teotihuacan has produced evidence of initial habitation at the beginning of the Classic period (1-150 CE). Designed in a strict grid plan, the vast city is laid out along the Avenue of the Dead, the main axis of the city which is skewed 15.5°±0.25 east of true north, and is more than two kilometers in length and 43 m in width. At the north end of this axis lies the Pyramid of the Moon, a monumental structure that measured 143.85 by 165.89 m at its base. Midpoint between the Pyramid of the Moon and the San Juan River, on a perpendicular axis to the Avenue of the Dead, is the Pyramid of the Sun, the largest monumental structure in Mesoamerica with a base of 215.72 by 215.72 m, built between 150 BCE and 150 CE. At the end of the Avenue of the Dead, also on a perpendicular axis, lies the Ciudadela, a complex that includes the Feathered Serpent Pyramid built between 150–200 CE during the resettlement of the population along this axis (Figure 6.19). The elements of urban planning were clearly defined by 200–350 CE. By that time, Teotihuacan already counted with sophisticated hydrological, transportation, ceremonial, residential and industrial facilities, as well as a network of water and drainage systems. The city had two main plazas: one dominated by the Pyramid of the Moon and the other, the Citadel, at the front of the Pyramid of the Feathered Serpent. In addition, there were several three-temple complexes, elite residential buildings and numerous apartment compounds around the city. By 600-650 CE, Teotihuacan declined and the core of the city was burned; by the late Classic period, the site core was barely inhabited (Manzanilla 2006).

Excavations in Teotihuacan have been undertaken since pre-Columbian times as the Aztecs considered it the mythical place created by the gods where two gods sacrificed themselves in sacred fire and became the Sun and the Moon (Cowgill 2015:14). However, the first recorded explorations have been carried out since 1675 and have continued to this day with major projects such as the ASU Research Laboratory and the Proyecto Arqueológico de Teotihuacan, among others. Currently, the main part of the city lies in the *Zona Arqueológica de Teotihuacan* (Figure 6.20).

6.4.1.2 Previous Archaeoastronomical Research

Teotihuacan has probably been the archaeological site most thoroughly studied by scholars, who have produced a large and impressive oeuvre of Mesoamerican scholarship. As Schávelzon affirms, the theories, models and interpretations which have emerged relating to this site have been fundamental for the comprehension of all Mesoamerica, and the histories of such works are currently found in archaeological thought, the technological evolution of excavation and restoration, and the discussion, confirmation and/or rejection of the early theories. Teotihuacán is a central case in the development of the thoughts concerning not only ancient México, but also for the entire Americas (1996:1).

Studies to explain the orientations of Teotihuacan have been no exception, particularly after Millon (1973) noted in his report that there are two slightly different orientations integrated into the urban grid of the city. His Teotihuacan Mapping Project demonstrated that the urban north axis, represented by the orientation of the Avenue of the Dead and the Pyramid of the Sun, had a clear deviation of 15.47°, while the urban north of the Citadel in the southern part of the city had a deviation of 16.5°. However, unlike monumental structures, many building and residential complexes exhibited a deviation of 15.5° while others a deviation of 16.5° (Aveni 2001:226). Along with the discoveries that have been made in Teotihuacan throughout the years, several theories have emerged to explain its orientations. Furthermore, aside from topographical surveys and measurements made by archaeologists, at least 29 carved pecked cross symbols (Figure 2.36) have been found in several locations in and outside the city. These symbols, which consisted of two perpendicular axes surrounded by concentric circles formed by small holes,

might have been intended as astronomical orientational devices, surveyor's bench marks or calendars (Aveni et al.1978:267). One of these pecked crosses was found south of the Pyramid of the Sun (TEO 1) and another was found 3 km to the west (TEO 5), which marked the urban east-west axis of the Pyramid of the Sun which front faces west.

One of the theories to explain this deviation was proposed by Dow who suggested that the orientation of the Pyramid of the Sun may have been determined by the position of the horizon of the autumnal setting of the Pleiades star cluster at the time of its construction. Dow also proposed that this alignment could have been determined by the rising on the east of Sirius, the brightest star in the sky (Galindo 123). Another interpretation was raised by Drucker in 1977 who suggested that the orientation of Teotihuacan was determined by the setting of the Sun on the axis of the Pyramid of the Sun on August 13 and 29 April in order to commemorate the Mesoamerican ritual calendrical cycle, since 260 days elapsed between those dates (124). Meanwhile, Malmström explained these dates arguing that the builders of Teotihuacan oriented the city on these dates to evoke each year the beginning of time which had started on August 13, 3114 BCE year on the long count (126).

However, it was Aveni—along with other researchers such as Hartung—who began to study more systematically the orientations of Teotihuacan. Their research in Mesoamerica demonstrated that many sites in Central Mexico had their urban north axis skewed between 15° and 20° east of north (Figure 5.23), so they called this group the "17° family of orientations " (Aveni 2001:234). Hence, Aveni suggested that Teotihuacan was the first place in Mesoamerica where the widespread use of these orientations as the main urban axes was established, and further proposed that some subsequent cultures adopted this orientation by imitation and reverence to the old sacred site.

Although other scholars continued to propose theories about the orientations of Teotihuacan, Šprajc (2001a) carried out a detailed survey of orientations in more sites in Central Mexico. Based on the measurements and observations made in Teotihuacan, Šprajc claimed that the 15.5° clockwise deviations from cardinal directions of both the urban north-south axis along Avenue of the Dead and the Pyramid of the Moon and the perpendicular axis of the Pyramid Sun, are the

deviations that dominate the central area of the city. His research also demonstrated that the location of the Pyramid of the Sun was determined by two axes, the first axis to Cerro Gordo with an azimuth of 15.5°, and the second axis to sunrises over a prominent peak on February 11 and October 29 and the sunsets on August 13 and 29 April. These dates mark the four critical moments of maize cultivation cycle; they are also separated by periods of 260, the length of the ritual calendrical cycle. Thereby, Šprajc demonstrated that the orientation of Teotihuacan was the result of a combination of astronomical and topographical criteria (Šprajc 2000:403).

Apart from the mostly astronomical theories based on the rising or settings of the Sun or stars, Heyden proposed that the cave under the Pyramid of the Sun may have determined its location, thus opening the possibility that other buildings could have been located on similar caves. However, she also stated that these caves also had an astronomical significance, citing the creation of the Fifth Sun in Teotihuacan: "[A]fter [Nanahuatzin] threw himself into the fire and was transformed into the Sun, another [divine personage] went into a cave and came out as the Moon" as described by Mendieta (Heyden 2000:174). The scope and variety of these theories are the reason why Šprajc rightly asserts that there is no single reason for the orientation of Teotihuacan, but rather a number of practical, religious and political reasons that influenced the urban design of the city (2000:403).

6.4.1.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the theories proposed by Aveni, Šprajc, and Heyden, the methodological steps for performing the digital and archaeoastronomical analysis were followed meticulously, even though they were not necessarily performed consecutively as every step involved cross referencing solar, topographic and cultural information. Therefore, the analysis began by determining the coordinates of the main structure of the site, the Pyramid of the Sun, which were defined as 19.692272,-98.843571. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of the city from these coordinates. These viewshed calculations placed into topographic context prominent peaks on the horizon of Teotihuacan, such as the Volcán Tlaloc at a 195.5° azimuth and 68 km distance, and even faraway peaks like

the Volcán Jocotitlan located at a 273° azimuth and 96 km distance, an impressive sight that can still be viewed on a clear day.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.21). To this end, the azimuths of the Avenue of the Dead and the east and west platforms of the Pyramid of the Sun were measured, which resulted in an azimuth of 15.5°±0.5 east of true north for the urban north-south axis. The perpendicular axis was determined by measuring the north and south sides of the platforms of the Pyramid of the Moon, the temples around the plaza of the Pyramid of the Moon and the platforms of the Pyramid of the Sun, which resulted in an azimuth of 105.5°±0.5 east of true north for the urban east-west axis. This alignment reference diagram was superimposed on Google Earth with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

These explorations lead to a more detailed analysis of the urban north-south axis, which resulted in the finding that this axis runs from Cerro Gordo in the Valley of Teotihuacan to Volcán Tlaloc, a peak more than 75 km south of the Valley of Mexico (Figure 6.22). Furthermore, a detailed exploration of the topographic and cultural features along this alignment also resulted in the finding that the Cuevas de Xometla (geologic formations of massive caves and springs) are located along this axis 6.69 km south of the Pyramid of the Sun. This is, interestingly, a similar distance as between the Pyramid of the Sun and Cerro Gordo along this same axis but towards the north (7.05 km). Therefore, the results obtained in this step not only reinforced the theories initially proposed by Heyden in relation to the relevance of mountains, caves and springs in Mesoamerican cosmology, but also lead to the theory that the location of the Pyramid of the Sun along the axis between Cerro Gordo and Volcán Tlaloc was probably determined by calculating the midpoint between Cerro Gordo and the Cuevas de Xometla.

Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align with the position of the rising and setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction (Figure

6.23). Due to the location of Teotihuacan within a valley, the altitude of the local topography affected the solar elevation, so both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from the Pyramid of the Sun, the urban east axis intersects the rising Sun on the local eastern horizon on February 11 and October 29 at a 105.5° azimuth, 1.96° altitude and a distance of 19 km; while the urban west axis intersects the setting Sun on the local western horizon on April 30 and August 13 at 285.5° azimuth, 0.58° altitude and a distance of 4.6 km. While these measurements confirmed the dates obtained by Šprajc (2000, 2001a:408), the analyses revealed that urban east-west axis does not align to any mountain to the west as suggested by Aveni (2001:Figure 76), but to a groove between two mountains in that direction. However, they defined with more precision the alignment of the urban east-west axis to the west proposed by Šprajc to Cerro Colorado, as the Sun rises just 561 m south of the summit of this mountain, thus framing the rising Sun on February 11 and October 29 (Figure 6.24).

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on Jun 21 (Cerro Xihuingo), September 22 (Cerro Tepayo), December 21 (Cerros de Coamilpa) and March 20 (Cerro Tepayo) on the eastern horizon. The same set of calculations were performed for the western horizon, but it became apparent that alignments to topographic features towards this direction were not easy to identify due to the similar altitude among them and to their distance from the Valley of Teotihuacan, some as far as 63.32 km. However, the analyses revealed that alignments could not only be marked with prominent peaks on the horizon, but also by the space between two mountains or other topographic features.

Once all of the information was determined, it was summarized in a diagram (Figure 6.25) and a table that included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons. This table was utilized to plot the main solar reference points for either the eastern or western horizon calendar of Teotihuacan (Figure 6.26). This information was also used to

calculate the days between the alignment of Teotihuacan and the solstitial and equinoctial solar dates, which resulted in the division of the year in three main intervals:

- Horizon calendar on the eastern horizon (105.5° urban E-W axis)
  February 11 > 260 days > October 29 > 53 days > June 21 > 52 days > February 11

- Horizon calendar on the western horizon (285.5° urban E-W axis)
  April 30 > 260 days > August 13 > 53 days > June 21 > 52 days > April 30

These calculations confirmed the theories suggested by scholars such as Aveni and Hartung (1986), Tichy (1990) and Šprajc (2001a), among others, that horizon calendars could be built utilizing topographic features on the horizon. Furthermore, they validated the theories that these "dates allowed the use of an observational calendar composed of intervals that included multiples of 20 days and a 260-day period" (Šprajc 2000:403). Even though some of these scholars have reconstructed possible horizon calendars for Teotihuacan by giving the dates, azimuth and altitude to prominent peaks on the horizon, the results of this research suggest that once the main sunrise or sunset locations of the carefully planned alignment of the site, equinoxes and solstices had been established, additional dates could be plotted on the horizon every 13 or 20 days to either prominent peaks, spaces between smaller peaks, the base of a prominent peak or any other topographic feature that could be easily distinguished from the site.

Regarding the urban north-south axis, the results obtained in this research confirmed the theories proposed by several scholars and the measurements made by Šprajc (2001a: Table 5.34) of the alignment of the Pyramid of the Sun to Cerro Gordo. However, it also revealed that this alignment goes beyond the Valley of Teotihuacan, as this 75-km-long axis runs from Cerro Gordo to Volcán Tlaloc via the Cuevas de Xometla. Even though this spatial relationship between the city and the natural environment was found with the digital applications utilized in these analyses, it was validated by Google Maps Street View. This application allowed the precise manipulation of the viewport since several parameters such as the location (latitude/longitude value), heading (compass heading of the camera), field of view (horizontal

field of view of the image) and pitch (up or down angle of the camera relative to the Street View) could be adjusted.

An observer standing on the Avenue of the Dead by the Ciudadela and looking towards the north is able to see the Pyramid of the Sun and the Pyramid of the Moon with Cerro Gordo perfectly embracing with its slope the former while surrounding the latter at a distance 8.38 km. Going down this axis by the San Juan River, the Pyramid of the Sun appears on the east side of the Avenue of the Dead while the Pyramid of the Moon begins to emerge from Cerro Gordo. Once the Pyramid of the Sun has been left behind, the Pyramid of the Moon and Cerro Gordo become one enormous volume, in spite of the mountain being 6.39 km away. When the observer arrives to the plaza of the Pyramid of the Moon, the Pyramid of the Moon has become the mountain (Figure 6.27).

Once the Pyramid of the Moon has been reached, an observer standing of top of its first platform and turning towards the south along the Avenue of the Dead is able to see a similar spectacle along this axis. On the east side of the Avenue of the Dead, the southeastern landscape can be perceived acting as a backdrop for the Pyramid of the Sun which even follows the same slope as Cerro Patlachique, a mountain 6.34 km away. Furthermore, the Volcán Tlaloc can be seen at the end of this axis 75 km away (Figure 6.28).

These spatial relationships between the city and its natural environment revealed a profound knowledge of astronomy, topography, mathematics and geometry which later cultures must have either inherited or learned from visiting Teotihuacan. Even though it is not known how this knowledge was recorded and transmitted in pre-Columbian times, the founders of Teotihuacan left a series of urban and architectural design principles embedded in the landscape that withstood the test of time, as maps such as the Mapa Saville can attest. This map clearly shows the urban north-south axis that visually connects Teotihuacan with the Cuevas de Xometla, even though it was probably elaborated between 1700 and 1767 CE (Lopez Luján 2008:15), almost 1500 years after the main axes of the city were designed (Figure 6.29). The Mapa Saville, and the finding in this research that the alignment between Cerro Gordo and Cuevas de Xometla determined the urban north-south axis of the city, not only reinforced the cultural significance of

mountains, caves and springs but also provided an additional explanation of the "Tlalocan" mural in the Tepantitla complex located in Teotihuacan. Besides the interpretation offered by scholars that the mountain connected to a cave through a river might be depicting the "paradise of Tlaloc" (Pasztory 1997:18), it might also represent the urban design of Teotihuacan as it has been demonstrated in the urban-topographic analysis (Figure 6.30).

Furthermore, the results of this research also suggest that, in addition to integrating buildings with their surrounding sacred landscape for religious reasons, these architectural and urban principles served to determine main topographic reference points for practical reasons. These distinct references on the horizon could also serve to guide travelers from different places around Mesoamerica to Teotihuacan, since it is widely known that trade was carried out with distant regions as far away as Tikal at the height of their economic power. The importance of these main topographic reference points can be found in several cartographic histories from the sixteenth century, such as the Codex Xolotl (Figure 2.15) and the Mapa de Cuauhtinchan No. 2 (Figure 2.17) among many others, where topographic features such as mountains, caves and springs are an integral part of the visual narrative.

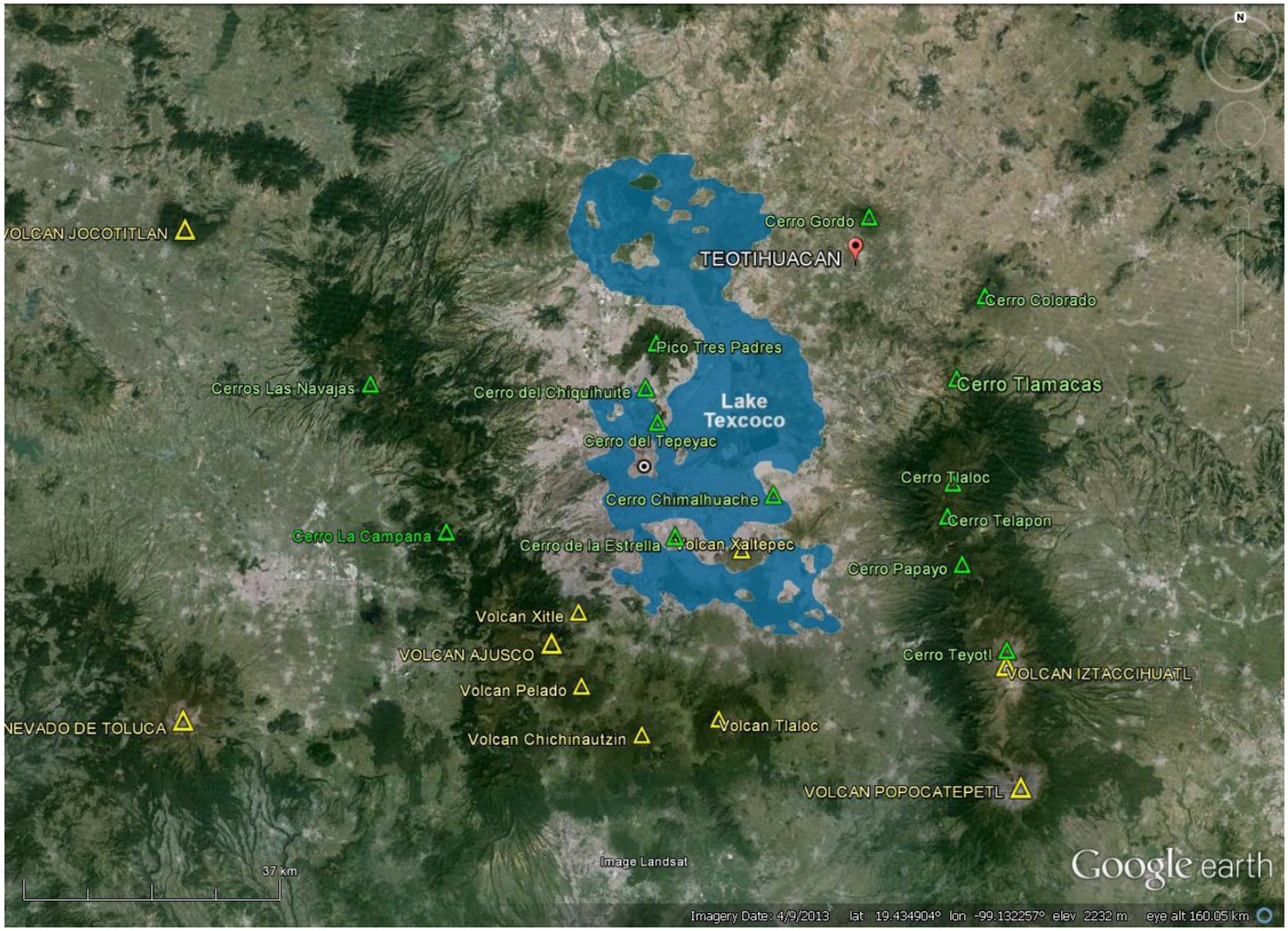


Figure 6.18. Location of Teotihuacan indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

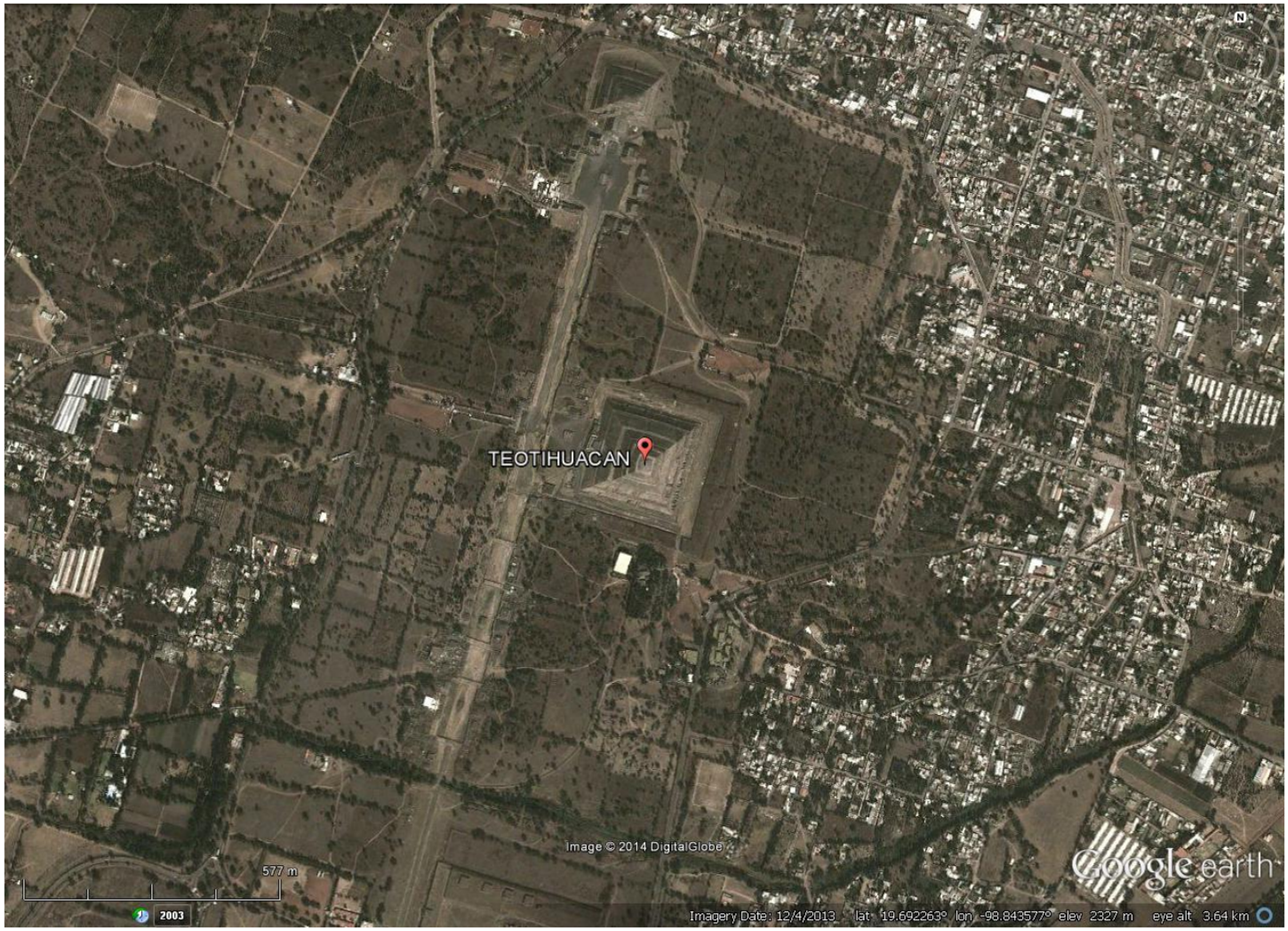


Figure 6.19. Aerial view of the archaeological remains of Teotihuacan, scale 1:200 (Map data: Google Earth).

Figure 6.20. Plan of archaeological remains of Teotihuacan (Teotihuacan Mapping Project from Millon 1973:Map 1).

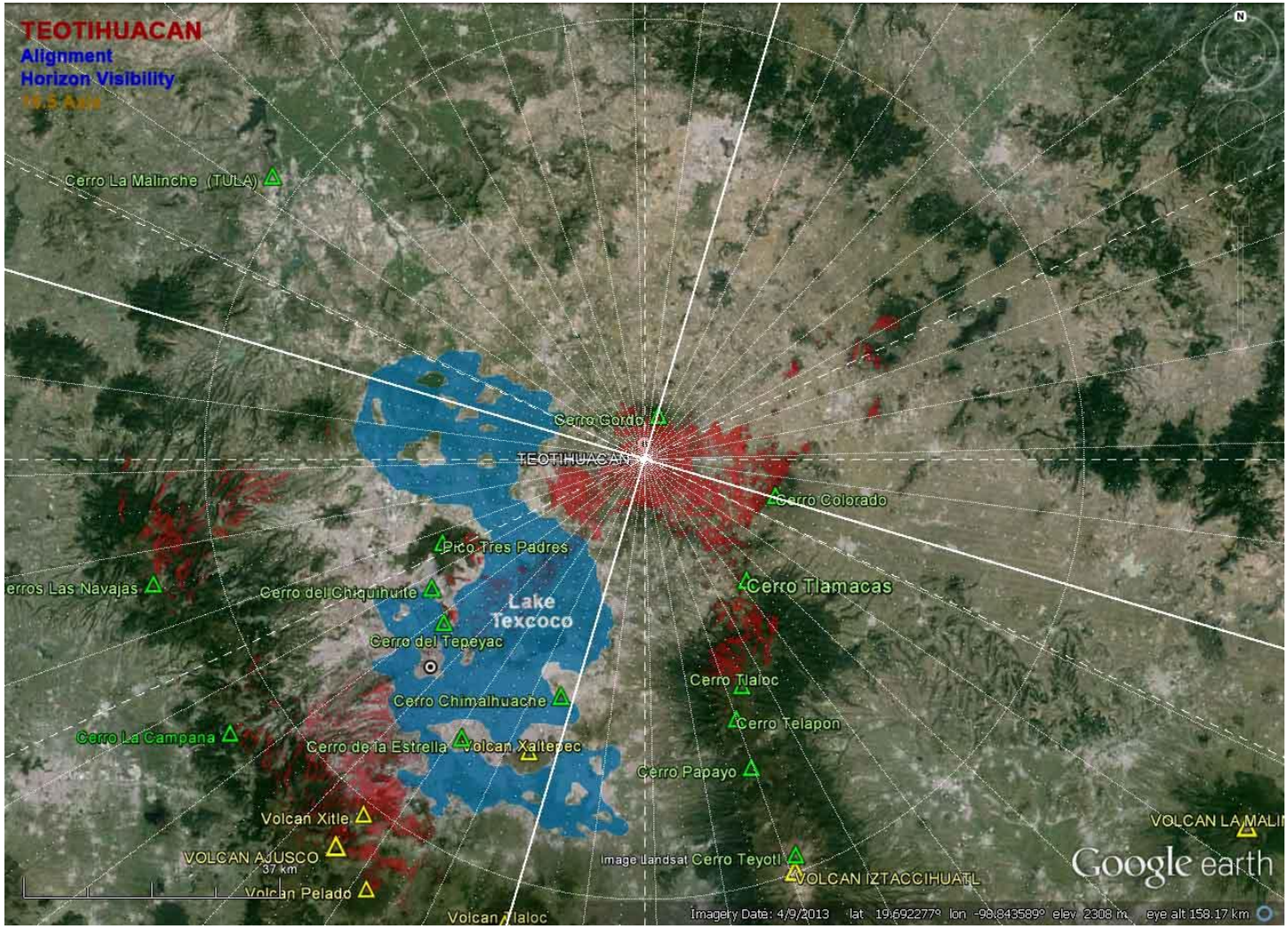


Figure 6.21. Alignment reference diagram superimposed on topographic landscape of Teotihuacan. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

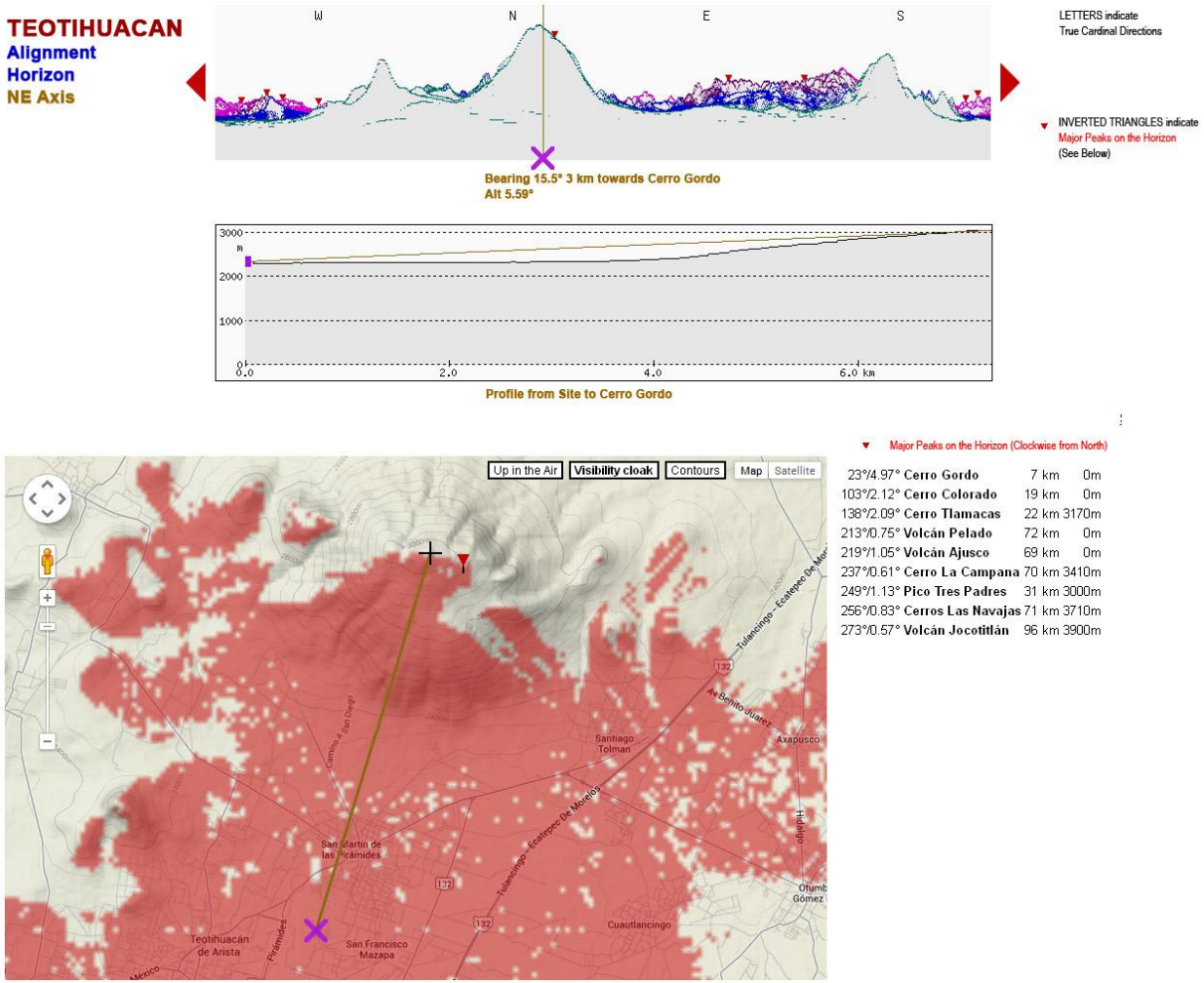


Figure 6.22. Alignment of Teotihuacan to Cerro Gordo along its the urban north axis, marked on diagram as NE axis (Map data: Google Maps and TA).

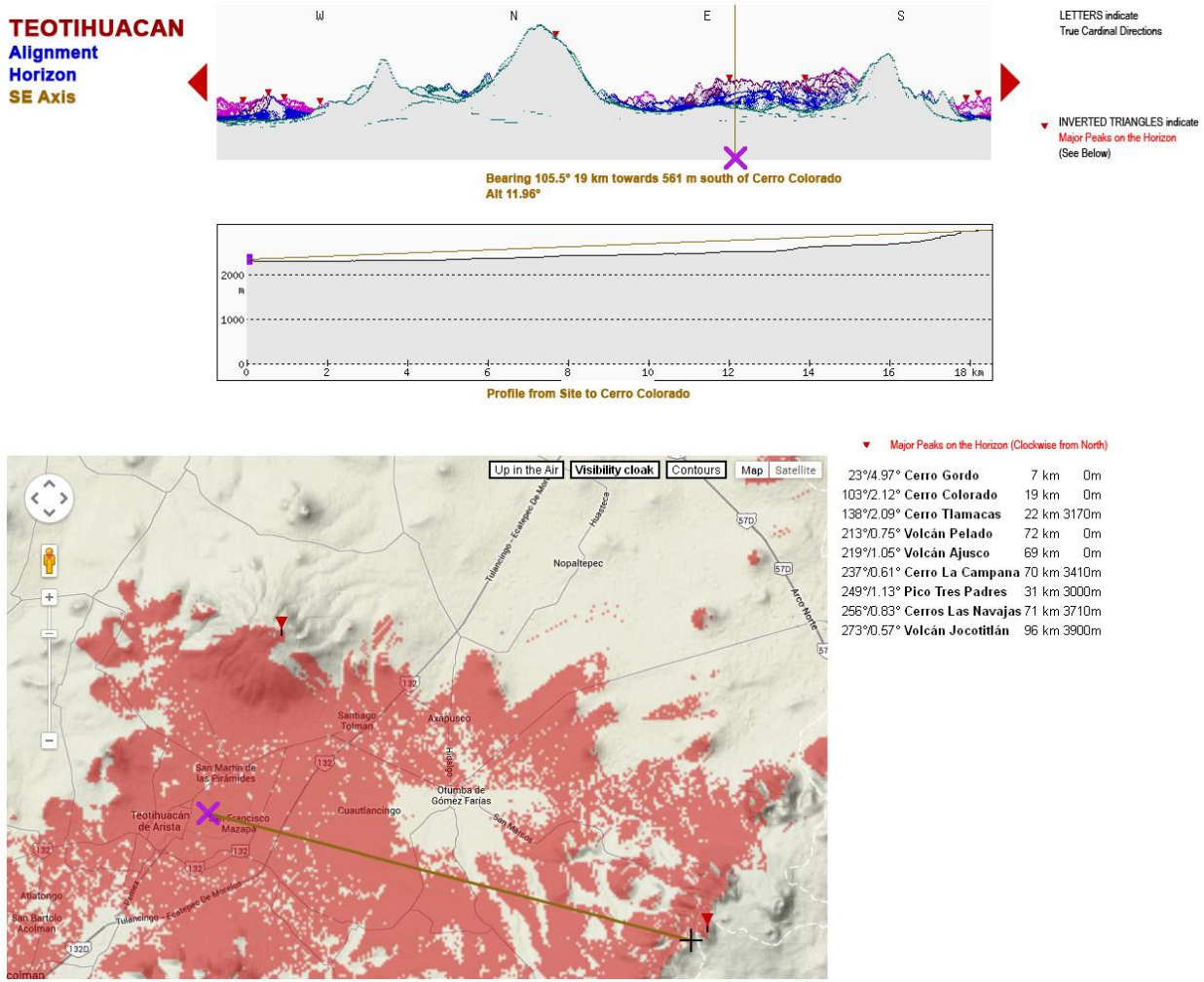


Figure 6.23. Alignment of Teotihuacan to a point 561 metres south of Cerro Colorado along its the urban east axis, marked on diagram as SE axis (Map data: Google Maps and TA).

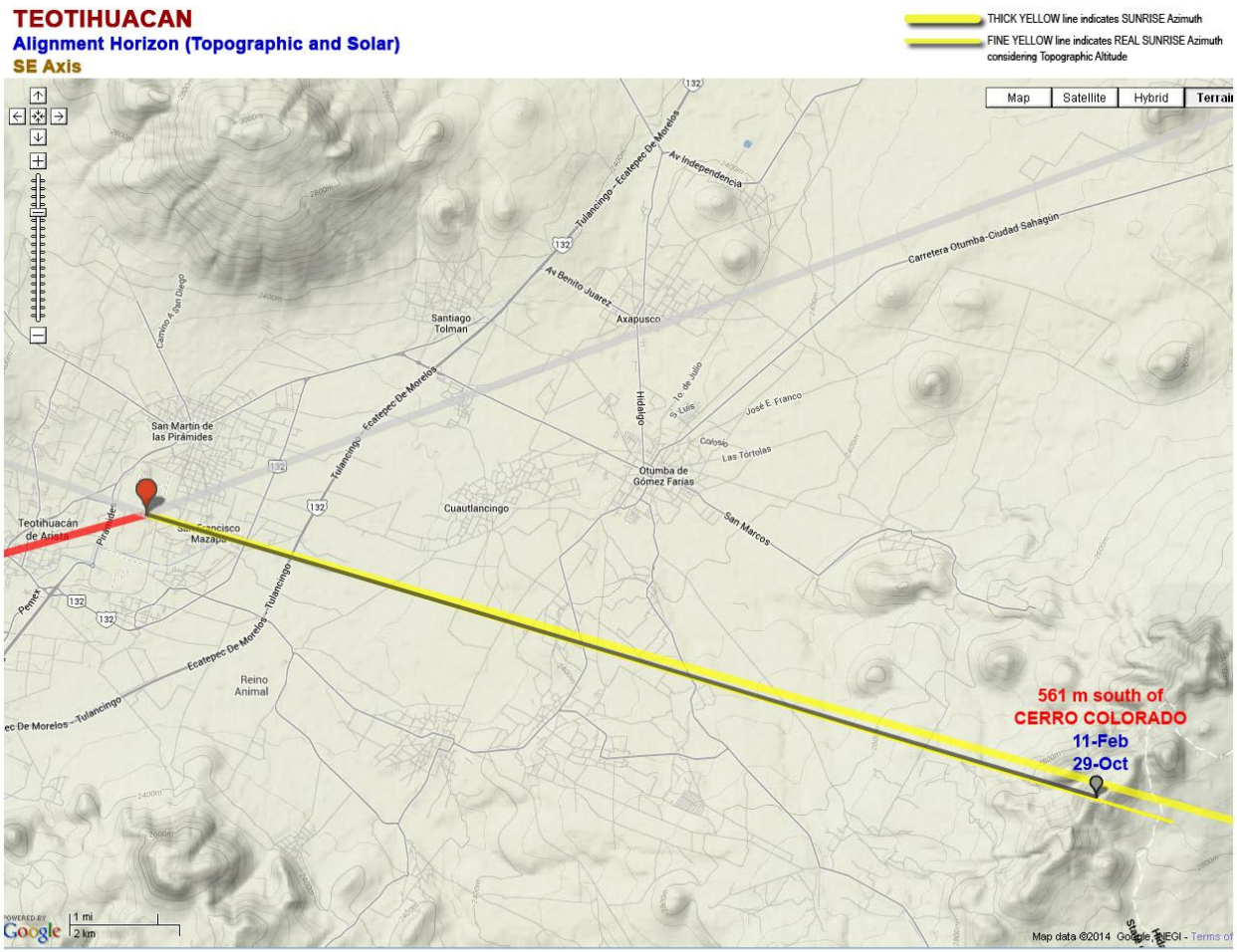


Figure 6.24. Position of the rising Sun along the 105.5° urban east-west axis of Teotihuacan considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

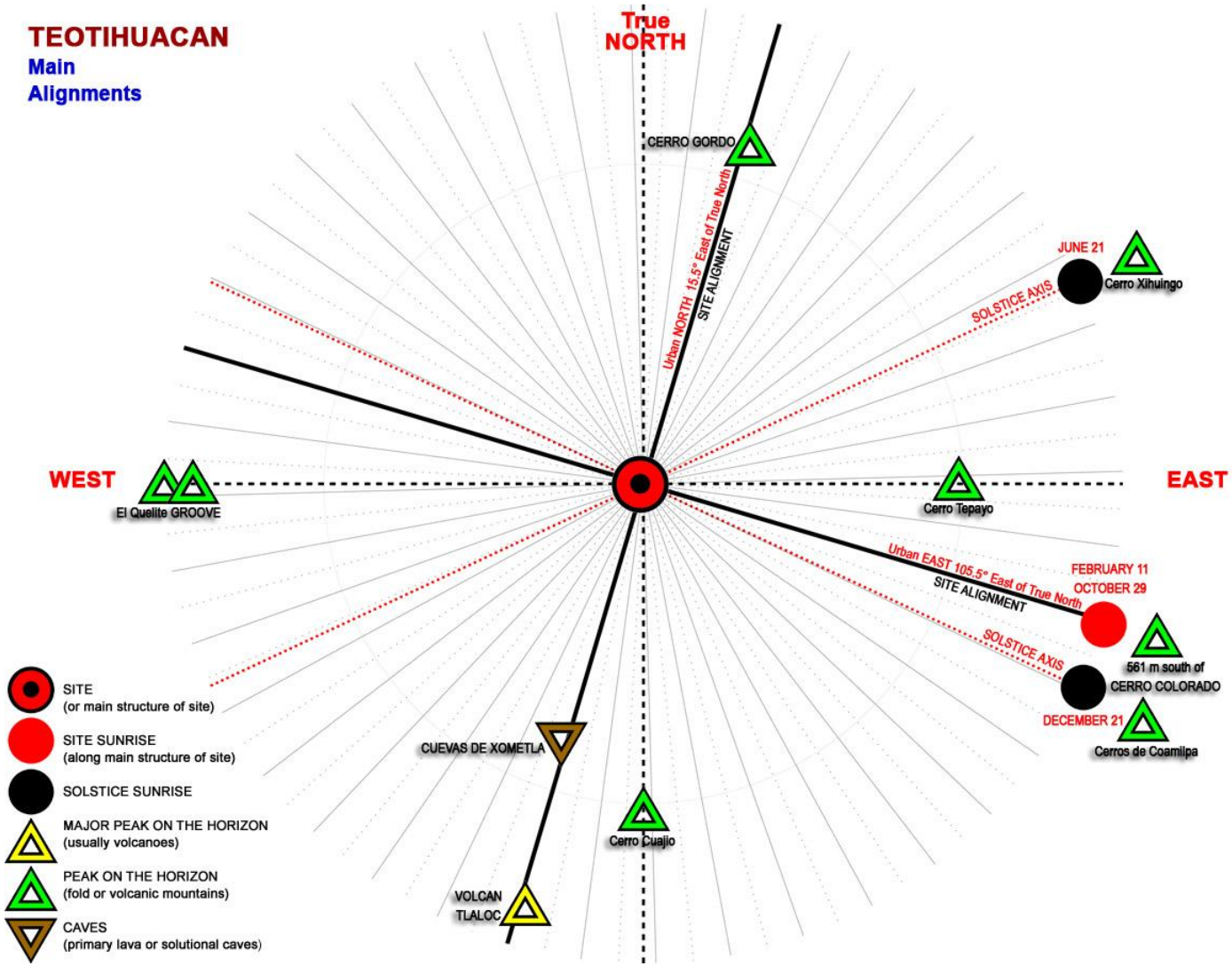


Figure 6.25. Main eastern alignments of Teotihuacan. True cardinal directions are indicated as black dotted lines; the main urban axes of Teotihuacan are indicated as black lines. The interactions between the urban north-south-east-west axes with the topography reveal the urban design principles of Teotihuacan.

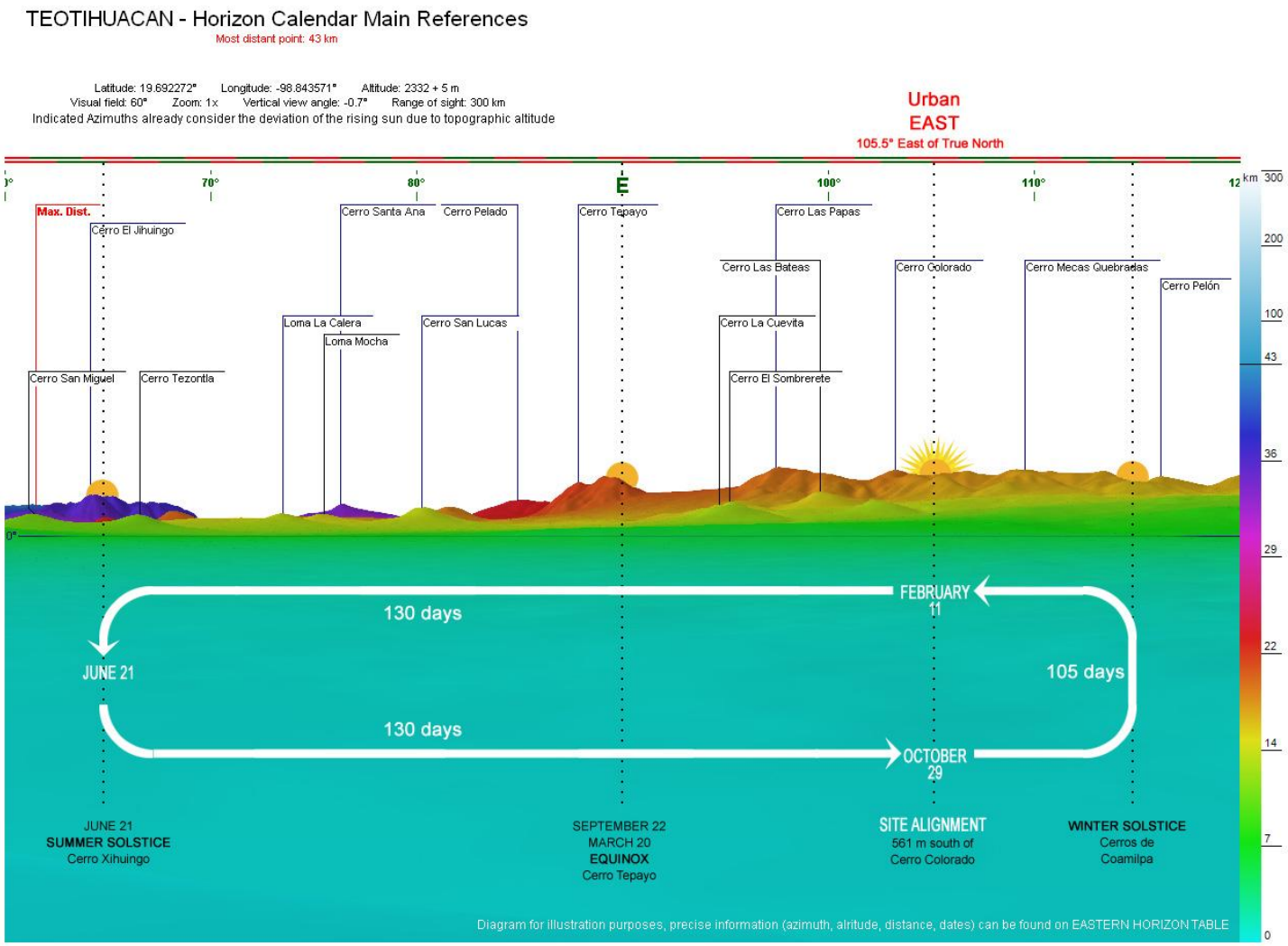


Figure 6.26. Main solar references on the 105.5° eastern horizon calendar of Teotihuacan and calendar cycle (Map data: Google, INEGI and UDI).

Figure 6.27 Viewpoints (clockwise) along the Avenue of the Dead towards the urban north axis where the Pyramid of the Sun and the Pyramid of the Moon emerge from Cerro Gordo. At the end of the spatial sequence, the Pyramid of the Moon becomes the Cerro Gordo (Map data: Google Street View).

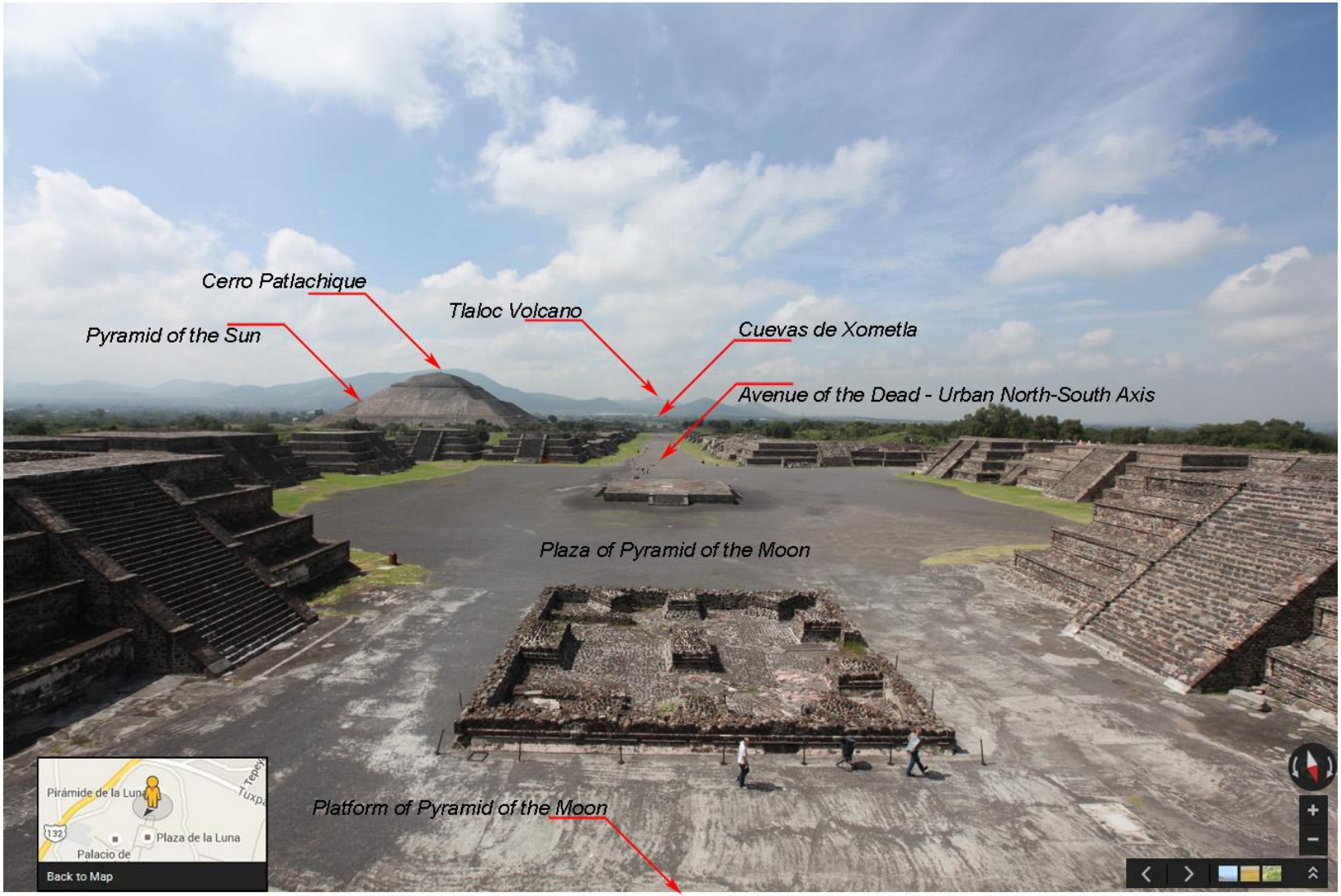


Figure 6.28. Viewpoint from the Pyramid of the Moon towards the urban south axis where the Pyramid of the Sun is an integral part of Sierra Patlachique in the southern horizon. Volcán Tlaloc marks the end of the spatial sequence that goes through the Cuevas de Xometla (Map data: Google Street View).

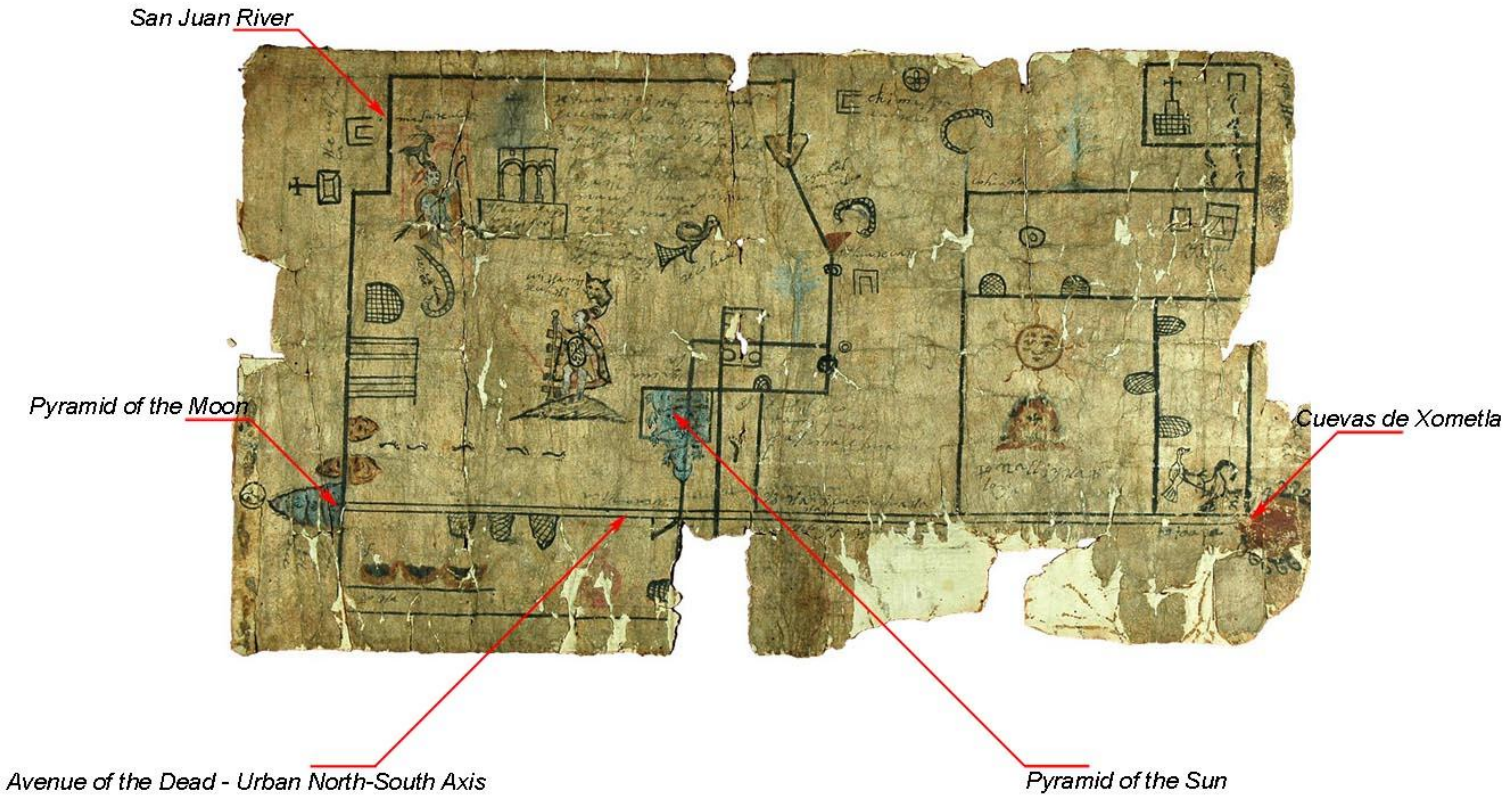


Figure 6.29. Mapa de San Francisco Mazapan, Teotihuacan (Mapa Saville) re-drawn around 1700 CE where the main urban axes are clearly depicted. The urban axes are marked by the Pyramid of the Moon on the left (north), the perpendicular axis of the Pyramid of the Sun (east) and the Cuevas de Xometla at the end of the axis (south) (American Museum of Natural History, New York, CC:BY-NC-SA 4.0).

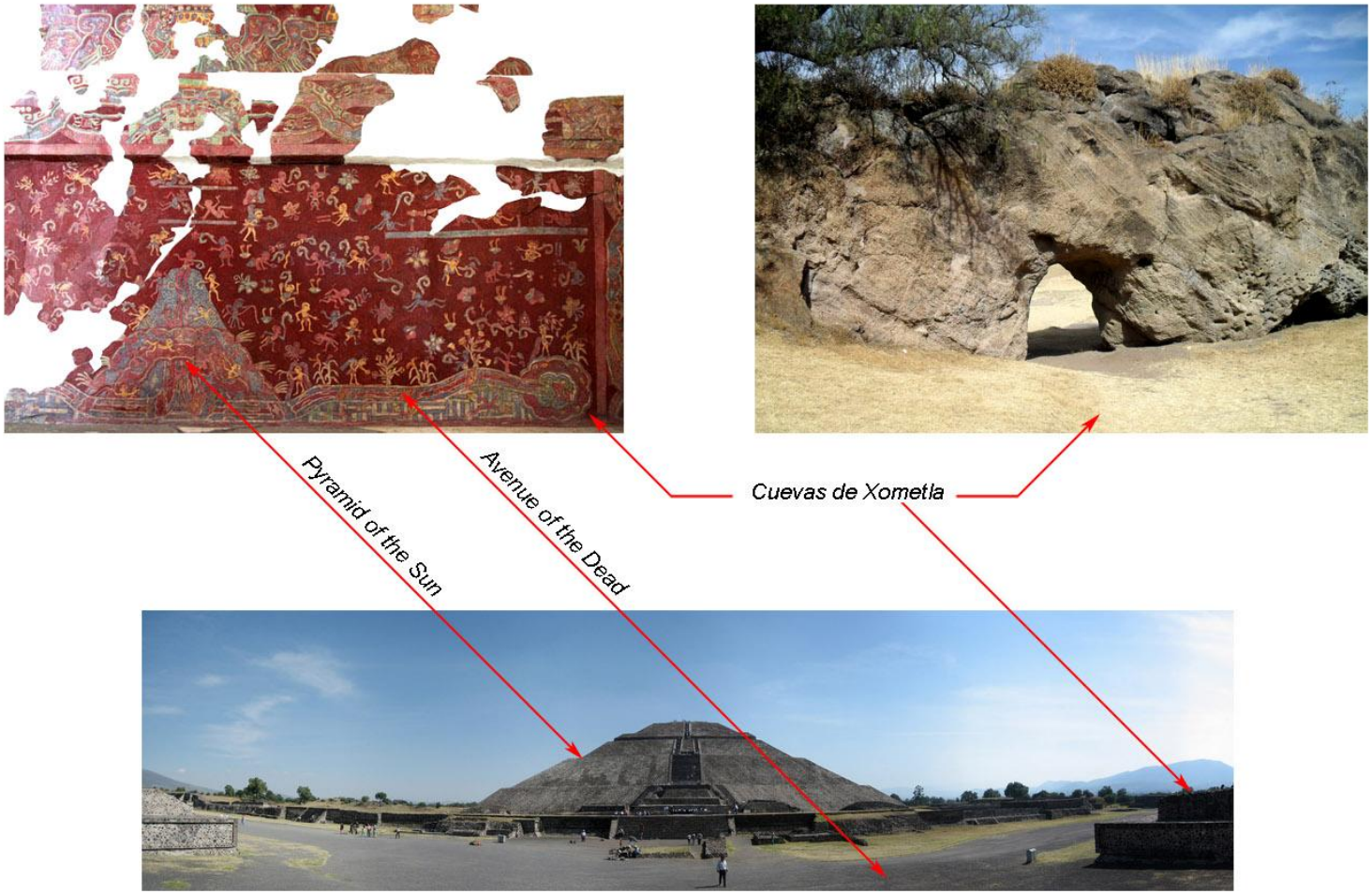


Figure 6.30. Proposed interpretation of the "Tlalocan" mural in Teotihuacan, where the large mountain (Pyramid of the Sun) is connected to a cave (Cuevas de Xometla) through a river (Avenue of the Dead) flanked by land parcels and maize plants; even the configuration of the stairs on the Pyramid of the Sun and the Tlalocan mountain are the same, as they are wide at street level and become more narrow as they reach the top. The graphic representation of the Cuevas de Xometla on the mural is also very similar to its representation on the Mapa Saville. The Pyramid of the Moon was likely depicted on the missing left part of the mural (clockwise, photographs by Jorge Ríos, Ejidos de Xometla and Carlos Sanchez - CC:BY-NC).

6.4.2 TULA

6.4.2.1 Historical Background

The site of Tula is located in the state of Hidalgo, 80 km north of Mexico City (Figure 6.31). Built on a mesa —an elevated flat area of land surrounded by steep terrain— between two rivers and a massive low mountain to the west, the city was the civic-ceremonial centre of Toltec civilization. Tula is also referred as "Tollan" in Aztec mythology, "although there is evidence that "Tollan" and "Toltec" are pan-Mesoamerican concepts whose origins may go back at least as far as Teotihuacan, if not earlier" (Mastache and Cobean 2012:373).

The site has produced evidence of initial habitation since the end of the Classic period (700-750 CE), when a civic-religious centre and several settlements were established on the northeastern area of the mesa and on nearby small mountains. Tula Chico, as this area is known, covered more than 5 square kilometers and, by 800 CE, its urban design was defined by a central plaza within an urban grid oriented to true north-south. All the streets, plazas and terraces in this period were built following this orientation. It is believed that the planning of the main plaza and the architecture of the buildings of Tula Chico, such as the pyramids, palaces and ball court, served as models for the structures that were built later on Tula Grande after Tula Chico was destroyed by the end of 900 CE (Mastache and Cobean 2001).

Around 1000 CE, the substantially larger civic-religious centre of Tula Grande was founded on the southwestern area of the mesa (Figure 6.32). Even though the organization of the buildings around a main plaza was kept in the urban design of the new centre, the position and orientation of the pyramids was modified. While the two main pyramids were situated side-by side along an *east-west* axis in Tula Chico, the pyramids in Tula Grande were located along two perpendicular axis, similar to the arrangement between the Pyramid of the Moon and the larger Pyramid of the Sun in Teotihuacan. Besides the change in size and design of the main plaza, a more radical modification was done to the orientation of the urban grid, as it was rotated clockwise 15° east of north. Like Tula Chico, the main civic-ceremonial plaza, streets, smaller plazas and terraces were built following this alignment. Even though the area had to be flattened and structures had to be

built on top of terraces and artificial hills, the main plaza compound arrangement of Tula Grande eventually became the urban model for the main precincts of many Postclassic Mesoamerican cities including several Aztec sites and Tenochtitlan (Mastache and Cobean 2001). This arrangement consisted of a central large plaza dominated by a large temple (Pyramid C) on the east; a ball court on the west; a smaller pyramid (Pyramid B) and an administrative and/or religious building (Building 3) on the north; and another smaller building (Building K) on the south. In addition to these structures, the compound also incorporated other architectural types such as a skull rack and a serpent wall. By 1050 CE, Tula was the most important economic, political and religious centre in Central Mexico organized in a complex urban system of streets and causeways linking different areas of the city that covered more than 15 square kilometers (Mastache and Cobean 2001). According to Mastache and Crespo (1982:28), it seems that the orientation of the urban grid was changed again from 15° to 18° at the end of the eleventh century, which entailed the construction of more terraces and buildings. However ,this time the change in the orientation in the urban grid did not affect the main plaza compound and its surrounding area (1982:28).

The causes of the destruction of Tula by the end of the twelfth century are unknown. Since its demise, archaeological evidence has revealed that the Aztecs consistently excavated and exhumed objects from Tula. They believed these "objects were imbued with the power of the gods who once dwelled in what the Aztecs considered Tollan, as well as an attempt to legitimize their claim to being Tollan's rightful heirs" as López Austin and López Lujan have argued (Mastache and Cobean 2012:380). Furthermore, they must have analyzed its architecture and planning principles, as the Aztecs later applied them in the urban plan of Tenochtitlan and its main ceremonial precinct as well as in the architectural design of its buildings (Chapter 3:121).

Excavations in Tula have been undertaken intermittently since 1858 when Désiré Charnay was commissioned by the French government to photograph and record ancient monuments. However, modern archaeological exploration started in 1940 with Jorge Acosta who lead an INAH project for 18 years, and continued in the late 1960s and 1970s with major projects conducted by the INAH and the University of Missouri which performed extensive surveys and excavations. Later excavations were conducted by INAH scholars and other institutions in the

1980s and 1990s, but large unprotected areas of the ancient Tula still remain unexplored (Healan 2012:103). Currently, the main parts of the cities (Tula Chico and Tula Grande) lie in the *Zona Arqueológica de Tula* (Figure 6.33).

6.4.2.2 Previous Archaeoastronomical Research

Studies to explain the orientations of Tula have been scarce. Even though the variation in the orientations of Tula were evident in the surveys carried out with aerial photography and field compass by Mastache and Crespo (1982), they did not postulate any theory to interpret them. Meanwhile, Aveni and Gibbs (1976:Table 1) measured the orientation of several structures in Tula Grande and concluded that it belonged to the 17° family of orientations originating in Central Mexico (Aveni 2001:234). However, after Šprajc measured the 13.0°±1° azimuth of Pyramid C, he postulated the theory that its orientation to the sunset on April 30 and August 13 made possible a horizon calendar to the west, although he did not exclude the possibility of a horizon calendar to the east (2001a:284).

6.4.2.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the theories proposed by Aveni and Šprajc, the methodological steps for performing the digital and archaeoastronomical analysis were followed meticulously, even though they were not necessarily performed consecutively again as every step involved cross referencing solar, topographic and cultural information. Therefore, the analysis began by determining the coordinates of the main structure of the site—Pyramid C—which were defined as 20.063485, -99.341232. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of the city from these coordinates. These viewshed calculations placed into topographic context prominent features on the horizon of Tula such as the massive Cerro Magoni to the west and the Cerros de Ajoloapan, a distinct mountain range also called Sierra Mesa Grande located 27 km away.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.34). To this end, the azimuths of Pyramid C were measured, but it soon

became clear that the western sides of the platforms did not have a consistent alignment as they varied from 11.25° to 12.66°. However there was not a substantial variation on the southern sides of the platforms that measured 103.36° ±0.5°. Since the platforms of Pyramid C were partially reconstructed, the azimuths of other structures in the main plaza were measured, obtaining average azimuths of 13.5°±0.5 east of true north for the urban north-south axis and 103.5°±0.5 east of true north for the urban east-west axis. This alignment reference diagram was superimposed on Google Earth with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

These explorations lead to a more detailed analysis of the urban east-west axis, which resulted in the finding that this axis runs from Cerro Magoni to Cerros de Ajoloapan (also called Sierra Grande), a mountain range characterized by the abundance of thermal springs and caves (Figure 6.35 and Figure 6.36). This is, interestingly, the same mountain-caves-springs relationship that Teotihuacan had between Cerro Gordo and the Cuevas de Xometla. Therefore, the results obtained in this step not only reinforced again the theories initially proposed by Heyden, but also supported the theory argued in this research that this mountain-caves-springs alignment urban design principle was applied during the planning of the city regardless of the direction of this axis.

Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align to the position of the rising and the setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction. Due to the location of Tula on a mesa, the altitude of the local topography affected the solar elevation particularly to the west due to the size and proximity of Cerro Magoni, so both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from Pyramid C, the urban east axis intersects the rising Sun on the local eastern horizon on February 15 and October 26 at a 103.5° azimuth, 1.77° altitude and a distance of 27 km (Figure 6.37); while the urban west axis intersects the setting Sun on the local western horizon on April 30 and August 13 at 283.5°

azimuth, 5.66° altitude and a distance of 1.0 km. While these measurements confirmed the dates obtained by Šprajc (2001a:281), the analyses suggest that the most feasible horizon calendar is to the east as the movement of the Sun could be tracked with clear reference points of the horizon. Similar to Teotihuacan, the rising Sun on its main urban east axis is framed by two mountains.

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and the setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on Jun 21 (plateau on Cerro Munitepec), September 22 (Cerros de Ajoloapan and Las Lumbreras Springs), December 21 (Cerro Blanco) and March 20 (Cerros de Ajoloapan and Las Lumbreras Springs) on the eastern horizon. The same set of calculations were performed for the western horizon, but it became apparent that alignments to topographic features towards this direction were not easy to identify due to the proximity of Cerro Magoni. However, the position of the Sun on the winter solstice could be clearly seen on top of Cerro la Bruja at a distance of 8.3 km. This suggests that it is possible that both horizon calendars were functional at the same time. While the eastern horizon calendar provided more precise intervals, the western horizon calendar served to adjust relevant dates.

Once all of the information was determined, it was summarized in a diagram (Figure 6.38) and a table which included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons This table was utilized to plot the main solar reference points for the either the eastern (Figure 6.39) or western horizon calendar of Tula. This information was also used to calculate the days between the alignment of Tula and the solstitial and equinoctial solar dates, which resulted in the division of the year in three main intervals:

- Horizon calendar on the eastern horizon (103.5° urban E-W axis)
  February 15 > 105 days > October 26 > 130 days > June 21 > 130 days > February 15

- Horizon calendar on the western horizon (285.5° urban E-W axis)

April 30 > 260 days > August 13 > 53 days > June 21 > 52 days > April 30

Similar to the results obtained in Teotihuacan, these calculations confirmed the theories suggested by Aveni and Hartung (1986), Tichy (1990) and Šprajc (2001a) among others, that horizon calendars could be built utilizing topographic features on the horizon. They also validated the theories argued in this research that once the main sunrise or sunset locations of the alignments, equinoxes and solstices of the site had been carefully established, additional dates could be plotted on the horizon every 13 or 20 days to either prominent peaks, spaces between smaller peaks, the base of a prominent peak or any other topographic feature that could be easily distinguished from the site as these analyses have suggested. Furthermore, they reinforced the theory proposed in Teotihuacan that the urban design of the city had to express the mountain-cave-spring relationship in its urban axis.

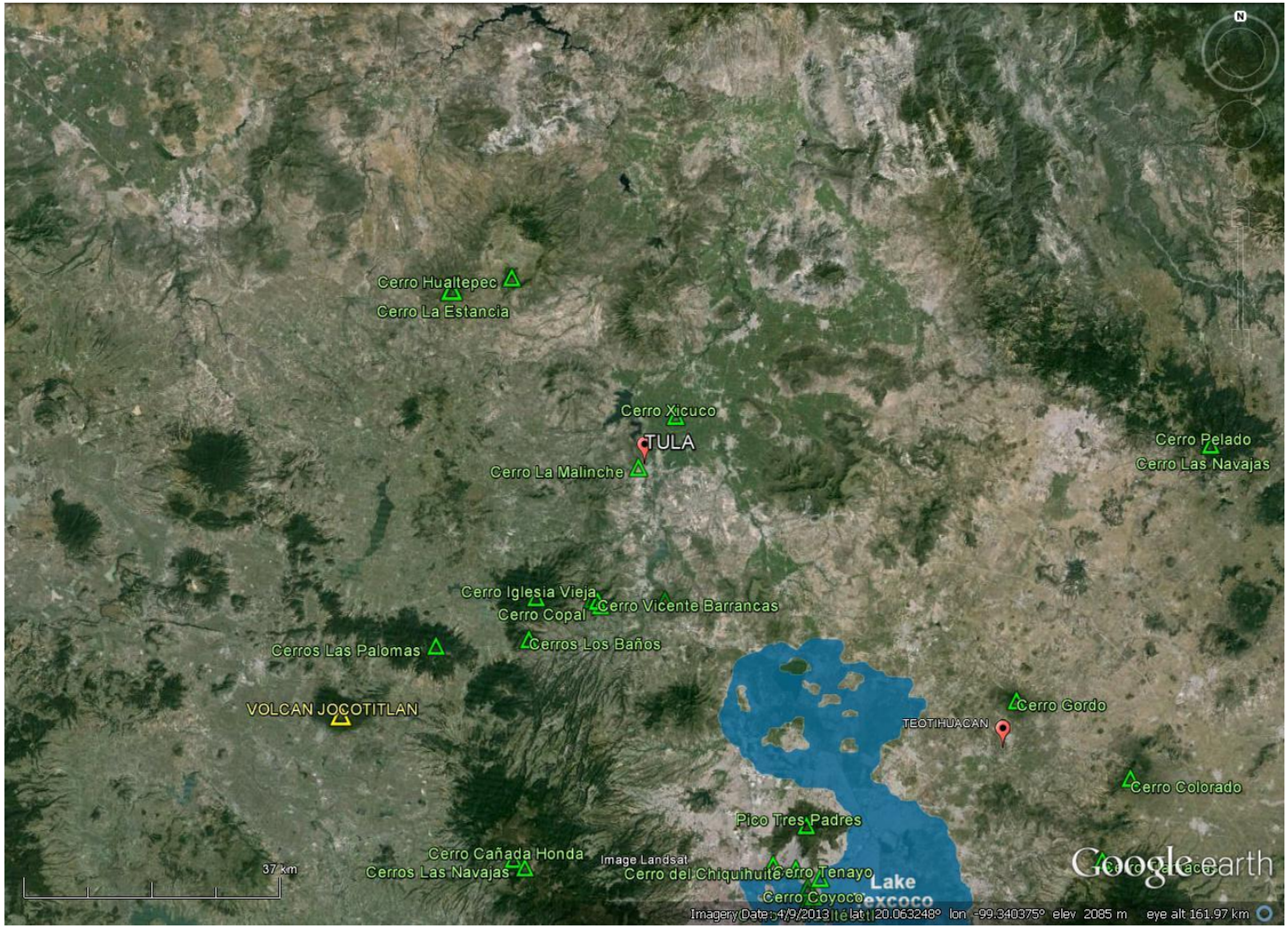


Figure 6.31. Location of Tula indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

Figure 6.32. Aerial view of the archaeological remains of Tula, scale 1:200 (Map data: Google Earth).

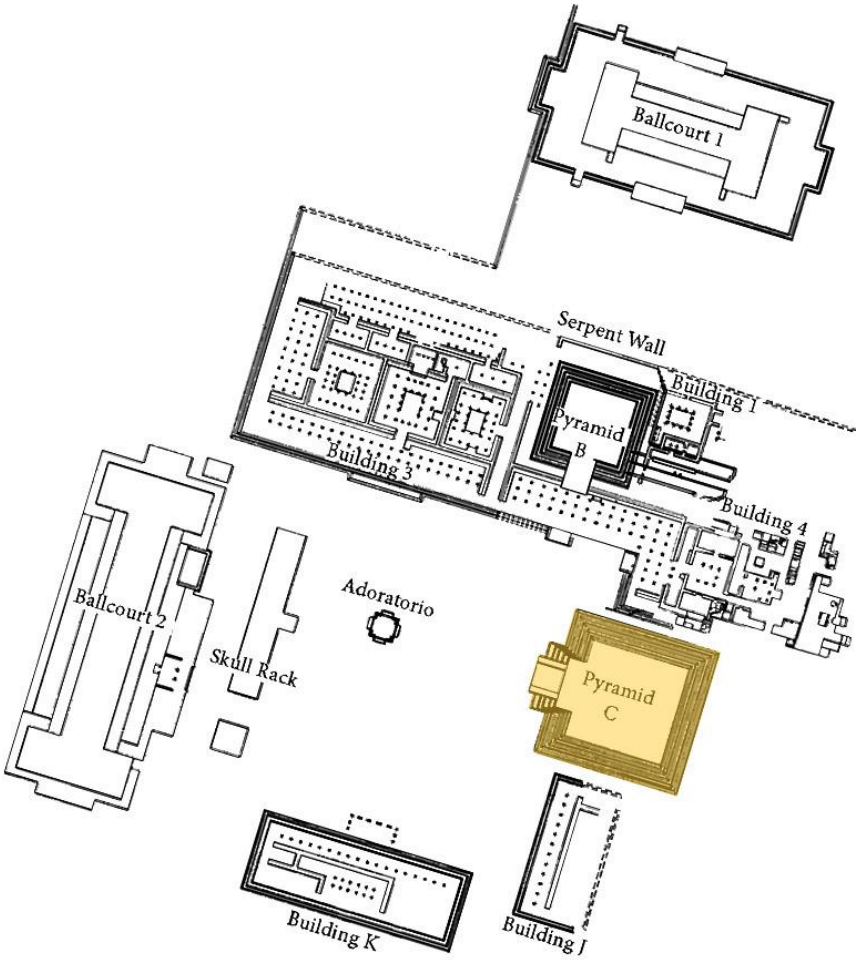


Figure 6.33. Plan of archaeological remains of Tula (Mastache and Cobean 2012:Figure 26.4).

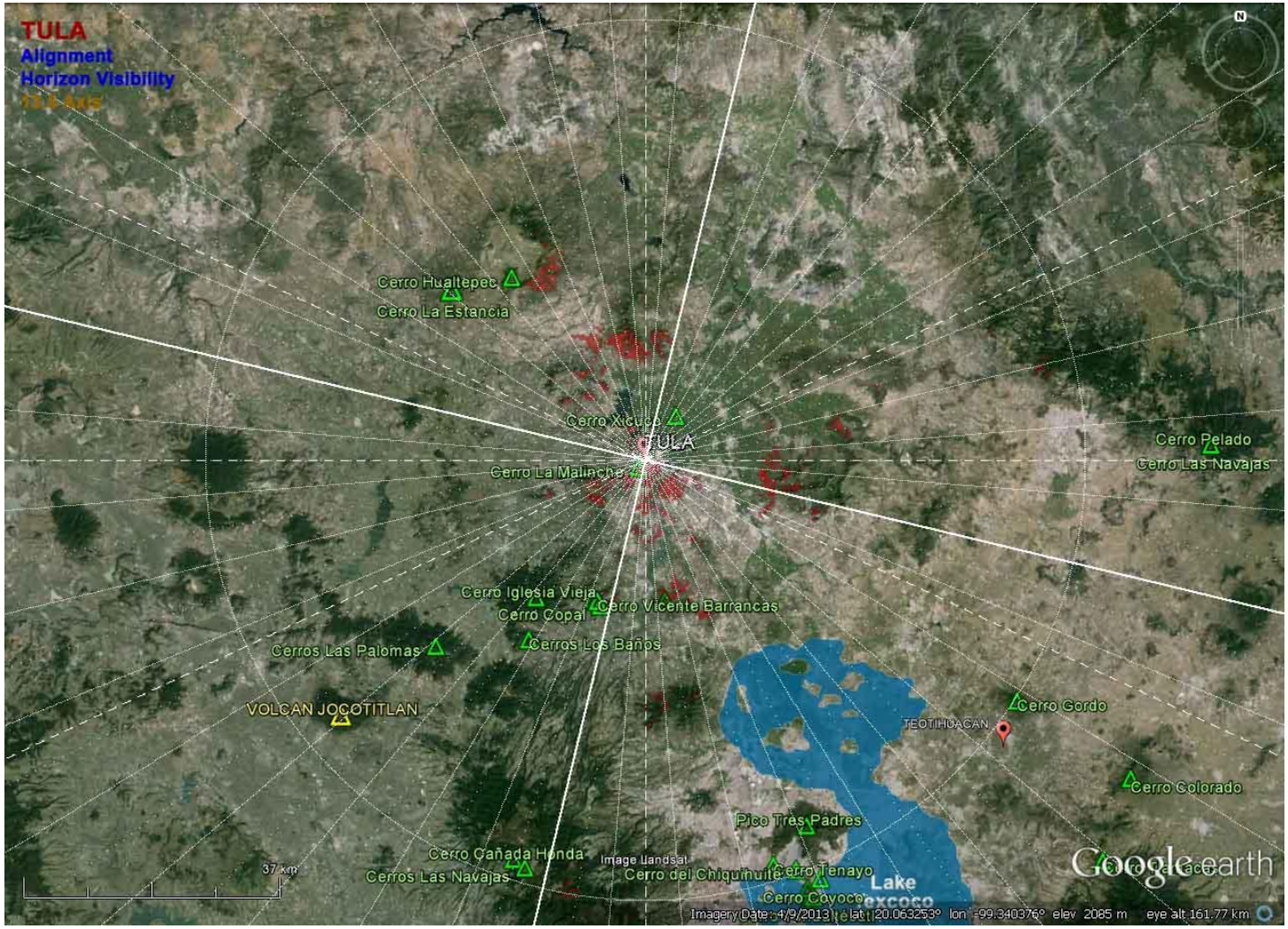


Figure 6.34. Alignment reference diagram superimposed on topographic landscape of Tula. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

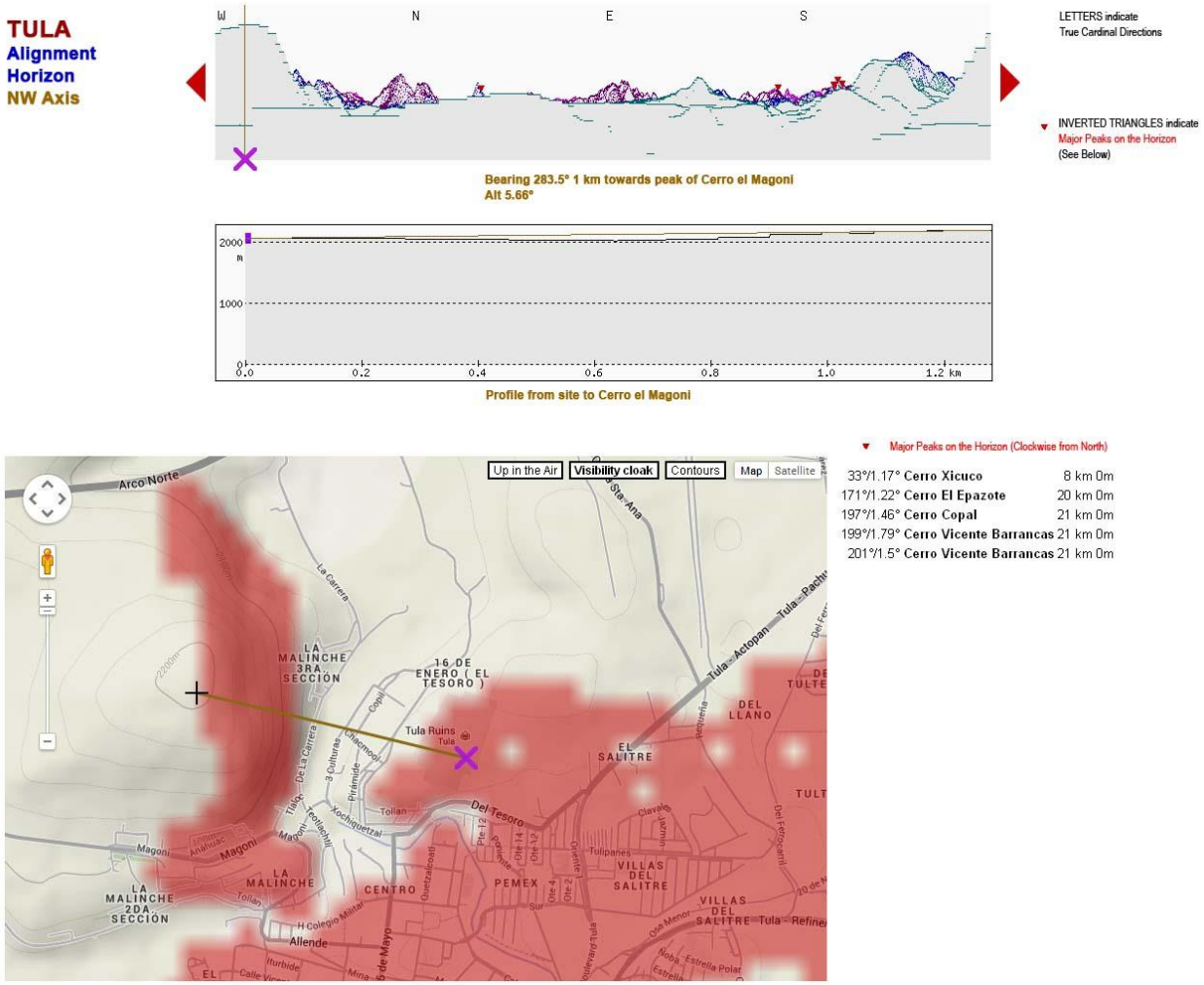


Figure 6.35. Alignment of Tula to Cerro el Magoni along its urban west axis, marked on diagram as NW axis (Map data: Google Maps and TA).

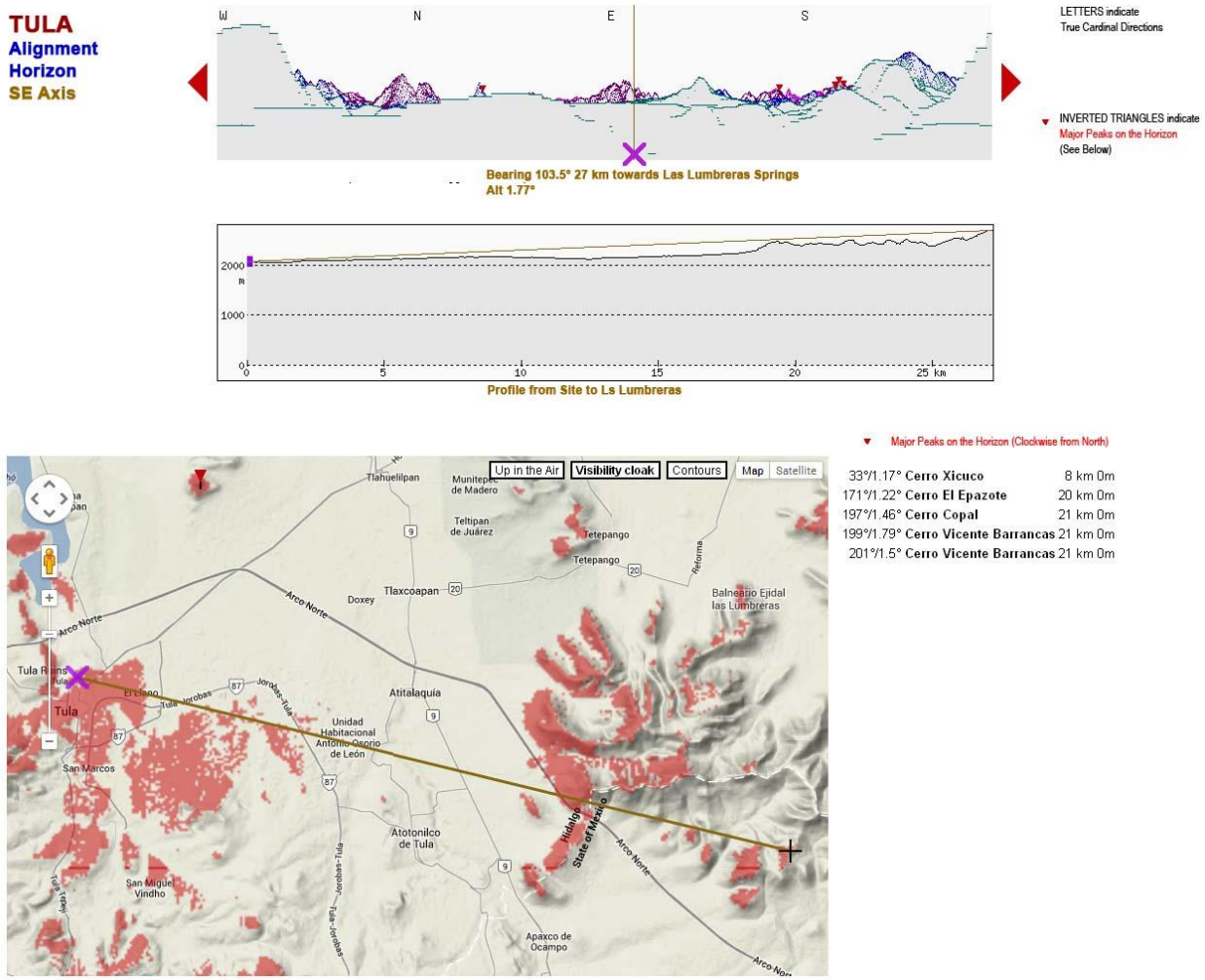


Figure 6.36. Alignment of Tula to las Lumbreras Springs along its urban east axis, marked on diagram as SE axis (Map data: Google Maps and TA).

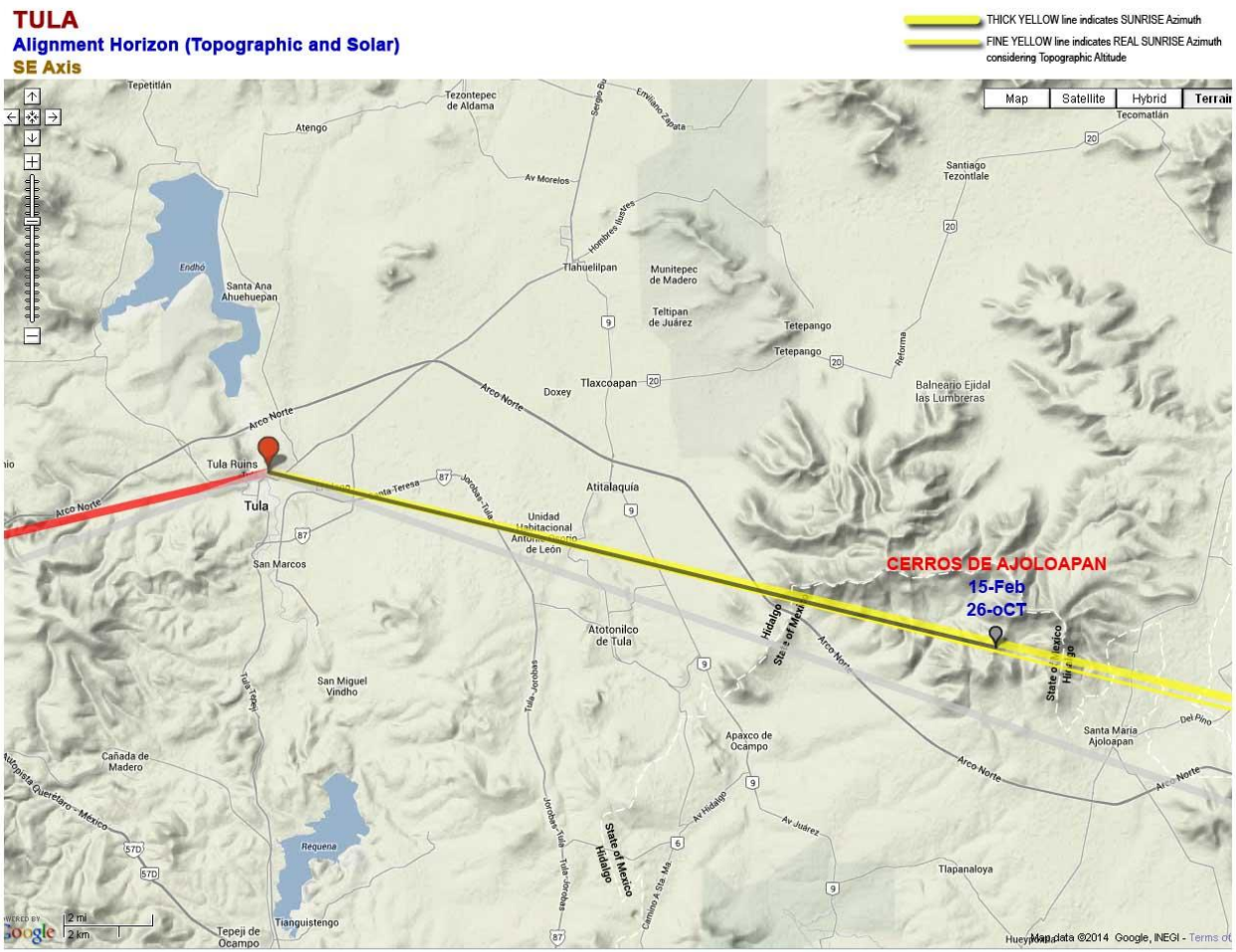


Figure 6.37. Position of the rising Sun along the 103.5° urban east-west axis of Tula considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

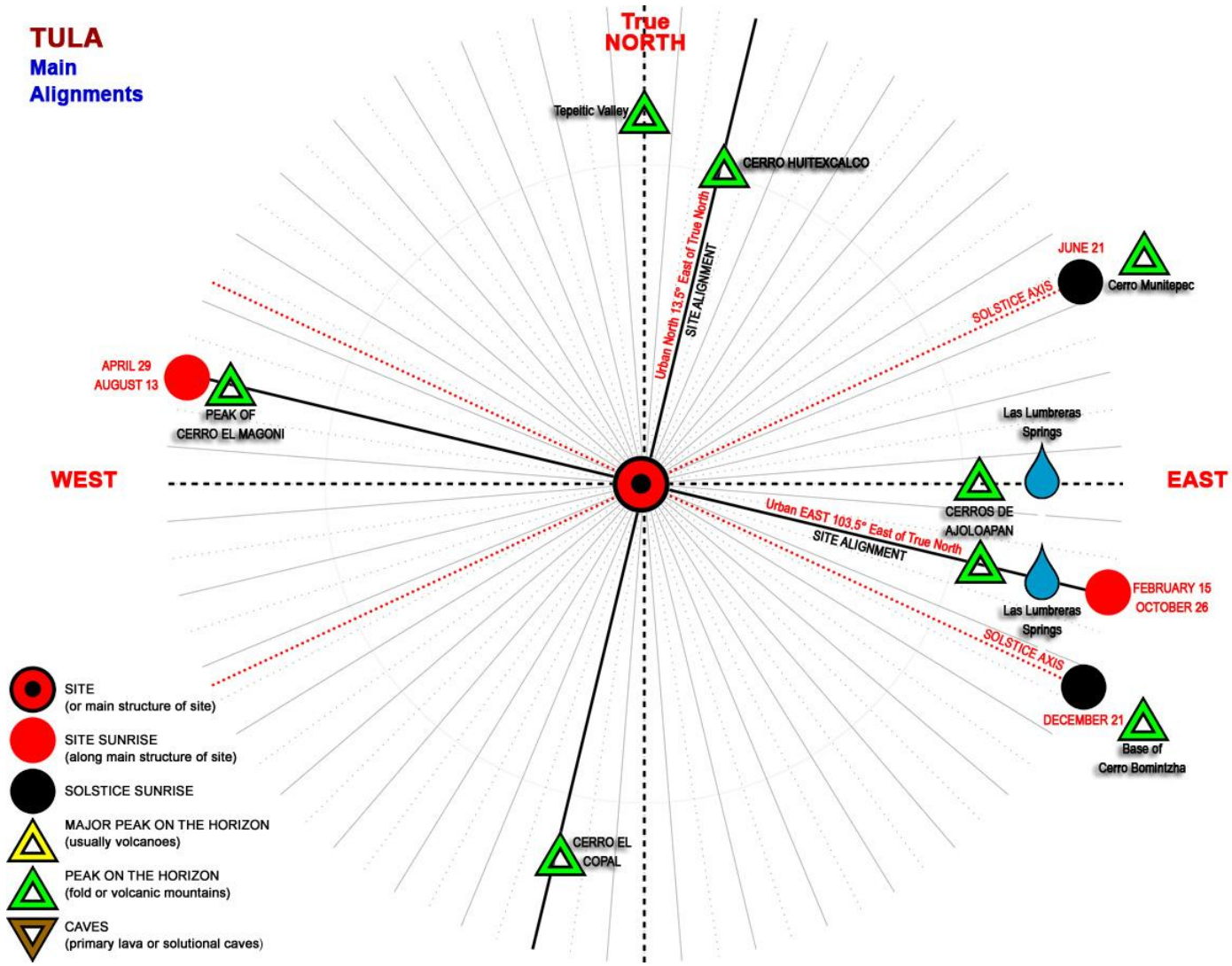


Figure 6.38. Main eastern alignments of Tula. True cardinal directions are indicated as black dotted lines; the main urban axes of Tula are indicated as black lines. The interactions between the urban north-south-east-west axes with the topography reveal the urban design principles of Tula.

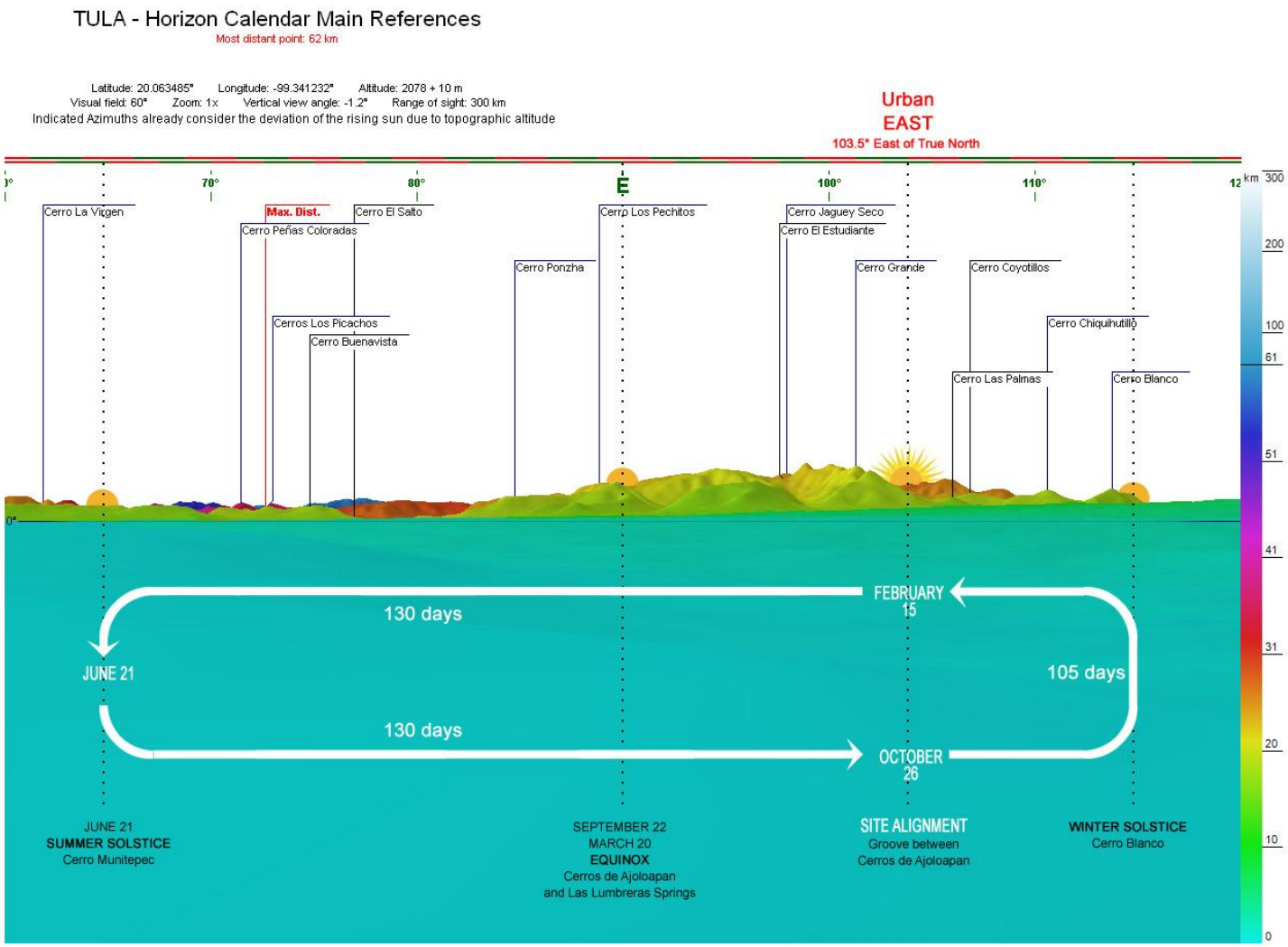


Figure 6.39. Main solar references on the 103.5° eastern horizon calendar of Tula and calendar cycle (Map data: Google, INEGI and UDI).

6.5 Archaeoastronomical Analyses of Selected Aztec Sites

6.5.1 TENOCHTITLAN

6.5.1.1 Historical Background

The site of Tenochtitlan is located under what is now Mexico City. Built on a carefully planned system of artificial islands (chinampas, Figure 3.17), causeways and canals, the city was the capital of the Aztec empire. Even though the urban area covered an expanse of about 12-15 square kilometers (Sanders, Santley, and Parsons 1979:54), only the Templo Mayor and its surrounding area, including four small temples, a portion of the precinct of the Eagle Warriors (Figure 3.4), the Coyolxauhqui (Figure 4.2 (b)) and Tlaltecuhtli monumental sculptures and a quauhxicalli (Figure 3.9), have been unearthed. Additional portions of other buildings, such as the calmecac (Figure 3.10), tzompantli (skull rack, Figure 3.5), in addition to single and circular base temples (Figure 3.1 and Figure 3.3), have also been excavated, although some of them remain underground.

Tenochtitlan has produced evidence of initial habitation since 1325 CE, the official foundation date of Tenochtitlan, when the settlers built a temple in honour of Huitzilopochtli (Figure 4.2 (a)) on an artificial island created in the middle of Lake Texcoco on marshy land; soil mechanics studies have proved that there was no natural island in this location (Mazari, Marsal and Alberro 1983:179). Between 1350 and 1450 CE, the power and influence of the Aztecs grew through substantial military expansion, and following the Tepanec war of 1428 CE, they began to redesign their city utilizing Teotihuacan and Tula as urban and architectural models in order to demonstrate their power and acquired wealth. The entire urban area of Tenochtitlan was "carefully planned and rebuilt according to fundamental political, religious and practical reasons." By the time the Spanish arrived in 1519 CE, its elements of urban planning were clearly defined. The island city was laid out on an uniform urban grid rotated clockwise 96.5°±0.5° east of true north and connected to the mainland by causeways that divided the city in four major districts. The major causeways originated at a central ceremonial precinct and the

districts were organized in smaller wards called calpulli, built on chinampas interconnected with canals, streets and minor temple complexes (Smith 2003:184-187).

The central area of Tenochtitlan held the ceremonial precinct, an area approximately 225 maitl by 260 maitl (Clark 2010:161), equivalent to 376.2 meters by 434.72 meters, where the Templo Mayor —the double temple dedicated to Tlaloc and Huitzilopochtli— dominated the large enclosed plaza (Figure 5.34 (b)). According to Sahagún, the sacred precinct included at least 78 buildings laid out hierarchically among the main axes of the Templo Mayor (Chapter 2:64). While major structures such as the precincts of the eagle and jaguar warriors (Figure 3.4), the tzompantli (skull rack, Figure 3.5), tlachtli (ball court, Figure 3.6), calmecac (school, Figure 3.10) and temples to gods like Quetzalcoatl (Figure 3.3) and Tonatiuh were organized around these axes, other temple complexes, that also included these architectural types in a smaller scale, were also located among the larger structures. There is widespread agreement among scholars such as Heyden (2000), Smith (2008b), López Austin and López Luján (2009), and Matos (2009), that the Aztecs incorporated urban and architectural traits of Teotihuacan and Tula into the urban plan and architecture of Tenochtitlan. They imitated the urban design of the city on an orthogonal grid along a main axis from Teotihuacan and the spatial arrangement of the ceremonial precinct from the main plaza plan in Tula, which consisted of the use of Mesoamerican building types and the placement of the largest temple along its *urban east-west axis* facing west (Chapter3:121). Moreover, scholars concur that the Huey Teocalli (Templo Mayor) located in the main ceremonial precinct of Tenochtitlan was the centre of the Aztec world.

Accidental discoveries in the central area of Mexico City have been numerous as the Spaniards razed Tenochtitlan and built their new capital on top of the old city utilizing the remains of the Aztec buildings as foundations or construction material (Mazari, Marsal and Alberro 1983:179). However, modern archaeological explorations started in 1900 when Leopoldo Bartres conducted salvage excavations of a structure that decades later turned out to be Templo Mayor (Figure 6.40). Since then, archaeological excavations have continued with large projects such as the Templo Mayor project and the ongoing Programa de Arqueología Urbana; these have yielded invaluable urban and architectural information that has complemented the information from

ethno-historical sources. Currently, the excavated part of the ceremonial precinct of Tenochtitlan lies in the *Zona Arqueológica Templo Mayor* (Figure 6.41).

6.5.1.2 Previous Archaeoastronomical Research

Even though studies to explain the orientations of Tenochtitlan have not been as abundant as those of Teotihuacan, several theories have been proposed by scholars such as Aveni and Gibbs (1976), Aveni, Calnek and Hartung (1988), Galindo (1994) and Šprajc (1999b, 2001a), among others. They all agree that the clockwise deviation between 6.5° and 7.5° of the urban east-west axis must have obeyed to astronomical considerations, however they differ slightly in three aspects: the viewing point, the dates and the event being commemorated by the alignment.

Aveni and Gibbs proposed that the orientation of the temple must have been chosen to view the sunrise between the two temples on top of the Templo Mayor during the equinox as ethnohistoric sources had described. They argued that despite a deviation of a few degrees to the east, an observer on the temple of Quetzalcoatl, theoretically located in front of the Templo Mayor, could view the sunrise between the two temples (1976:513-516). This theory relied on two uncertain variables, the height of the Templo Mayor and position of the temple of Quetzalcoatl (Figure 6.3). The uncertainty of these variables also meant that each time the Templo Mayor was enlarged, the size and position of temple of Quetzalcoatl needed to change as well, hence the theory was difficult to support as there were no ethnohistoric and archeological records mentioning these changes.

Several years later, Aveni, Calnek and Hartung (1988) reconsidered the theory that the equinox must have determined the orientation of the Templo Mayor. In this study, they suggested that the Sun came out for the Cerro Telapon and Cerro Tepetzinco 20 days before and after the spring equinox and thus created an eastern horizon calendar organized by veintenas (20-day periods). They assumed that the alignment to Cerro Tepetzinco must have coincided with the spring equinox and the festivals that took place the last day Aztec month of Tlacaxipehualiztli. Even though Cerro Tepetzinco lies below the eastern horizon and is hence an unlikely reference point for a calendar, they brought into the orientation discussion the connection between the Templo

Mayor and Cerro Tlaloc, a tetzacualco (mountain shrine) where pilgrimages and sacrifices were made "at the height of the dry season, to call forth rain from the mountain and to initiate the season of regeneration and agriculture" (Townsend 1991:28) (Figure 4.15). What is more, they presented ethnohistoric evidence that clearly defined directional references to mountain peaks and caves located to the east and north in the foundation of Tenochtitlan by citing the passage in the Crónica Mexicayotl where Alvarado Tezozomoc described this event:

> and they saw that rocks and caves stood face to face.
> The first rock and cave were seen where the Sun rises
> and is called: Fire Water, Where
> the Water is Burning.
> And the second rock and cave were
> seen in the direction of the realm
> of the dead [the north]
> *—therefore they cross each other—*
> It is called Blue Water
> and its name is Yellow Water.
> And when they had seen that,
> the old people cried, and said:
> "So this will be the place,
> for we have seen what
> has been told and explained to us
> by the priest Huitzilopochtli. . . . "
> (Aveni, Calnek and Hartung 1988:292)

This passage demonstrated what the Aztec priests were looking for during their pilgrimage around Lake Texcoco: the precise intersection point between the axis of the rising Sun and the axis of a mountain to the north. Hence, in spite of not exploring this information further, Aveni, Calnek and Hartung provided the foundations for further exploration of the orientation of the Templo Mayor.

Taking into consideration the systematic archaeological research carried out in the 1980s and 1990s that revealed that important civic and ceremonial buildings in Mesoamerican sites were mostly oriented to the position of the rising or setting Sun on certain dates of the tropical year which frequently did not coincide with the solstices and equinoxes, Šprajc (1999b, 2001b) measured the orientation of 37 archeological sites in Central Mexico. His aim was to explore if these dates could be interpreted in terms of their relevance in the agricultural cycle and the

computations related to their calendar system as archaeoastronomers such as Tichy had suggested (1990). Even though his results coincided with the previous theories, they differed in the structure and operation of the horizon calendars. He demonstrated that important civic and ceremonial buildings were not only oriented towards sunrise or sunset on a particular date, but they were also built on precise locations where the prominent peaks on the surrounding topography could be utilized as reference points for horizon calendars. He proposed that the main reference points could have been utilized to mark critical moments of the agricultural cycle and that additional points must have had another auxiliary function. Since the 13- or 20-day intervals that separated these points were multiples of the basic periods of the agricultural and ritual calendar, the horizon calendars could easily serve to predict important dates. Based on his analyses, Šprajc studied the orientation of the Templo Mayor and confirmed his theory that the most important building of the Aztecs rested on a carefully selected location. He made the observation that the precise orientation of the building must have slightly changed over time due to the unstable subsoil of the artificial island where it was built. This was probably the reason why Moctezuma had one of its stages rebuilt as Motolinía stated in his Memoriales (Šprajc 1999b:73-98).

6.5.1.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the research carried out by Aveni, Calnek and Hartung (1988), Galindo (1994), Šprajc (1999b, 2001a), Heyden (2000) and Montero (2000, 2004), the methodological steps for performing the digital and archaeoastronomical analysis were followed meticulously, although special attention was placed on the topographic and cultural features in the local horizon. Even though these steps and their corresponding interpretations were included in the previous section to illustrate the methodology, the findings of this research are summarized in this section. The findings confirmed the theories postulated by these archaeoastronomers, particularly by Šprajc. However, they also added new information about the urban axes, offered an explanation for a *73-day horizon calendar* (Figure 6.16) and proposed an additional way in which important solar events might have been viewed by incorporating the Templo Mayor into its landscape, similar to the way the Pyramid of the Moon was incorporated to Cerro Gordo in Teotihuacan.

The archaeoastronomical analyses of the urban north-south axis confirmed that it runs from the highest point of Pico Tres Padres (known in Nahuatl as Cuauhtepec, "the Mountain of the Eagles") in the north (Figure 6.10), to Cerro Acopiaxco in the south (Figure 6.12), "an inconspicuous cinder cone located on the massive Chichinautzin volcanic field, specifically on an area characterized by multiple caves of great extension, the same topographic-urban relationship that Teotihuacan has along its urban south axis to the Xometla caves," as mentioned in step 9; and a similar relationship, but in a different axis, that Tula has along its urban east-west axis with Cerro Magoni in the west and the mountains, caves and springs of Las Lumbreras in the east.

The archaeoastronomical analyses of the urban east-west horizon revealed that it runs from a nondescript topographic feature in the west (Figure 6.13) "to the intermediate point (19.391519°, -98.716064°) which marked the concave space between the binary volcanic system of Cerro Tlaloc (also called Mount Tlaloc) and Cerro Telapon (Figure 6.11), thus framing the rising of the Sun on March 6 and October 7 (96.5°) (Figure 6.8) or on March 4 and October 9 (97°)." By finding these axes, this research confirmed the passage described by Alvarado Tezozomoc in the Crónica Mexicayotl (Aveni, Calnek and Hartung 1988:292) that Tenochtitlan was founded in the intersection point between the axis of the rising Sun and the axis of a mountain to the north.

The analysis of the eastern horizon confirmed that, with the positions of the Sun on the summer and winter solstices, and on the date in which Tenochtitlan aligned to the rising of the Sun between Cerro Tlaloc and Cerro Telapon, "the year could be divided in intervals (or multiples) of 73 days, "a number related to the Xiuhpohualli calendar (73 days x 5 = 365), Tonalpohualli calendar (260 days x 73 years = 18 980 days = 52 years ‘calendar round’ when both calendars coincided), and the Venusian year (584 days = 73 Earth days x 8)," as explained in Chapter 4:132 . This date also validated the ethnohistoric information recorded by Motolinía who stated that the festival of Tlacaxipehualiztli "fell when the Sun was in the middle of [the temple of] Huitzilopochtli, which was the equinox" and the image of the Sun rising between the double temples of Tlaloc and Huitzilopochtli of the Great Temple within the ceremonial precinct of Tenochtitlan depicted in the Nuremberg Map (Figure 5.7).

The confirmation that the alignment of Tenochtitlan made possible a calendar that could function in intervals of 73 days (Figure 6.16), raises the possibility that the Aztecs might had utilized different calendars simultaneously that could have provided them with more reference dates to adjust the dates of the agricultural cycle (Šprajc 2008:241) or to recalibrate the calendar when needed due to the real duration of 365.24219 days of the solar year. Considering that solar monumental sculptures (Figure 2.30) such as the Aztec calendar stone frequently incorporate Venus symbols around their edges, thus relating the counting of the days of the solar year with the counting of the days of the Venusian year, the results of this research suggest that the Aztec might have also incorporated solar and Venusian references to the same horizon calendar, which might explain the 219-73-73 horizon calendar of Tenochtitlan (Figure 6.42).

The results of the analyses performed in Tenochtitlan also validated the results obtained in Teotihuacan and Tula, which confirmed that horizon calendars could be built utilizing topographic features on the horizon as suggested by Aveni and Hartung (1986), Tichy (1990) and Šprajc (2001a), among others. However, unlike these scholars who tried to build local horizon calendars with only prominent peaks on the horizon, the results obtained in these analyses corroborated the theories argued in this research: that once the main sunrise or sunset locations of the alignment of the site and solstices had been carefully established, additional dates could be plotted on the horizon every 13 or 20 days *to either prominent peaks, spaces between mountains, the base of a prominent peak or any other topographic feature that could be easily distinguished from the site.*

Furthermore, the finding that the main urban axes of Tenochtitlan intersect exactly in one point (as demonstrated in this research and confirmed by ethnohistoric records Figure 6.17) prompted a more detailed exploration of this intersection since, geometrically, an infinite set of points are possible along a circular arc given two points in a diametric chord (Figure 6.43). This means that several locations on Lake Texcoco could be have been selected where perpendicular axes could be aligned to the highest peak of Pico Tres Padres and the space between Cerro Tlaloc and Cerro Telapon.

In order to execute this exploration, the point where the two true north-south and east west axes intersect were used as initial exploration points. Theoretically, this intersection point offered a precise alignment to true north (the highest peak of Pico Tres Padres) and to true east (concave space between Cerro Tlaloc and Cerro Telapon) during the equinox on March 21±1 day, and hence would have been an ideal location. In spite of its location, this point was not chosen (Figure 6.44). The most obvious reason might have been that this small island between the lakes of Chalco and Texcoco was already occupied by the people of Iztacalco. According to ethnohistoric sources, Iztacalco was one of the last places the Aztec visited before founding Tenochtitlan since they also went through Zoquipan and Temazcatitlan after staying in Iztacalco (Castañeda 2002:164); they were clearly looking for another place that would meet *an additional condition*. An analysis of plate 6 of the Codex Azcatitlan provided the answer. This image depicts the birth of Huitzilopochtli on Cerro Coatepec where a vertical line with hanging signs representing four nights and three days ending on a star can be identified. A small description of this portion of the image could be translated as *"On the way night fell, and after three days and four nights without the star appearing, it finally shone"* (Castañeda 2002:186) (Figure 6.45).

Taking into consideration that the founders of Tenochtitlan wanted to commemorate the myth of the birth of Huitzilopochtli (who is depicted *between two mountains* as a warrior —in full regalia holding a shield and a *Xiuhcoatl (snake)* representing a spear— in Figure 4.2) in Coatepec as a way to mark the beginning of the Fifth Era for the Aztecs, and hence the reference to Venus (Castañeda 2002:184-186), the explorations proceeded to look for a date where the urban axes of Tenochtitlan intersected the arc on March 5±1 day, the beginning of the Tlacaxipehualiztli month, as this festival focused on the "sacrifice of Xipe in front of a temple housing two Venus gods" (Milbrath 2013:81). The only point where the axes and the dates coincided was the precise location of Tenochtitlan. Hence, this passage confirmed through the ethnohistorical record the theory suggested by the results of this research: *the alignment of Tenochtitlan was determined by the highest point of Pico Tres Padres (also called Cerro Cuauhtepec "Mountain of the Eagles"), the position of the rising Sun between Cerro Tlaloc (also called Mount Tlaloc) and Cerro Telapon, and the synodic cycle of Venus.*

This finding seemed to indicate that the Aztecs might have also done this same geometric exploration on their canoes in order to get the precise location where the alignments to Cuauhtepec and rising of the Sun between Tlaloc and Telapon met on March 5±1 day. A map of the Aztec migration based on the Codex Azcatitlan (Castañeda 2002:Figure 5) supports this theory, as the path of the migration follows a similar pattern as the geometric exploration (Figure 6.46).

In addition to these findings, the observations made through this research suggest that the alignment of the Templo Mayor should be not only be considered by measuring the alignments of the building and calculating a point (e.g. from the Temple of Quetzalcoatl, the quauhxicalli in the middle of the ceremonial precinct or the upper platform of the Templo Mayor) where the Sun came out between the temples of Tlaloc and Huitzilopochtli on March 5±1 day, but this alignment should also be viewed in the context of the architectural-urban-landscape interplay between the two temples and the binary volcanic system of Cerro Tlaloc and Cerro Telapon, thus reproducing the same spatial experience as Teotihuacan where this interplay could be observed from several viewpoints rather than by a single viewpoint. Hence, similar to the symbolic and spatial relationships designed in Teotihuacan where the landscape was part of the architecture (Cerro Gordo-Pyramid of the Moon and Cerro Patlachique-Pyramid of the Sun), the architecture of the temples of Tlaloc and Huitzilopochtli were an integral part of the landscape defined by the binary volcanic system of Cerro Tlaloc and Cerro Telapon as ethnohistoric sources have confirmed. This spatial relationship might also explain why the Tlaloc temple (Cerro Tlaloc-water-Iztaccihuatl, inactive volcano) was always located on the north side of the Great Temple and the Huitzilopochtli temple (Cerro Telapon-fire-Popocatepetl, active volcano) was always located on the south side of the Great Temple. Furthermore the main causeways that connected Tenochtitlan to the mainland were designed to produce the same spatial experience as the Avenue of the Dead in Teotihuacan. Walking along the long Iztapalapa causeway (almost 8 kilometers long) looking towards the urban north, the Huey Teocalli was integrated into Pico Tres Padres, while walking along the shorter island segment of the Tacuba-Chapultepec causeway (almost 2 kilometers long) looking towards the urban east, the Huey Teocalli was integrated into Cerro Tlaloc and Cerro Telapon. As in the case of Teotihuacan where the longer avenue was along the urban north axis, and the shorter avenue along the west axis towards the

Pyramid of the Sun, these spatial relationships between the city and the its natural environment revealed a profound knowledge of astronomy, topography, mathematics and geometry. This finding also strengthens the theory proposed by López Austin and López Luján (2009) that the Aztecs merged both temples into single temple teocalli.

In light of the findings of this research, new interpretations for sculptures, as well as for depictions of the foundation of Tenochtitlan, were proposed. The sculptures included the Teocalli of the Guerra Sagrada, the Tlaloc-Tlaltecuhtli, the Tlaltecuhtli of the Hotel Majestic sculptures and the Tlaltecuhtli monumental sculpture located along the main urban west axis of the Huey Teocalli. The pictorial representations comprised several plates of the foundation of Tenochtitlan (Codex Aubin, Codex Mendoza and the *Historia de las Indias de la Nueva España* by Durán.) These innovative interpretations included:

The Teocalli de la Guerra Sagrada monumental sculpture (Figure 6.47) can be read a visual summary of the architectural and urban principles of the foundation of Tenochtitlan. In this sculpture, the rising Sun is flanked by Huitzilopochtli and Moctezuma on the front of the upper rectangular prism of the teocalli; Cerro Tlaloc and Cerro Telapon are represented by the Tlaltecuhtli in squatting birth position on the top of the same upper rectangular prism; Cerro Tlaloc is represented by images associated with Tlaloc, the water god, on the left (north) side of the teocalli; and Cerro Telapon is represented by images associated with Xiuhtecuhtli, the fire god, on the right (south) side of the teocalli. In this context, the image carved on the back of the teocalli symbolizes the precise location of the foundation of Tenochtitlan, as it includes Pico Tres Padres (eagle), the rising Sun (fire-water *atl tlachinolli* dichotomy symbol of the fire serpent and shield held by the Sun god Huitzilopochtli after he was born between the thighs of his mother Cerro Tlaloc and Cerro Telapon (Figure 4.2)[35]), and a nopal bearing [bright red] tuna fruits (heart of Copil).

[35] The symbolic meaning of the union of glyphs for water and scorched earth [by fire] has been the subject of numerous interpretations by several key scholars such as Caso (1953), Heyden (1998), Lopez Austin (1994, 1995) and Townsend (2009), among others. Even though their interpretations differ, most of them agree that these symbols are the union of two binary opposite forces such as male-female, dry-rainy seasons, fire-water (Figure 2.16(b)), or attack and defense, as illustrated in the image of Huitzilopochtli in the Codex Tovar (Figure 4.2 (a)) where he is holding a snake (fire-Cerro Telapon-Volcán Popocatepetl) and a shield (water-Cerro Tlaloc-Volcán Iztaccihuatl) between two mountains (Cerro Tlaloc and Cerro Telapon).

In Figure 6.48, the Tlaloc-Tlaltecuhtli sculpture, the architectural and urban design principles of Tenochtitlan and the Huey Teocalli are more clear, since the solar cycle is represented by the rising Sun between Cerro Tlaloc and Cerro Telapon in the eastern horizon (thighs of Tlaltecuhtli in squatting birth position) and the resting place of the setting Sun in the Earth in the western horizon (vessel holding water poured by Tlaloc and where every living being will be born and where it will return after death).

The Tlaltecuhtli of the Hotel Majestic (Figure 6.49) is another example of the female aspect of Tlaltecuhtli (Matos 1997:13), where the solar cycle is represented by the rising Sun between Cerro Tlaloc and Cerro Telapon in the eastern horizon (thighs of Tlaltecuhtli in squatting birth position) and the resting place of the setting Sun in the Earth in the western horizon (vessel holding water poured by Tlaloc). However, unlike the Tlaloc-Tlaltecuhtli sculpture, the designs contain more detail. The Sun is surrounded by 20 small day glyphs and 13 larger glyphs, thus corroborating the relationship between the local horizon and the calendar.

The monumental sculpture of the Tlaltecuhtli (Figure 6.50), found along the 97.0±0.5° urban east axis of the Huey Teocalli of Tenochtitlan, confirms the symbolism embedded in the Teocalli de la Guerra Sagrada, the Tlaloc-Tlaltecuhtli and the Tlaltecuhtli of the Hotel Majestic. However, its precise location reveals that this sculpture was an integral part of the interplay between architecture and the solar cycle, where the Sun was born between the double temples on the Huey Teocalli and returned to the Earth on the sculpture of the Tlaltecuhtli. Furthermore, it validates the theory that location of Tenochtitlan commemorated the birth of Huitzilopochtli, as the skirt of the goddess has a waistband with Venusian symbols (Figure 6.42).

The depictions of the foundation of Tenochtitlan illustrated in several ethnohistorical sources share some common elements with Teocalli de la Guerra Sagrada such as the eagle (Pico Tres Padres) holding the snake (Sun). However the representations of Cerro Tlaloc and Cerro Telapon are subtler, as they are represented as straw huts and faintly drawn mountains at a distance (Figure 6.51).

Lastly, in Figure 6.52, several drawings in the *Historia de las Indias de la Nueva España*, the images of two clearly drawn mountains at a distance are incorporated in every scene. The presence of these mountains is evident in the scenes where the Aztec emperor appears with his subjects, with a snake rather than a Sun, coming out between the two mountains (Cerro Tlaloc and Cerro Telapon).

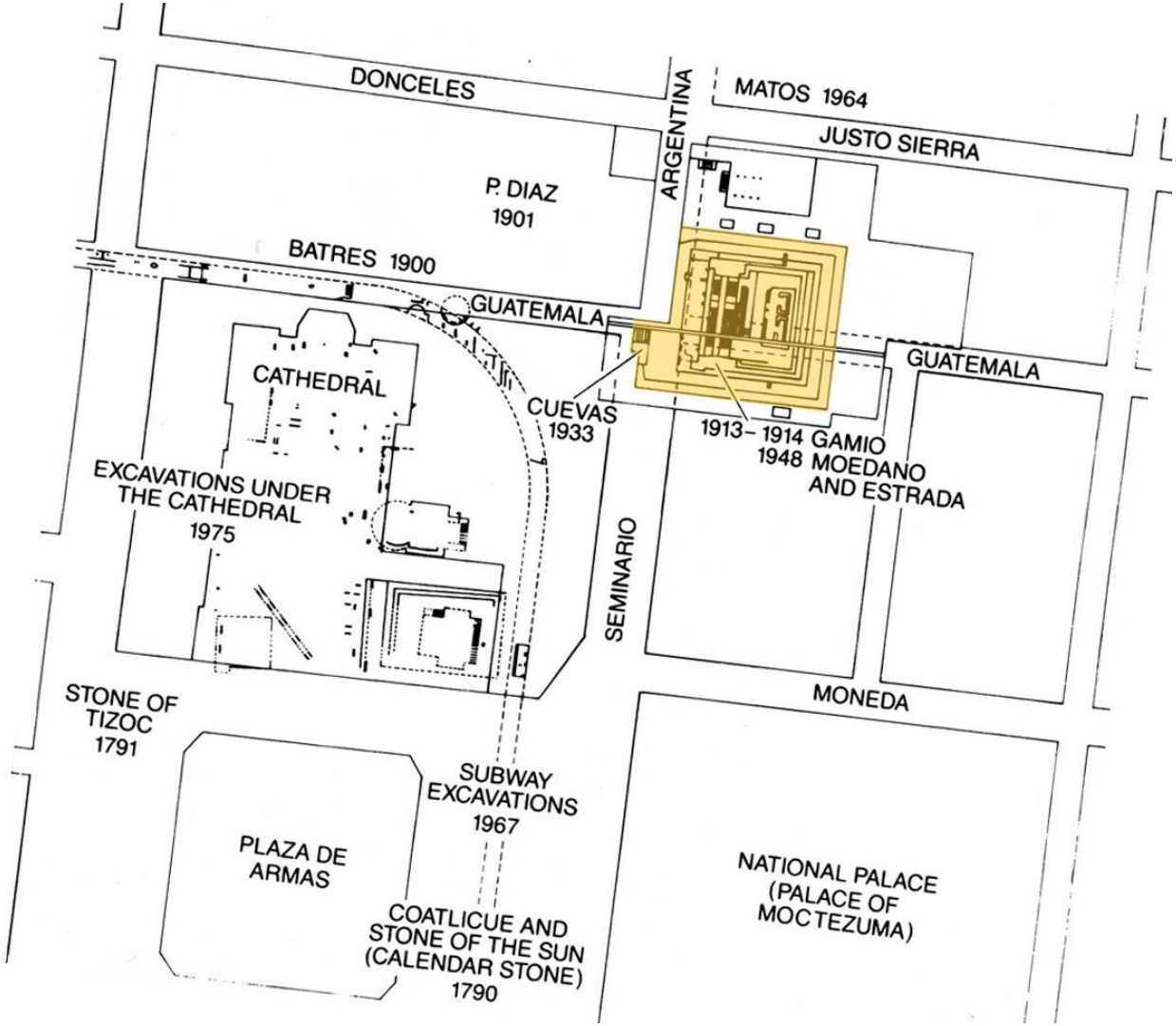


Figure 6.40. Accidental discoveries in downtown Mexico City (Matos 1988:Figure 7).

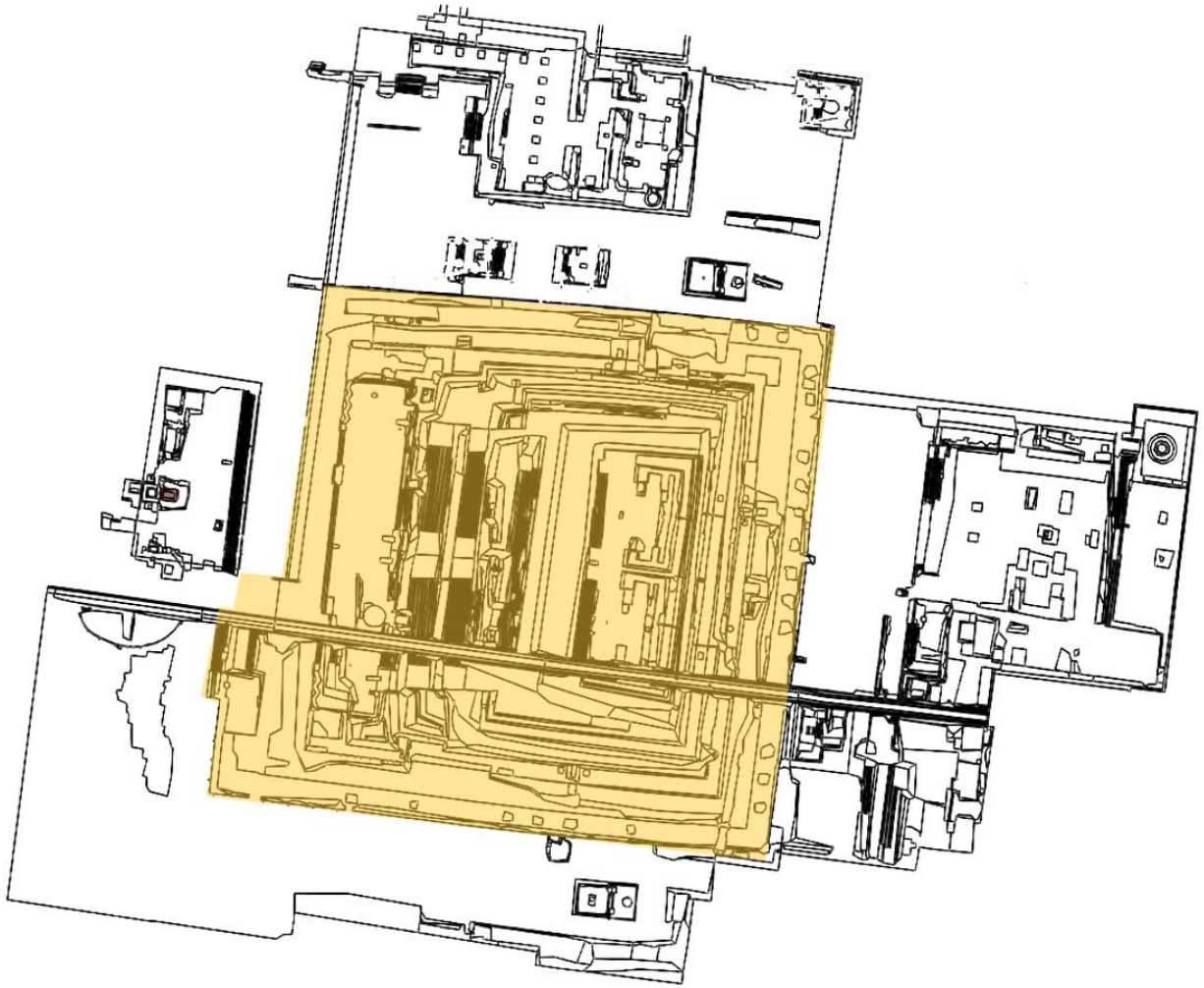
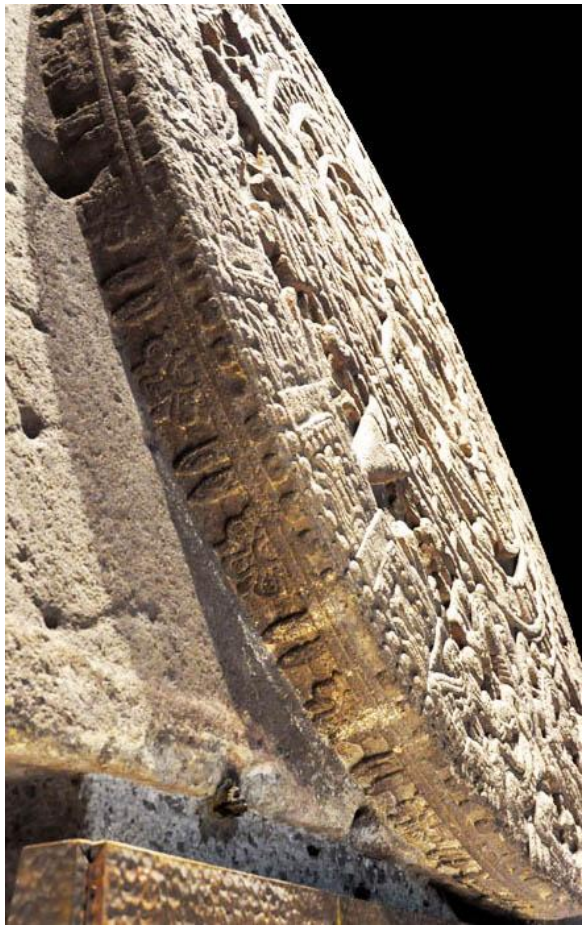


Figure 6.41. Plan of archaeological remains of Tenochtitlan (Drawing by Michelle De Anda, *Projecto Templo Mayor, Séptima Temporada, INAH,* 2013).



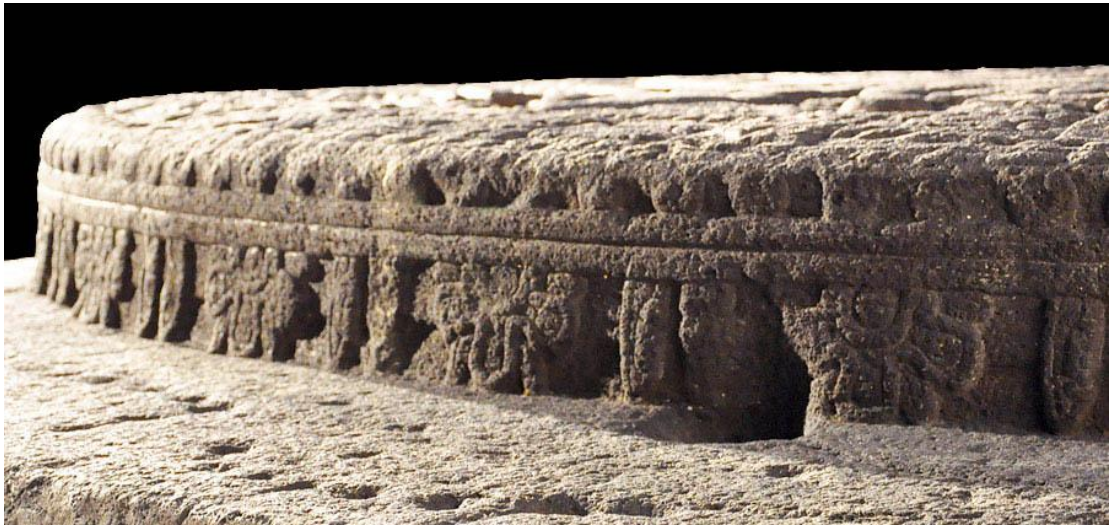


Figure 6.42. Venus signs along the edge of the Aztec Sun Stone or Calendar Stone relating the counting of the days of the solar year with the counting of the days of the Venusian year (Photographs by Ian Mursell - CC:BY).

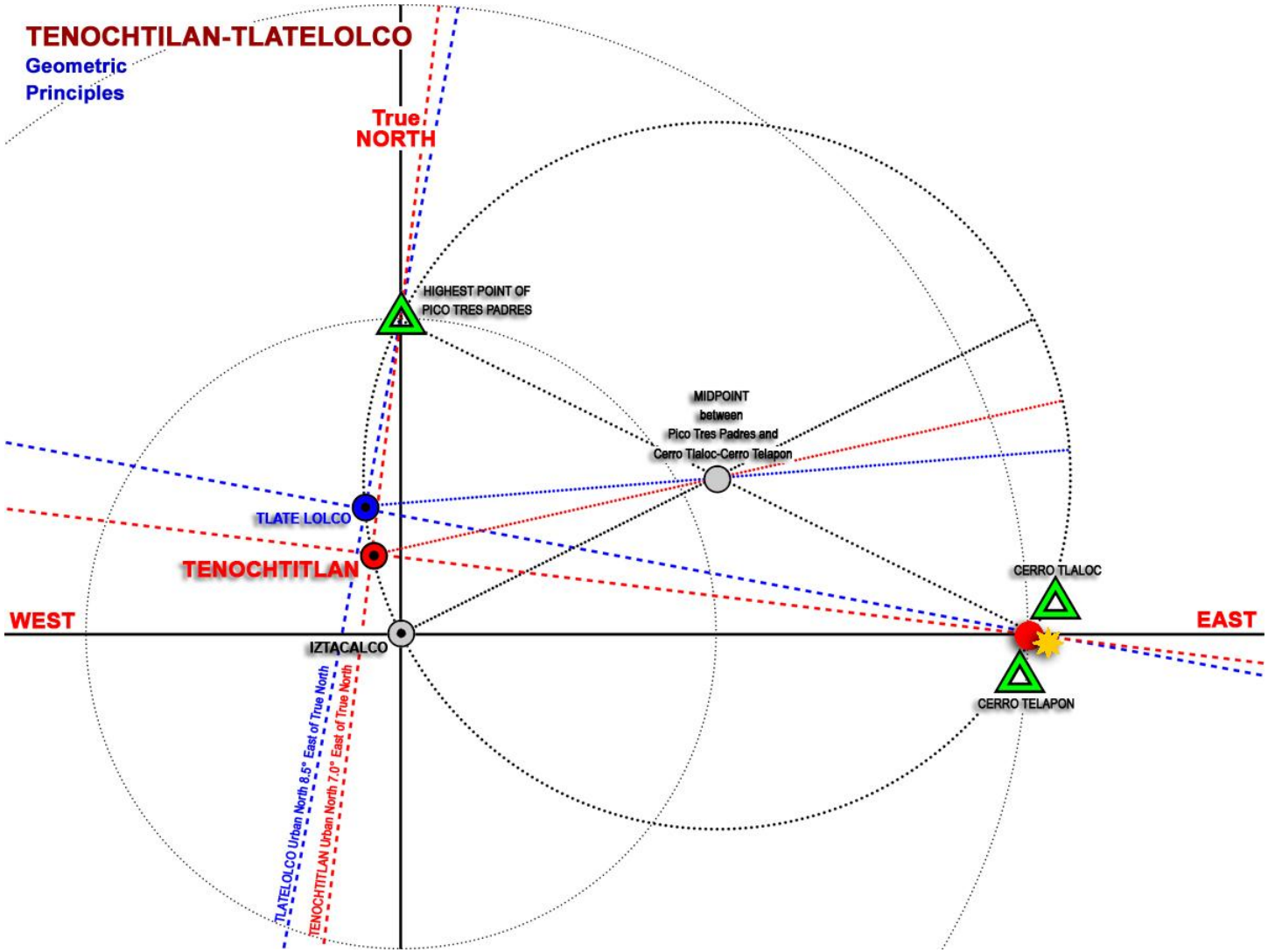


Figure 6.43. Geometrical exploration of the Aztec migration route following a search pattern where the urban north axis aligns to Pico Tres Padres and the urban east axis to the concave space between Cerro Tlaloc and Cerro Telapon. Even though there are an infinite set of points along this arc, it is only in the precise location of Tenochtitlan where these axes intersect on March 4 and October 9. This reference point on the horizon calendar alludes to the birth of Huitzilopochtli (sunrise) and the rise of Venus (every 8 years), and allows the division of the year in 73-day intervals (73x8x5=2920 days).

Figure 6.44. ***Parroquia de San Miguel Arcángel*** **in contemporary Iztacalco (Figure 6.44), a small island that was located at the intersection of the true north and true east axes aligning to Pico Tres Padres and the concave space between Cerro Tlaloc and Cerro Telapon. The decoration of the altar with faces inside golden Suns (similar to the Sun with a face depicted between the twin temples of the Huey Teocalli in the Nuremberg Map) as well as the rays emanating from the dome to the altar are probably a reminder of the cultural importance of the Aztec Sun god at this location (Photograph by Enrique López-Tamayo - CC:BY).**

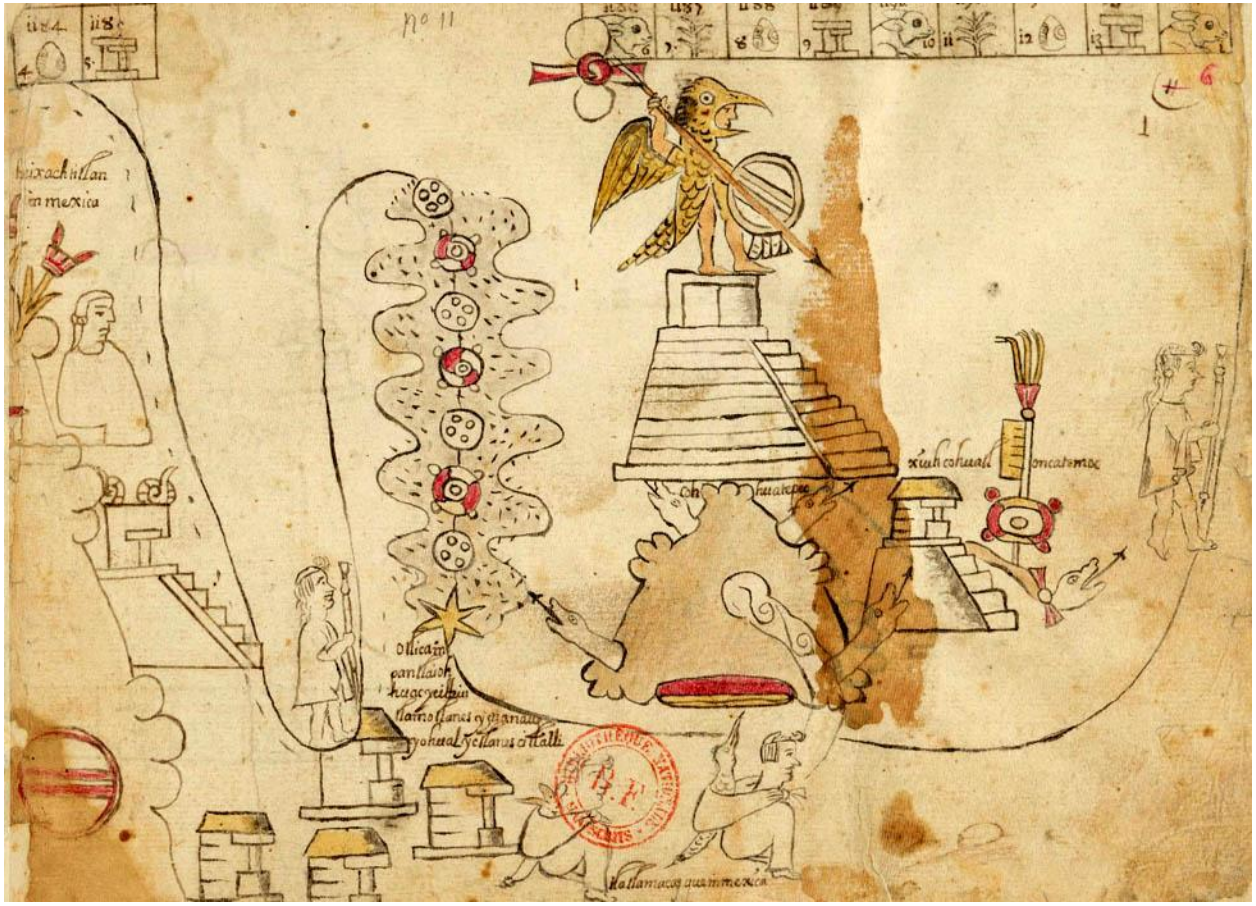


Figure 6.45. Birth of Huitzilopochtli on Cerro Coatepec with the date of his birth represented by four nights and three days ending on a star (Venus) to the left of Cerro Coatepec in the Codex Azcatitlan, Folio 6 (*Bibliothèque Nationale de France*, CC-BY-NC-SA 4.0).

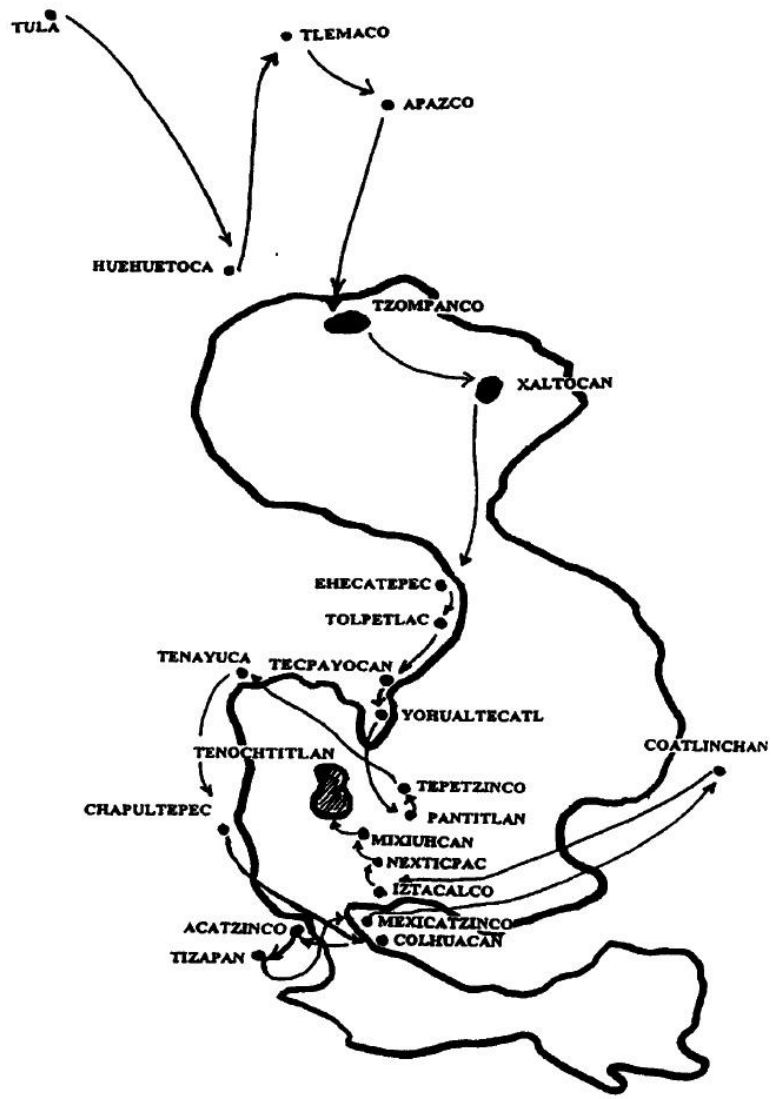


Figure 6.46. Aztec migration route along the Valley of Mexico according to the Codex Azcatitlan (Castañeda 2002:Figure 5). The findings of this research suggest that the westerly locations along this route might have served as viewpoints to calculate the position of the rising sun on the local horizon at a certain date where they could recreate through architecture and urban planning the mythical birth of Huitzilopochtli, the Sun god.

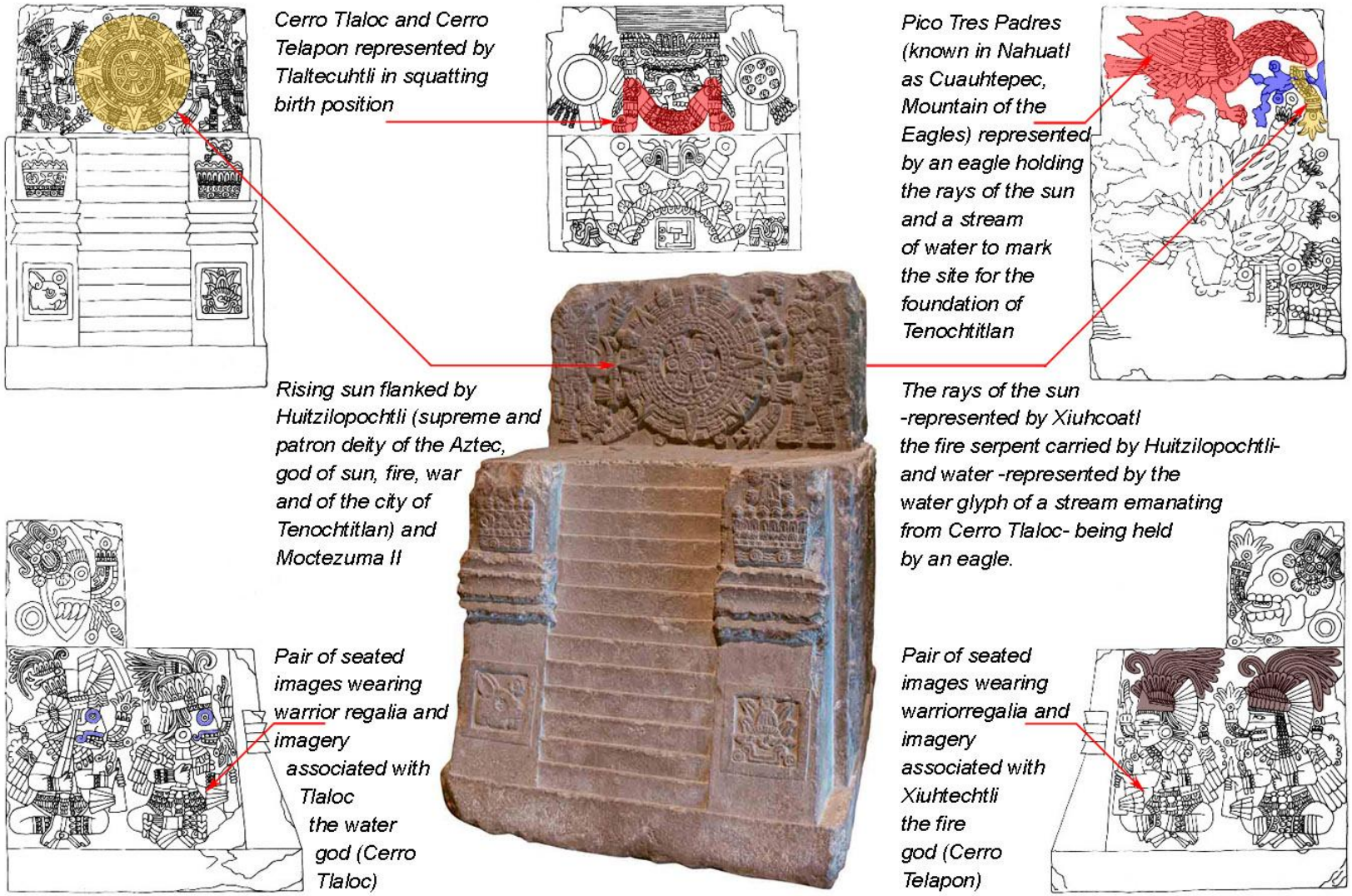


Figure 6.47. Interpretation of the *Teocalli de la Guerra Sagrada* sculpture (Drawings by Marquina 1964:Figures 11 to 14; photograph *Museo Nacional de Antropología/INAH* CC:BY-NC-SA 4.0).

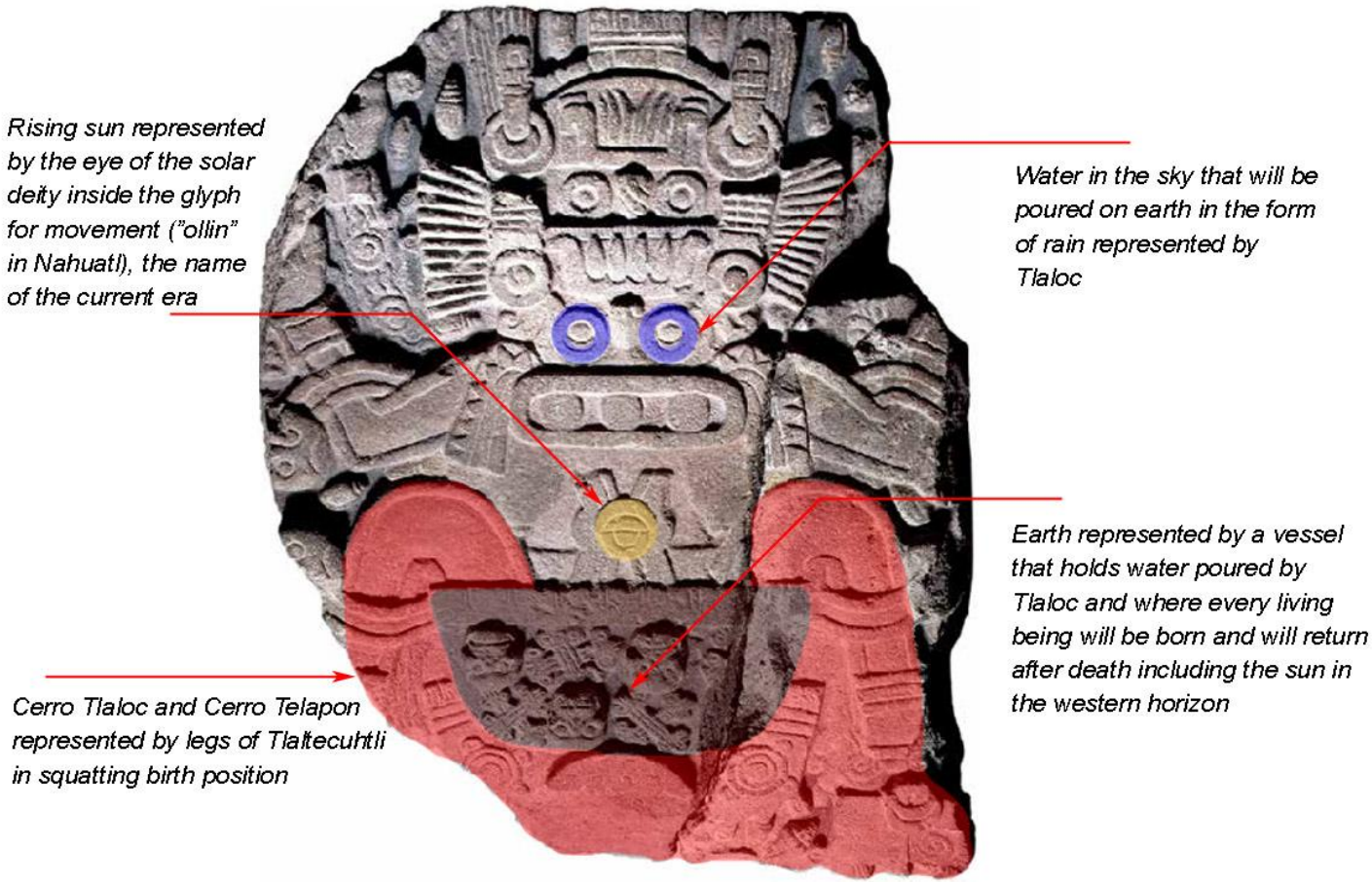


Figure 6.48. Interpretation of the Tlaloc-Tlaltecuhtli sculpture (Photo by Marco Antonio Pacheco/Raíces CC:BY-NC).

Figure 6.49. Interpretation of the Tlaltecuhtli of the Hotel Majestic sculpture(Lopez Luján 2010:91).

Figure 6.50. Interpretation of the location of the Tlaltecuhtli (three-dimensional scanned model of Tlaltecuhtli) (López Luján 2010:51); reconstructive drawing of the relief sculpture by Julian Romero (López Luján 2010:76); plan of the group of eight caches placed at the cardinal and intercardinal ends of the monolith (*Proyecto Templo Mayor/INAH*)).

Figure 6.51. From left to right, depictions of the birth of Huitzilopochtli within ethnohistoric sources where Cerro Tlaloc and Cerro Telapon are represented as two straw huts (Codex Aubin Folio 25v) and two mountains at a distance (Durán Folio 14v and Durán Folio 225v).

Figure 6.52. Clockwise, several scenes within the *Historia de las Indias de la Nueva España* by Durán where Cerro Tlaloc and Cerro Telapon are represented as two mountains at a distance. On the scenes to the left, a snake is depicted between two mountains (*Biblioteca Digital Hispánica* Folios 7v, 18v, 25r 37r, CC:BY-NC-SA 4.0).

6.5.2 TLALTELOLCO

6.5.2.1 Historical Background

The site of Tlatelolco is located under what is now Mexico City (Figure 6.53). It was situated on one of the islands northeast of Tenochtitlan. Even though it was a large urban centre that included a ceremonial precinct and the largest marketplace in Mesoamerica, to date only a small area including a large main double temple, a circular base temple, smaller temples, shrines, a palace, a coatepantli and a tzompantli (skull rack) have been uncovered.

Tlatelolco has produced evidence of initial habitation since 1337 CE, when it was founded by a group of dissident Aztecs and went through developments similar to Tenochtitlan. They had a rivalry, probably caused by the enormous economic power that the Tlatelolcas had attained due to its commercial character, which resulted in the conquest by Axayacatl in 1473 and its incorporation into the city of Tenochtitlan. By the time the Spanish arrived in 1519, both cities had expanded to form a single urban centre (Matos 1988a:181). Archaeological evidence suggests that the urban arrangement of its ceremonial precinct might have been similar to the arrangement of the main precinct of Tenochtitlan as they share several architectural types and a main double temple —or Great Temple— that dominates the complex. This building, which is oriented clockwise 8.5±1° east of north, determined the urban axes of the precinct as most structures followed this alignment (Figure 6.54). However, there are other structures such as the Ehecatl temple that exhibit an orientation of 12.50±1° east of north.

Excavations in Tlatelolco have been undertaken since 1944 (Matos 1988a:183-189); they continue to this day with the Proyecto Arqueológico de Tlatelolco. Currently, the main part of the city lies in the *Zona Arqueológica de Tlatelolco* (Figure 6.55).

6.5.2.2 Previous Archaeoastronomical Research

Studies to explain the orientations of Tlatelolco have been scarce. Even though the variation from 7.65° to 11.78° east of north in the orientations of the main double temple of Tlatelolco

were recorded by Aveni and Gibbs (1976:512), their report did not include a theory to explain this variation. Years later, in the late 1990s, Šprajc carried out measurements of the main double temple, the Calendar Temple and the Ehecatl Temple and noticed there was a considerable difference among them. The stages in the main double temple had an average orientation of 98.52±1°, the Calendar temple had an average orientation of 97.37±0.5°, and the Ehecatl Temple an average orientation of 12.50±1°. Even though prominent peaks on the horizon could not be viewed from the site because it is a heavily built area in Mexico City, he was able to plot a horizon calendar based on the Cerro de los Remedios-Cerro Tepetzinco axis. However, he utilized the grazing Sun archaeoastronomical phenomenon theory to explain the orientations of the stairs of the main double temple, and implied that the differences in the orientations were probably due to the lack of importance given to the north-south axis (Šprajc 2001a:372-383).

6.5.2.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the analyses carried out in this research on Teotihuacan, Tula and Tenochtitlan, the analysis began by determining the coordinates of the main double temple, which were defined as 19.451180,-99.137372. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of Tlatelolco from these coordinates. These viewshed calculations placed into cultural and topographic context prominent features on the horizon that could have been viewed from Tlatelolco such as the Pico Tres Padres to the north and the binary volcanic system of Cerro Tlaloc (also called Mount Tlaloc) and Cerro Telapon located 16 km to the east.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.56). To this end, the azimuths of the main double temple were measured, but it soon became clear that the western sides of the different construction stages of the building did not have consistent alignments as they varied from 8.44° to 10.55° (8.5° to 11° rounded). These calculations were consistent with the measurements taken by Šprajc on this main double temple (2001a:374), but differed by -1.0° with those taken by Aveni and Gibbs (1976:512). Due to this variation, the azimuths of other structures in the main plaza were measured, obtaining average values of 8.5±0.5° east of true north (except for the Calendar

Temple, the Ehecatl Temple and the reconstructed phase II of the main double temple) for the urban north-south axis and 98.5±0.5° east of true north for the urban east-west axis. This alignment reference diagram was superimposed on Google Earth with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

The archaeoastronomical analyses of the urban north-south axis confirmed that it runs —similar to Tenochtitlan— from the highest point of Pico Tres Padres (Cerro Cuauhtepec, "the Mountain of the Eagles") in the north (Figure 6.57), to Cerro Oyameyo in the south, a conical crater that is one of the mouths of the Volcán Xitle, located on the Sierra Ajusco, an area also characterized by its abundance of springs. The same topographic-urban relationship that Tenochtitlan has along its urban south axis from Pico Tres Padres to the cinder cone of Cerro Acopiaxco on the Sierra Chichinautzin.

The archaeoastronomical analyses of the urban east-west axis revealed that it runs — similar to Tenochtitlan— from a nondescript topographic feature in the west to the intermediate point (19.391519°, -98.716064°) that marks the concave space between the binary volcanic system of Cerro Tlaloc (also called Mount Tlaloc) and Cerro Telapon (Figure 6.58), thus framing the rising of the Sun on March 1 and October 12. Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align to the position of the rising and the setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction. Due to the location of Tlatelolco on a lake within the Valley of Mexico, both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from the main double temple of Tlatelolco, the urban east axis intersects the rising Sun on the local eastern horizon on March 1 and October 12 at a 98.5±0.5°) azimuth, 1.73° altitude and a distance of 44.7 km (Figure 6.59); while the urban west axis intersects the setting Sun on the local western horizon on August 30 and April 11 at 278.5±0.5° azimuth, 2.21° altitude and a distance of 32 km. While these measurements confirmed the dates obtained by Šprajc (2001a:382) for the

main double teocalli, the analyses suggest that the most feasible horizon calendar is to the east as the topographic features on the western horizon have similar shapes and altitudes.

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and the setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on June 21 (low distant group of mountains more than 56 km away), September 22 (base of Cerro Tlaloc), December 21 (base of Cerro Teyotl) and March 20 (base of Cerro Tlaloc) on the eastern horizon. The same set of calculations was performed for the western horizon, but it became apparent that alignments to topographic features towards this direction were not easy to identify due to its similar altitude. This confirmed that Tlatelolco had probably one functional horizon to the east that could have been used to mark its local district festival, and followed the main calendar of Tenochtitlan.

Once all of the information was determined, it was summarized on a diagram (Figure 6.60) and a table which included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons. This table was utilized to plot the main solar reference points for the either the eastern (Figure 6.61) or western horizon calendar of Tlatelolco. This information was also used to calculate the days between the alignment of Tlatelolco and the solstitial and equinoctial solar dates, which resulted in the division of the year in three main intervals:

- Horizon calendar on the eastern horizon (98.5±0.5°urban E-W axis)

March 1 > 225 days > October 12 > 70 days > December 21 > 70 days > March 1

The results of this research might explain why the orientation of Tenochtitlan (97.0±0.5°) was different from the orientation of Tlatelolco (98.5±0.5°) despite their proximity. Even though both are oriented to the same peak on the north (highest point of Pico Tres Padres) and a sunrise to the east between Cerro Tlaloc and Cerro Telapon, the date that connects these alignments to Venus via 73-day intervals can only happen in the precise coordinates of Tenochtitlan. Thus, when

Tlatelolco was founded, they only kept the alignments but not the connection to the synodic cycles of Venus, as the horizon calendar marked 70-day intervals rather than 73-day intervals.

In order to investigate this theory, the same geometric exploration that was done for Tenochtitlan, was executed for Tlatelolco. Several points along the arc formed by the 47.4 km diametric chord defined by Pico Tres Padres and the concave space between Cerro Tlaloc and Cerro Telapon, were analyzed. These geometric explorations revealed that Tlatelolco is located along the same arc as Iztacalco and Tenochtitlan. Since this arch is formed by a diametric chord, the three locations had the same distance (23.7 km) to the midpoint between Pico Tres Padres and the space between Cerro Tlaloc and Cerro Telapon. Similar to Tenochtitlan, this finding suggests that the Aztecs might have also done this same geometric exploration on their canoes in order to determine a location where the alignments to Pico Tres padres and rising of the Sun between Tlaloc and Telapon met close to the date of the beginning of Tlacaxipehualiztli month. This theory also adds information to the discussion regarding the foundation dates of both cities, as some scholars have argued that Tlatelolco was built before Tenochtitlan. Nevertheless, these analyses strengthen the argument that Tlatelolco was founded *after* Tenochtitlan.

Like Tenochtitlan, these findings suggested that the main double teocalli —or Great Temple— of Tlatelolco could have been viewed also in the context of the architectural-urban-landscape interplay between the two temples of Tlaloc and Huitzilopochtli and the binary volcanic system of Cerro Tlaloc and Cerro Telapon from several viewpoints, which was the same symbolic and spatial relationship that Teotihuacan and Tenochtitlan had between their architecture and their sacred landscape. By founding Tlatelolco in this location, the Aztecs demonstrated how they applied their profound knowledge of astronomy, topography, mathematics and geometry to their urban and architectural design.

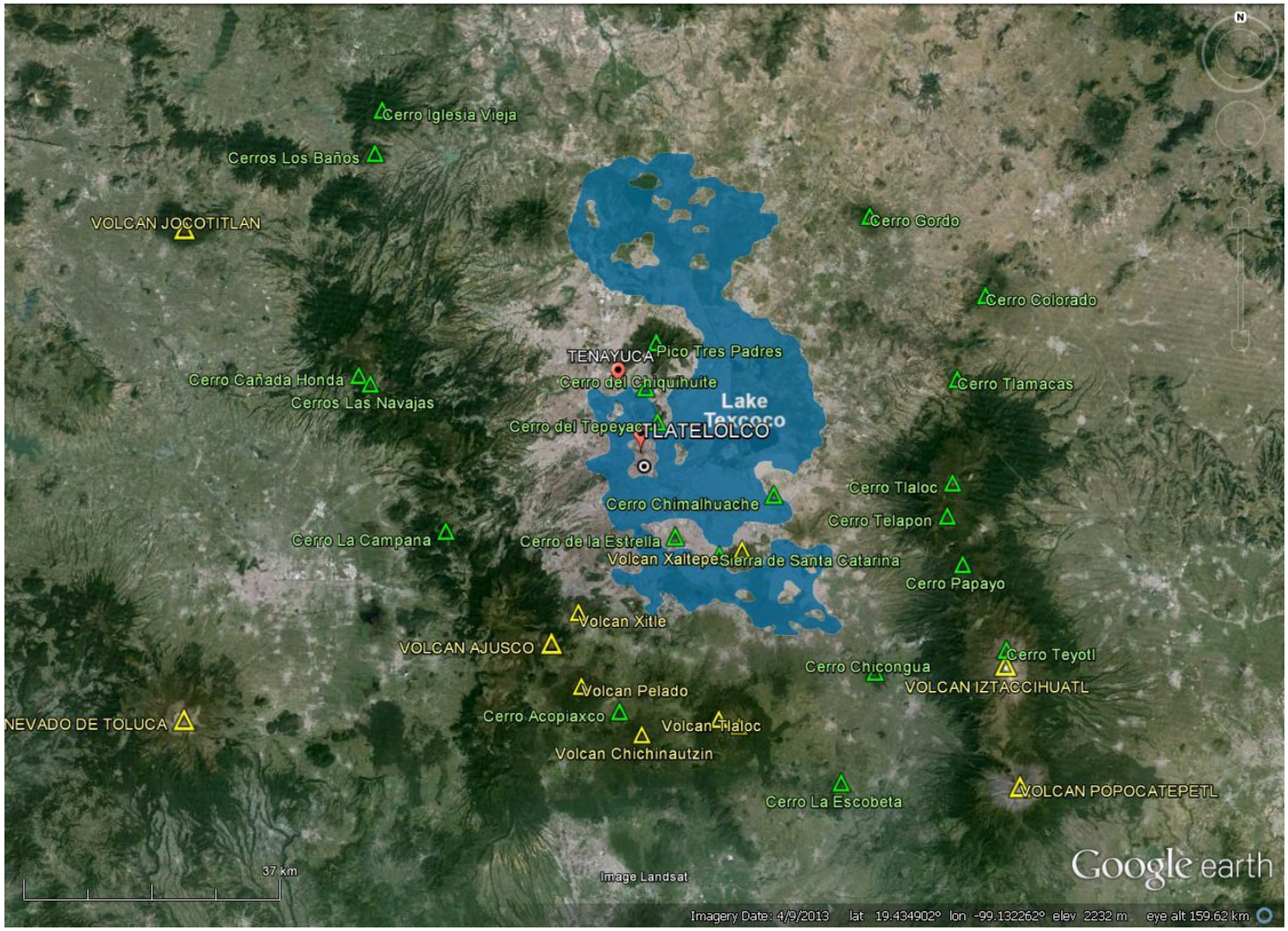


Figure 6.53. Location of Tlatelolco indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

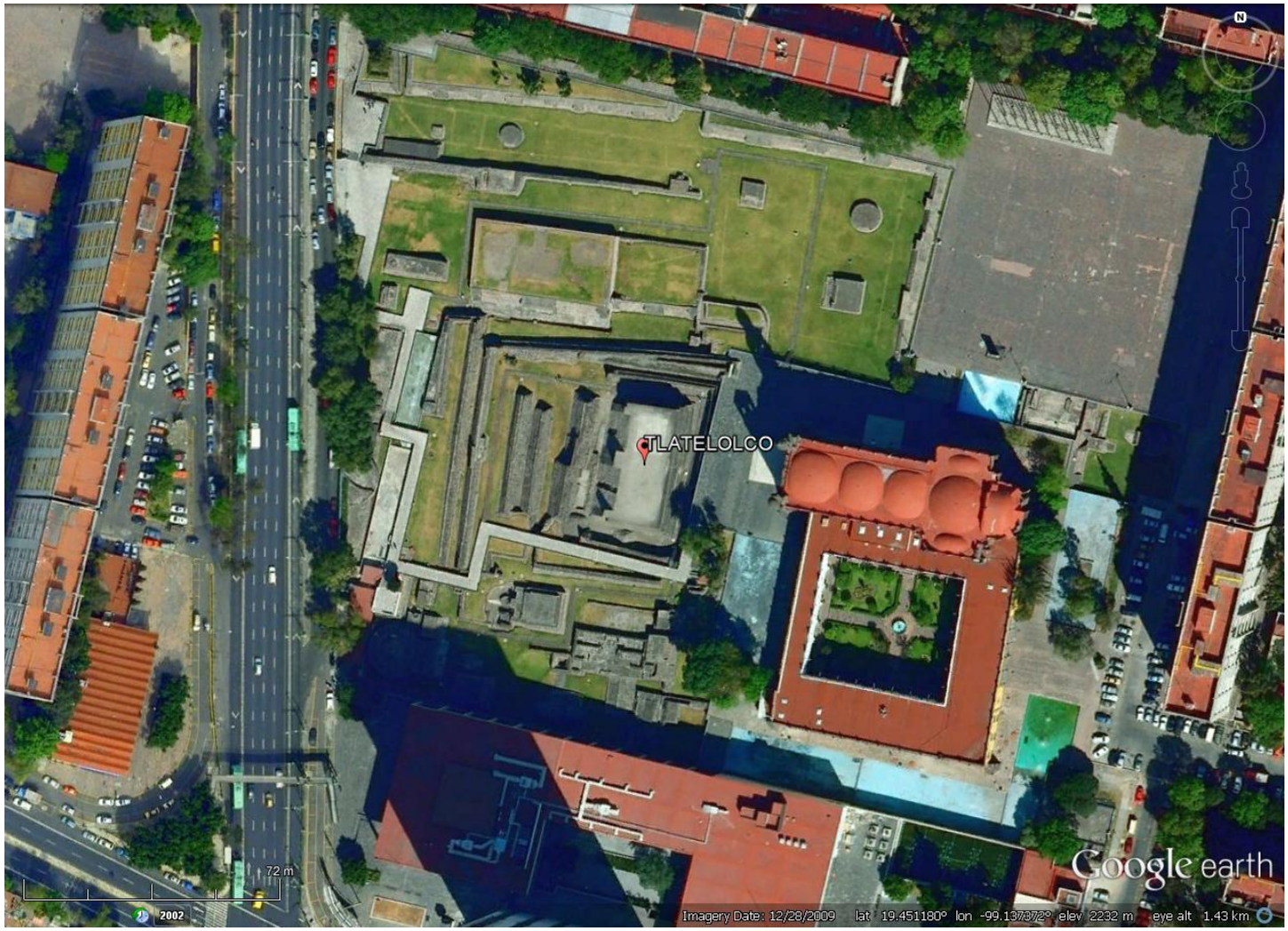


Figure 6.54. Aerial view of the archaeological remains of Tlatelolco, scale 1:200 (Map data: Google Earth).

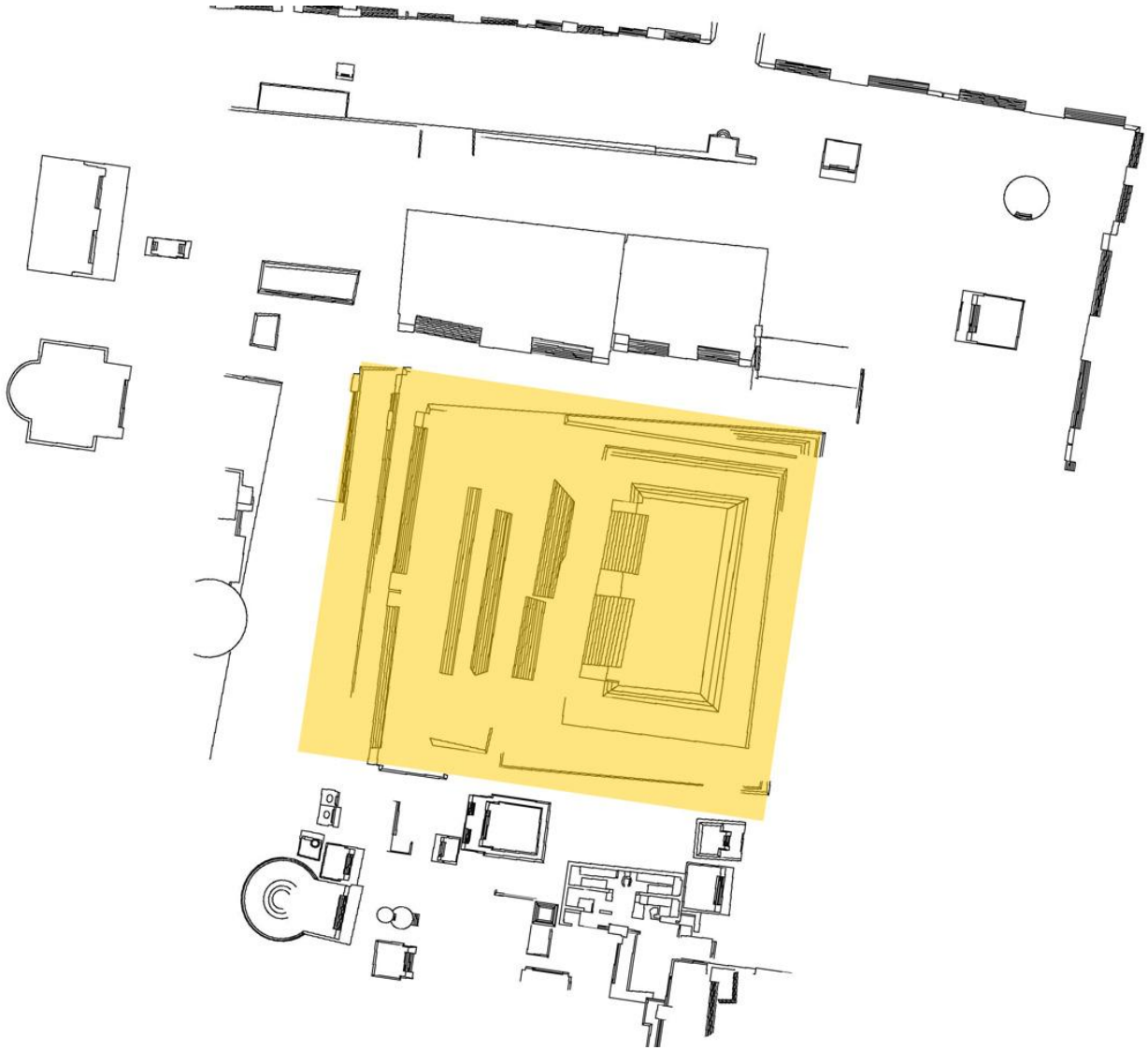


Figure 6.55. Plan of archaeological remains of Tlatelolco (Guilliem 2008:Figure 2).

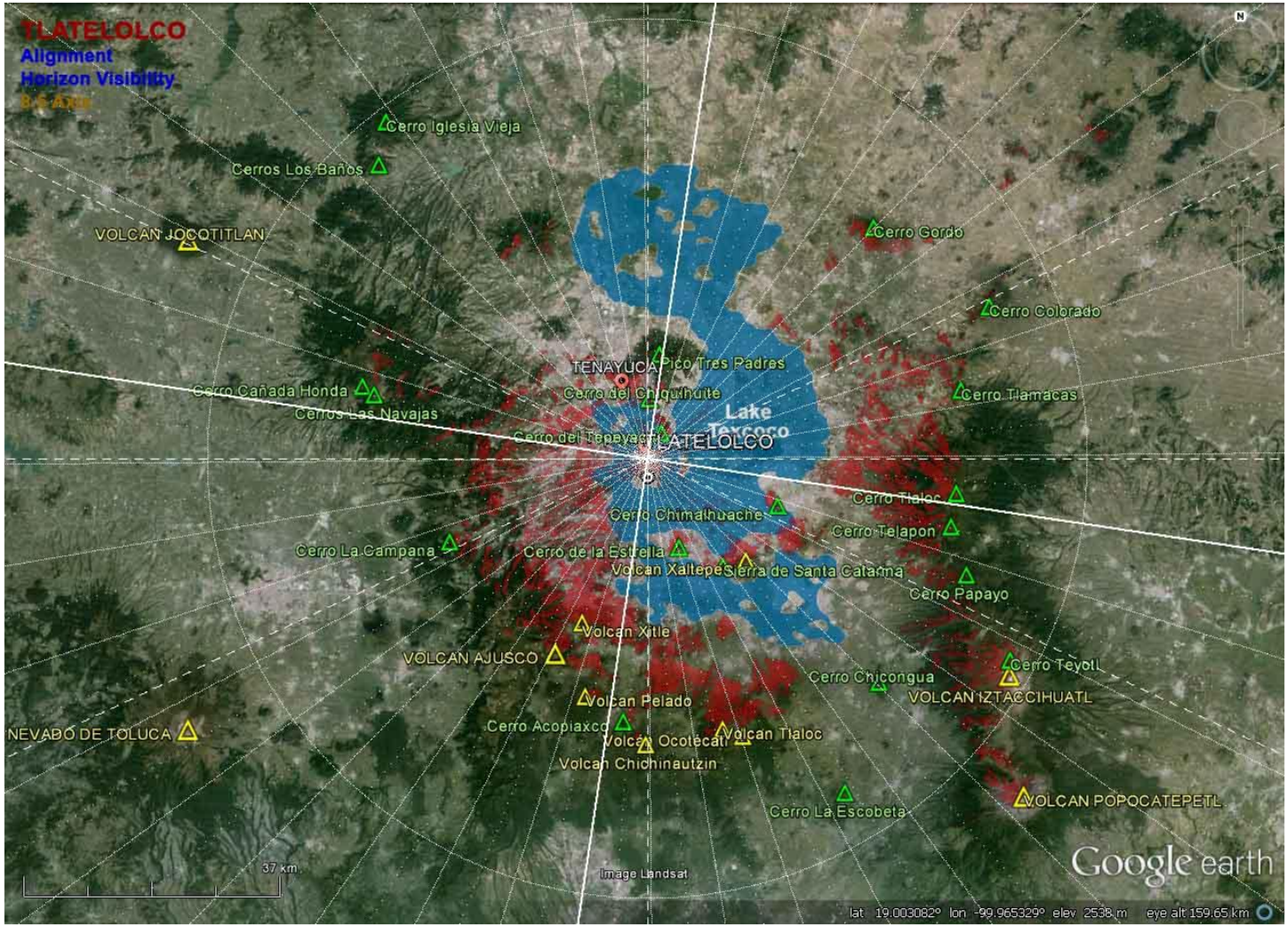


Figure 6.56. Alignment reference diagram superimposed on topographic landscape of Tlatelolco. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

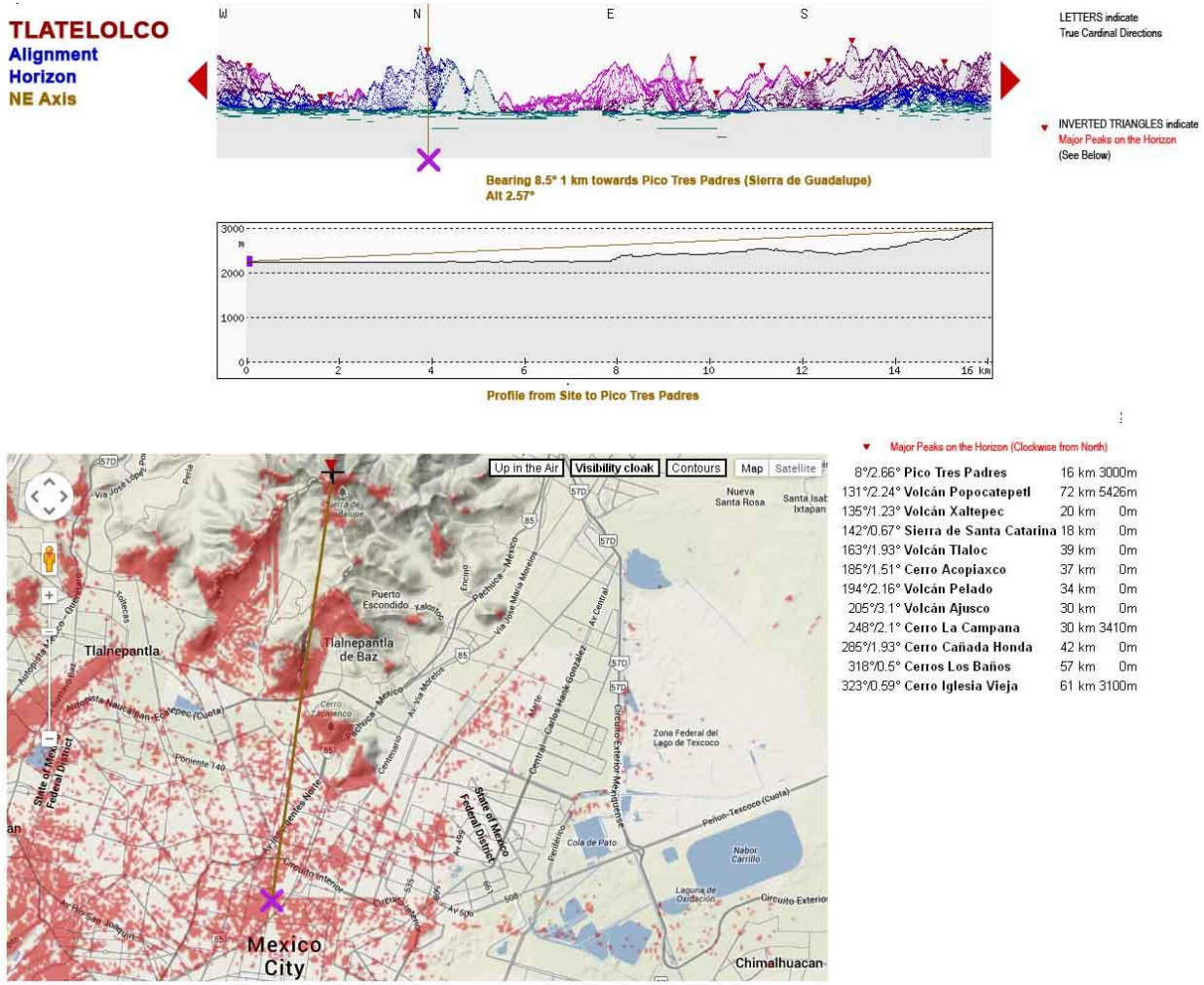


Figure 6.57. Alignment of Tlatelolco to the highest peak of Pico Tres Padres (within the Sierra of Guadalupe) along its urban north axis (marked on diagram as NE axis). This diagram contains three views from Tenochtitlan to the highest point of Pico Tres Padres: a 360° topographic panorama showing the alignment, a topographic profile section, and an aerial view (Map data: Google Maps and TA).

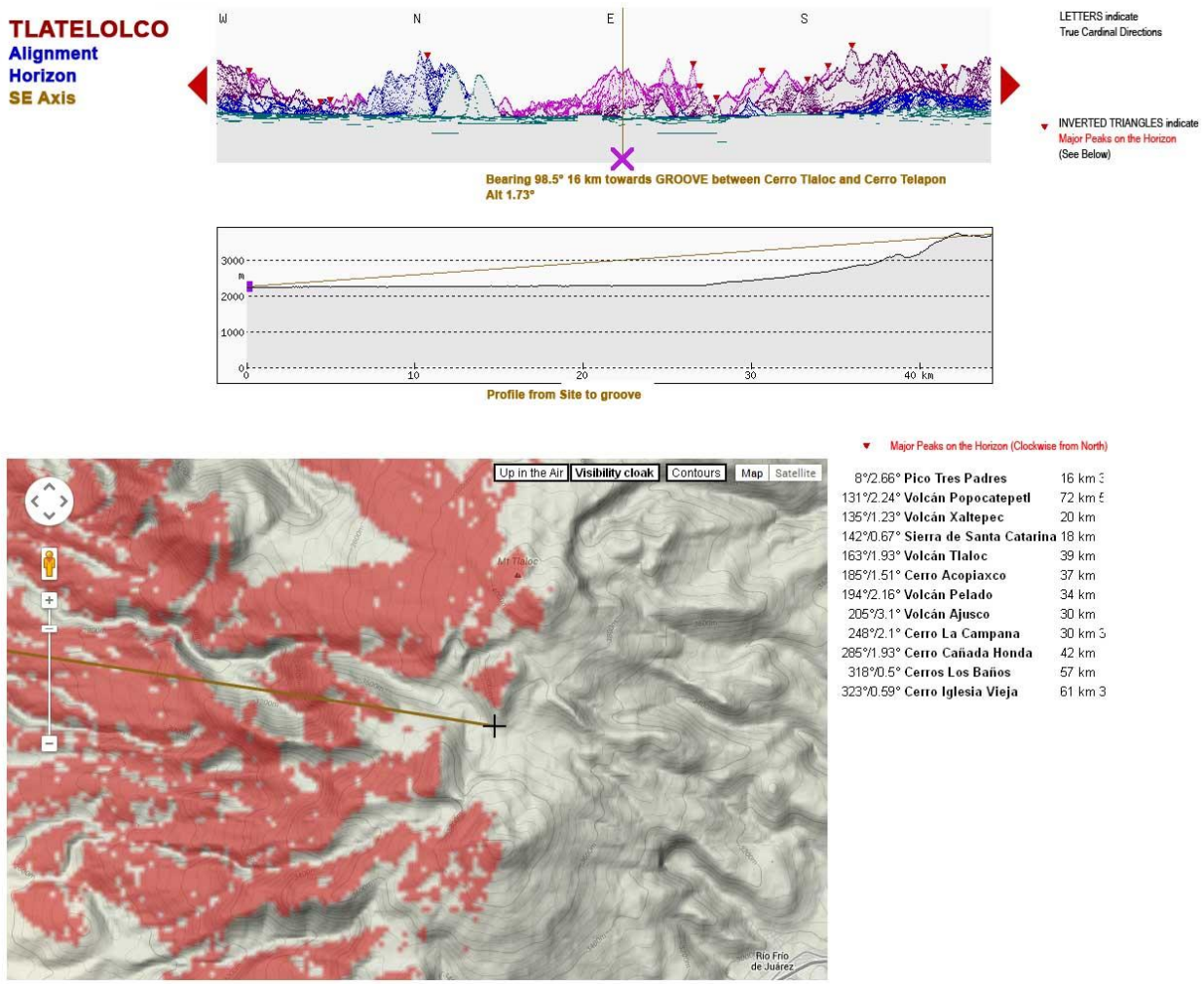


Figure 6.58. Alignment of Tlatelolco to the intermediate point (19.391519°, -98.716064°) between the binary volcanic system of Cerro Tlaloc and Cerro Telapon along its urban east axis (marked on diagram as SE axis). This diagram contains three views from Tenochtitlan to Cerro Tlaloc and Cerro Telapon: a 360° topographic panorama showing the alignment, a topographic profile section and an aerial view (Map data: Google Maps and TA).

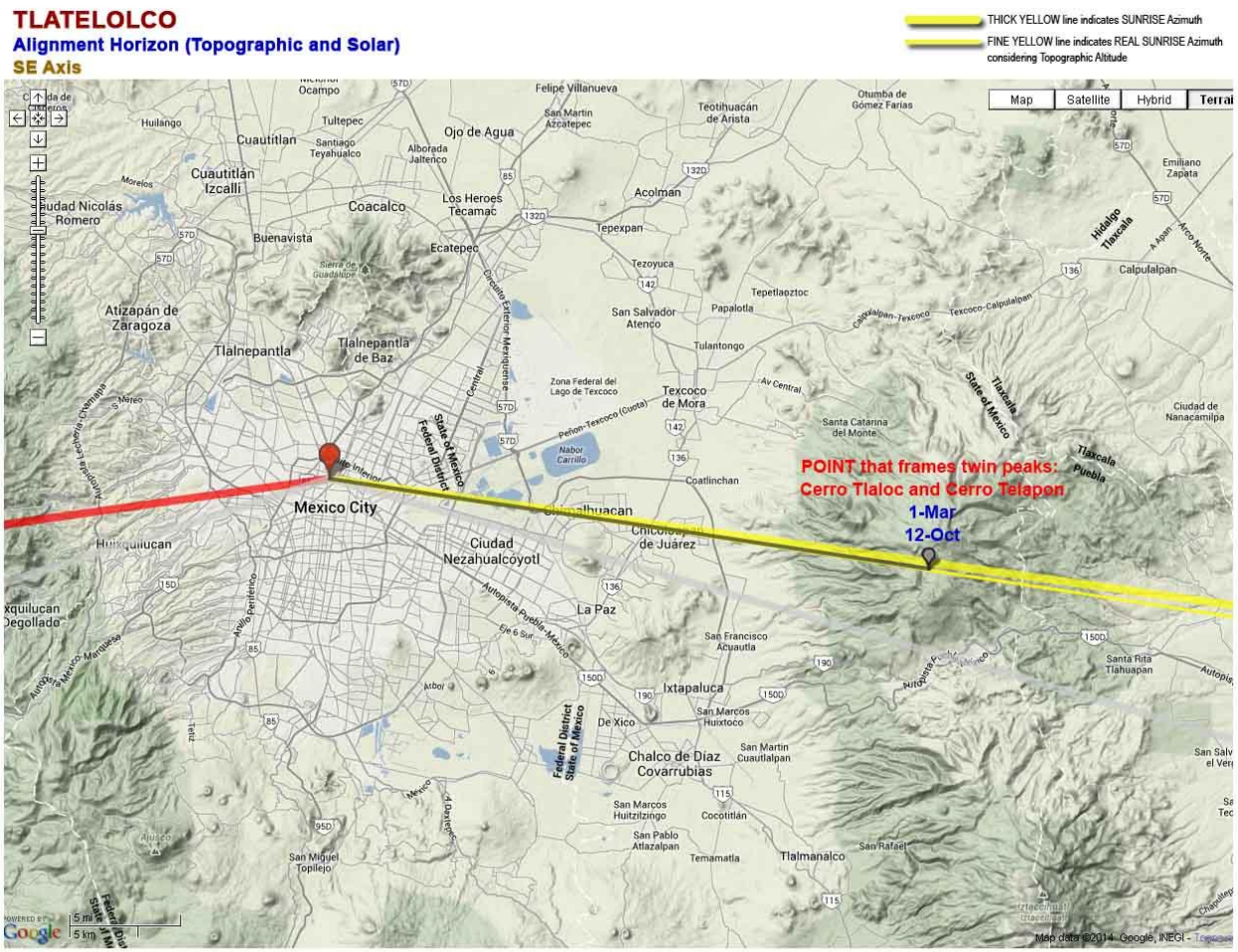


Figure 6.59. Position of the rising Sun between Cerro Tlaloc (also known as Mount Tlaloc) and Cerro Telapon along the 98.5° urban east-west axis of Tlatelolco considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

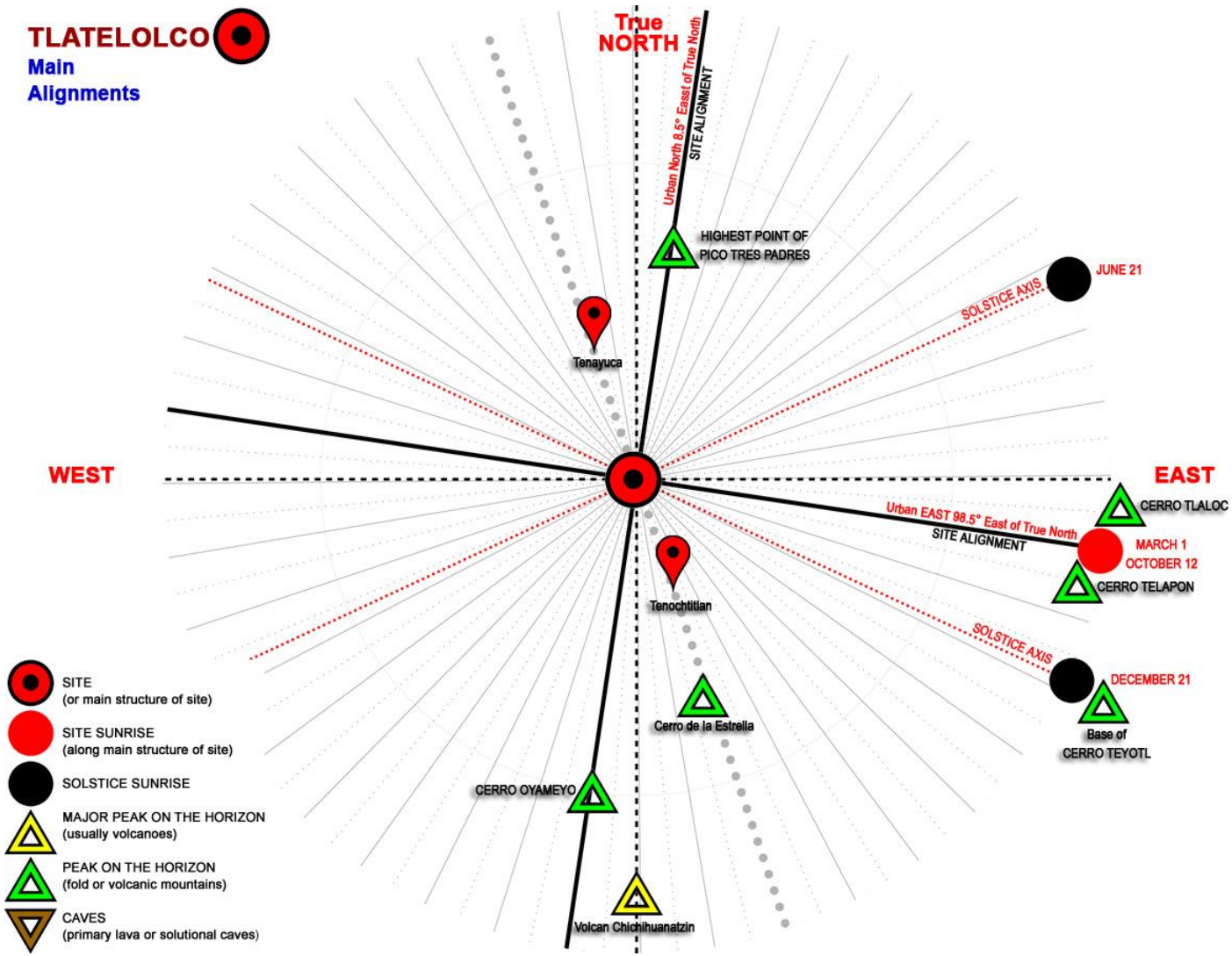


Figure 6.60. Main eastern alignments of Tlatelolco. True cardinal directions are indicated as black dotted lines; the *main urban axes* of Tlatelolco are indicated as black lines. The interactions between the *urban north-south-east-west axes* with the topography reveal the urban design principles of Tlatelolco.

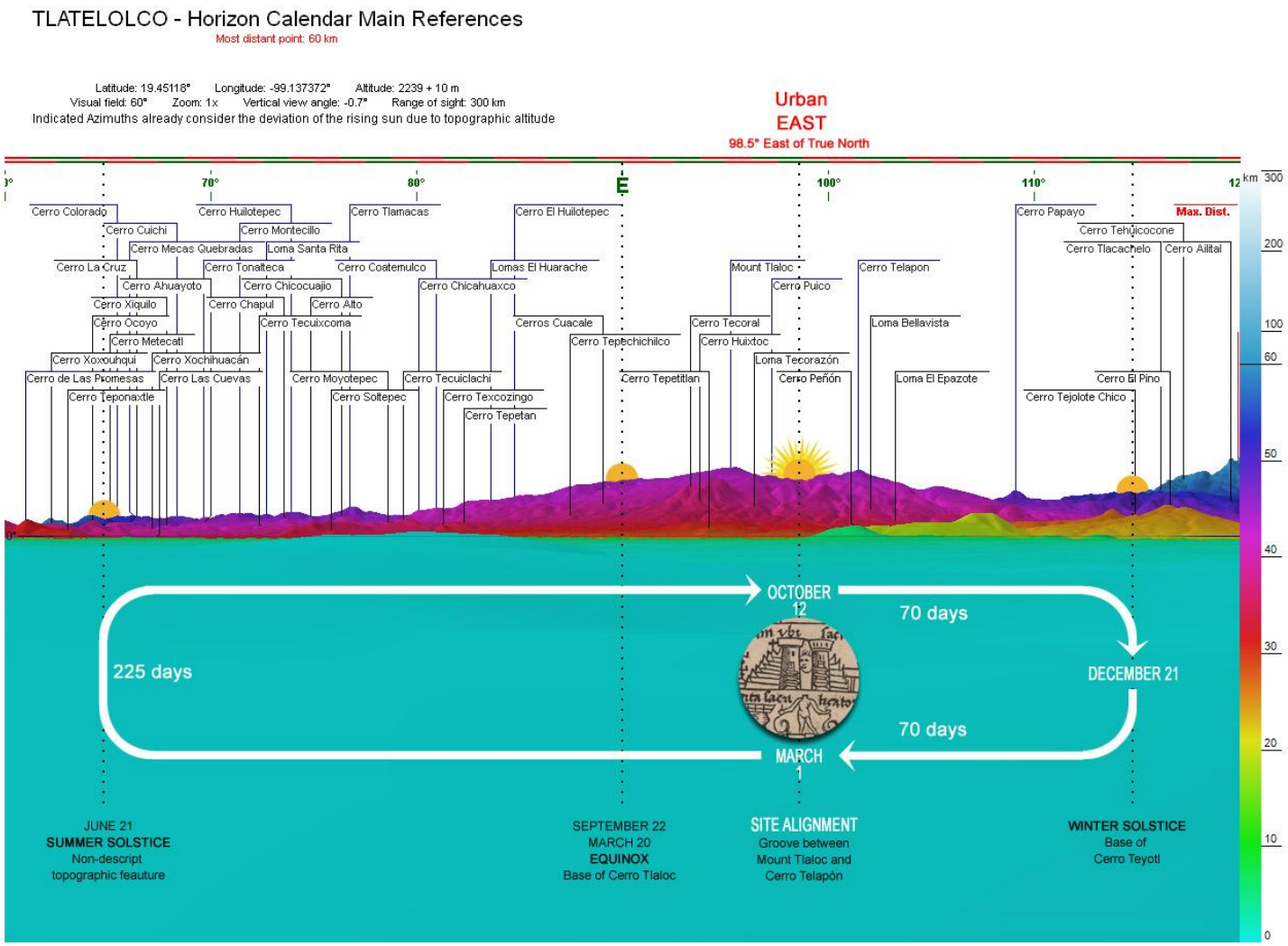


Figure 6.61. Main solar references on the 98.5° eastern horizon calendar of Tlatelolco and calendar cycle (Map data: Google, INEGI and UDI).

6.5.3 TENAYUCA

6.5.3.1 Historical Background

The site of Tenayuca is located in the State of Mexico, 12 km northwest of Mexico City (Figure 6.62). The site lies on an area dominated by the mountains of the Sierra de Guadalupe to the north and a closer mountain, Cerro Tenayo, to the northeast. Even though this area is surrounded by colonial and modern buildings, a large double temple with a coatepantli (wall of serpents) and four small shrines occupying most of the site, have been excavated (INAH).

Tenayuca has produced evidence of initial habitation since 1224 and has been considered the first Aztec city. It was founded by King Xolotl and was the capital of the Chichimecs until it was occupied by the Tepanecs of Azcapotzalco. In 1425 after the Triple Alliance, it came under the control of the Aztecs of Tenochtitlan (Aguilar Moreno 238).

Excavations in Tenayuca were undertaken after the Mexican Revolution when archaeologists became interested in Aztec sites inspired by the Indigenismo. In the 1930s an interdisciplinary project led by Ignacio Marquina and José Reygadaz uncovered six stages of construction in the main double temple, revealing a continuous process of rebuilding and rededication (Figure 6.63). The coatepantli around the last stage of the main double temple had a wall of 52 serpents and two Xiuhcoatl, which associated this building with fire renewal and the 52-year calendar. According to Smith, "Tenayuca marks the initial appearance of the twin-temple plan —two temples, each with its own stairway, on a single pyramid platform— in central Mexico" (2000:31-32). Currently, the main part of the city lies in the *Zona Arqueológica de Tenayuca* (Figure 6.64).

6.5.3.2 Previous Archaeoastronomical Research

Since Marquina and Reygadas introduced their theory to explain the 106.5±0.5° east of true north orientation of Tenayuca, other scholars such as Aveni and Gibbs (1976:512), Galindo (1994:152-154) and Šprajc (2001a), among others have postulated other theories. Although

Marquina noted that "*the axes of the structures do not match but overlap, significantly displacing them south… so the temple on the north always stayed in the same place while the south temple was moved further south at each successive stage,"* he attributed the orientation of the last stage to the location of the setting Sun during its zenithal passage (Šprajc 2001a:310). However, Galindo pointed out that Marquina had based his theory on the astronomical horizon and not on the local horizon, thus questioning its validity. Meanwhile, he proposed that this orientation marked the beginning of the Nemontemi (unlucky) days in the 365-day Xiuhpohualli calendar on February 7 and November 4 (Galindo 1994:152-153).

In the late 1990s, Šprajc measured the orientation of the uncovered three stages of the main double temple and obtained an average azimuthal value of 106.45° for the east-west axis (2001a:296). Rather than offering a theory just for the orientation of the 106.5±0.5° east of true north axis, he proposed that the increasing displacement and rotation of the axes to the south was due to the position of the rising Sun on the northeast mountain in the dates where the temple had first been built. This event "marked the dates with more precision if this phenomenon was viewed from the southern section of the upper platform." Hence this mountain to the northeast became an important calendrical reference point in the local horizon, which he utilized to build a horizon calendar (309-311). Even if this was the reason behind the shifting orientation of the axes of the main double temple, the viewpoint possibilities ("the southern section of the upper platform") would have made the horizon observations potentially imprecise.

6.5.3.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the analyses carried out in this research on Teotihuacan, Tula and Tenochtitlan, the analysis began by determining the coordinates of the main double temple, which were defined as 19.532084,-99.168409. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of the Tenayuca from these coordinates.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.65). To this end, the azimuths of the main double temple were measured. The results were 16.5±0.5° east of true north for the urban north-south axis and

106.5±0.5° east of true north for the urban east-west axis. This alignment reference diagram was superimposed on Google Earth with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

The archaeoastronomical analyses of the urban north-south axis confirmed that it runs from the southwest peak of the Sierra de Guadalupe in the north (Figure 6.66), to the Volcán Ajusco in the south, an area also characterized by its abundance of springs. This is similar topographic-urban relationship that Tenochtitlan has along its urban south axis from Pico Tres Padres to the Sierra Chichinautzin.

The archaeoastronomical analyses of the urban east-west horizon revealed that it runs from a nondescript topographic feature in the west, passes through Tenayuca, continues between the groove between Cerro del Chiquihuite and the Cerro Zacatenco and, after 49.73 kilometers, ends in in a location 1.39 km south of Cerro Tlaloc towards Cerro Telapon (Figure 6.67), thus framing the rising of the Sun on February 8 and November 3. Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align to the position of the rising and the setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction. Due to the location of Tenayuca within an area dominated by mountains at a short distance, both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from the main double temple of Tenayuca, the urban east axis intersects the rising Sun on the local eastern horizon on February 8 and November 3 at a 106.5±0.5° azimuth, 1.73° altitude and a distance of 49.73 km (Figure 6.68), while the urban west axis intersects the setting Sun on the local western horizon on August 8 and May 3 at 286.5±0.5°azimuth, 1.58° altitude and a distance of 13 km. These analyses suggest that the most feasible horizon calendar is to the east as the topographic features on the western horizon have similar shapes and altitudes. These dates are consistent (±1 day) with the dates obtained by Galindo and confirmed the relationship of Tenayuca with Cerro Tlaloc. He illustrated this relationship by referring to the foundation of Tenayuca depicted in the Codex Xolotl(Chapter

2:39). According to the codex, "when the Chichimecs arrived to the Valley of Mexico in the 13th century, Prince Nopaltzin climbed Cerro Tlaloc to examine suitable places to settle" (Galindo 1994:152).

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and the setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on June 21 (Sierra de Guadalupe), September 21 (Cerro del Chiquihuite), December 21 (Cerro Zacatenco) and March 20 (Cerro del Chiquihuite) on the eastern horizon. The same set of calculations were performed for the western horizon, but it became apparent that alignments to topographic features towards this direction were not easy to identify due to its similar altitude. This confirmed that Tenayuca had probably one functional horizon to the east that could have been used to mark the beginning of the Nemontemi days as discussed by Galindo (1994:153) and followed the main calendar of Tenochtitlan throughout the year.

Once all of the information was determined, it was summarized on a diagram (Figure 6.69) and a table which included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons This table was utilized to plot the main solar reference points for the either the eastern (Figure 6.70) or western horizon calendar of Tenayuca. This information was also used to calculate the days between the alignment Tenayuca and the solstitial and equinoctial solar dates which resulted in the division of the year in three main intervals that resembled the 260-53-52 intervals in the calendar of Teotihuacan:

- Horizon calendar on the eastern horizon (106.5±0.5° urban E-W axis)

  February 8 > 133 days > June 21 > 135 days > November 3 > 97 days > February 8

However, the 106.5±0.5° urban E-W axis alignment allowed a horizon calendar to the east, but it did not explain the displacement and clockwise rotation of the different stages of the main double temple of Tenayuca. Moreover, the fact that *"the temple on the north always stayed in the*

same place while the south temple was moved further south at each successive stage" described by Marquina (Figure 6.71) was not consistent with the stages excavated in the Templo Mayor of Tenochtitlan where both of the temples dedicated to Tlaloc and Huitzilopochtli were always the centre of the subsequent enlargements of the building. So a new theory regarding the different orientation of these enlargements was explored.

To this end, a geometric analysis of the original —not the hypothetical reconstruction— plan of the excavations by Marquina was performed in order to determine the axes of the different stages. The results confirmed the observations made by Marquina that the first stage had an approximate azimuth of 105.5°±0.5° while the last stage had an approximate azimuth of 106.5°±0.5°. In addition, the main axis of the first stage was displaced with respect to the main axis of the last stage to an approximate location of 19.5321, -99.1683. The analysis proceeded to calculate the point where the east-west axis of the first stage intersected with the eastern horizon at sunrise. Remarkably, this point was the summit of Cerro Tlaloc, located 49.73 km away at 1.95° altitude. What is more, it happened on February 11/12—the beginning of the Xiuhpohualli year—at the same date marked by the alignment of the Pyramid of the Sun in Teotihuacan.

These findings also lead to the proposal of the theory that, initially, the temple of Tenayuca founded by the Chichimecs was a single temple dedicated to Tlaloc and aligned to Cerro Tlaloc as described in the Codex Xolotl on February 11/12, the same dates as at Teotihuacan. However, when they made their first enlargement they were already culturally aware of the water-fire duality (Figure 2.16 (b)) associated with Cerro Tlaloc and Cerro Telapon, an excavation detail Acosta had already associated to the change from "Coyotlatelco" ceramics found in stage I to the "Azteca II" ceramics found in stages II, III and IV (1963:126). Hence, every time they enlarged their temple, they rotated its axis towards the south in order to position it between Cerro Tlaloc and Cerro Telapon, the birthplace of the Sun. Since the original temple dedicated to Tlaloc was already in the position aligned to Cerro Tlaloc, they only had to extend the southern part of the platforms in order to make space for the temple dedicated to Huitzilopochtli.

The results of this research suggested that —in spite of the location of Tenayuca surrounded by mountains— the alignment and the symbolic meaning of the Sun coming out between two

mountains was specifically intended in the enlargement of its consecutive stages in spite of the fact that the initial alignment was to the summit of Cerro Tlaloc. Similar to Tlatelolco, the founders of the city only kept the alignments to the birthplace of Huitzilopochtli in the concave space between Cerro Tlaloc and Cerro Telapon, but not the connection to the synodic cycles of Venus, as the horizon calendar did not mark 73-day intervals. Even though these calendar references were not separated by a 260-day interval like at Teotihuacan, it was the best approximation given the design constraint to align the main east-west axis of the site between Cerro Tlaloc and Cerro Telapon. These findings also support the theory that the main double teocalli —or Great Temple— of Tenayuca could be viewed in the context of the architectural-urban-landscape interplay between the two double temples of Tlaloc and Huitzilopochtli. In addition, the *space* between two mountains that could be observed from several possible viewpoints was the same symbolic and spatial relationship that Tenochtitlan had between their architecture and their sacred landscape. By adapting their initial single temple architectural design to a double temple architectural design in the subsequent stages of the Great Temple of Tenayuca, the Aztecs demonstrated how they applied their profound knowledge of astronomy, topography, mathematics and geometry into their urban and architectural design.

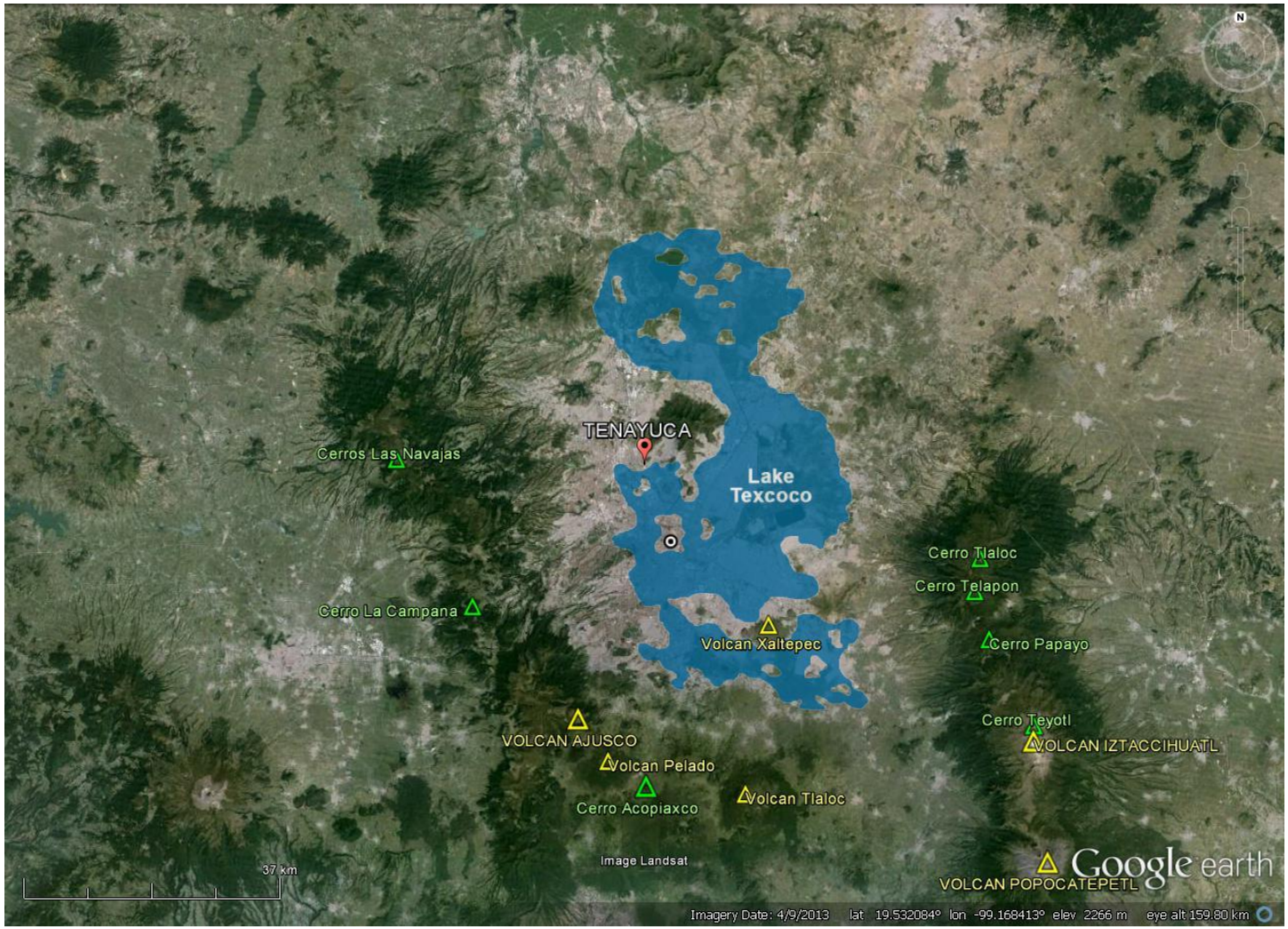


Figure 6.62. Location of Tenayuca indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

Figure 6.63. Aerial view of the archaeological remains of Tenayuca, scale 1:200 (Map data: Google Earth).

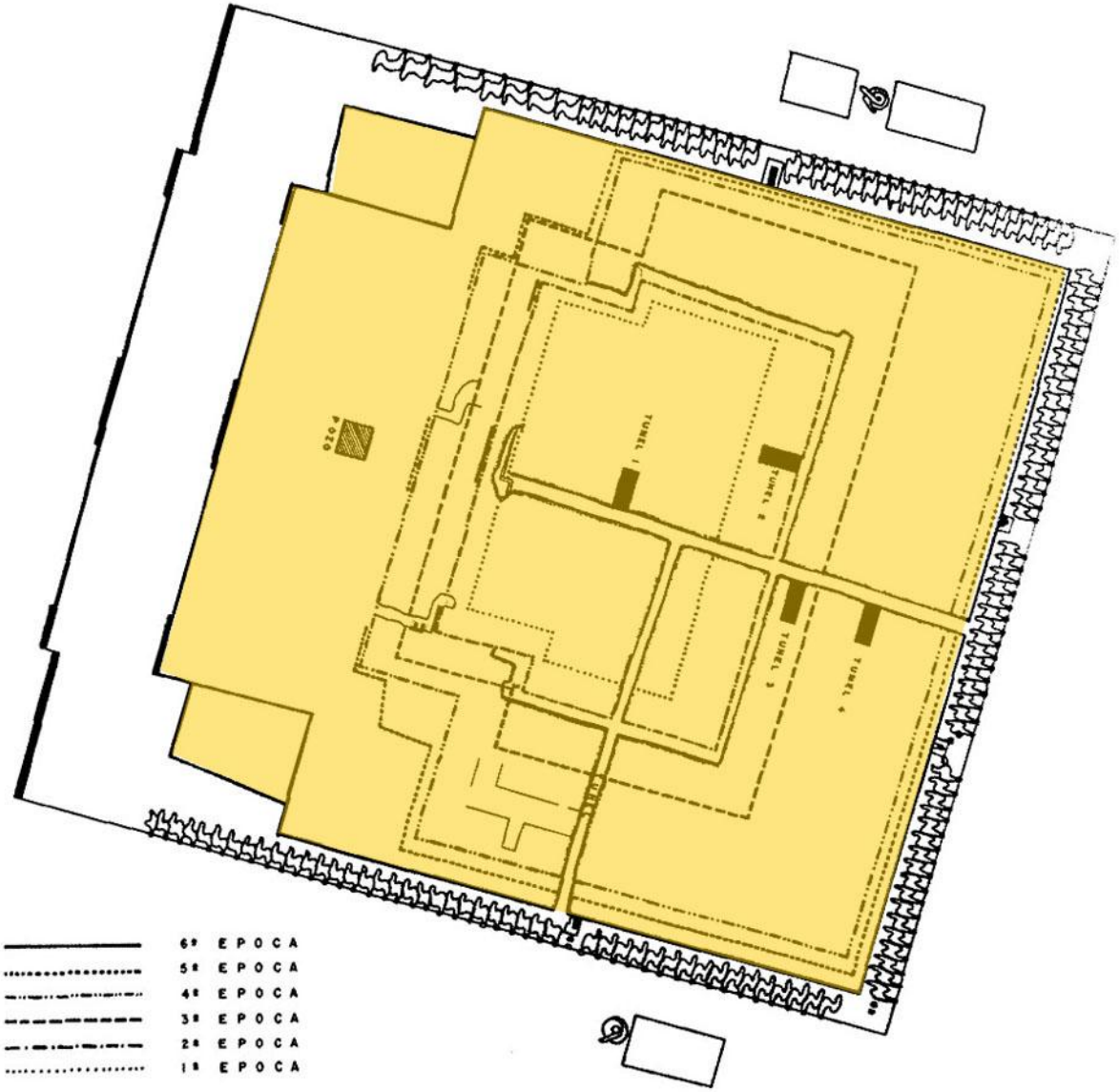


Figure 6.64. Plan of archaeological remains of Tenayuca (Acosta 1963:Figure 1).

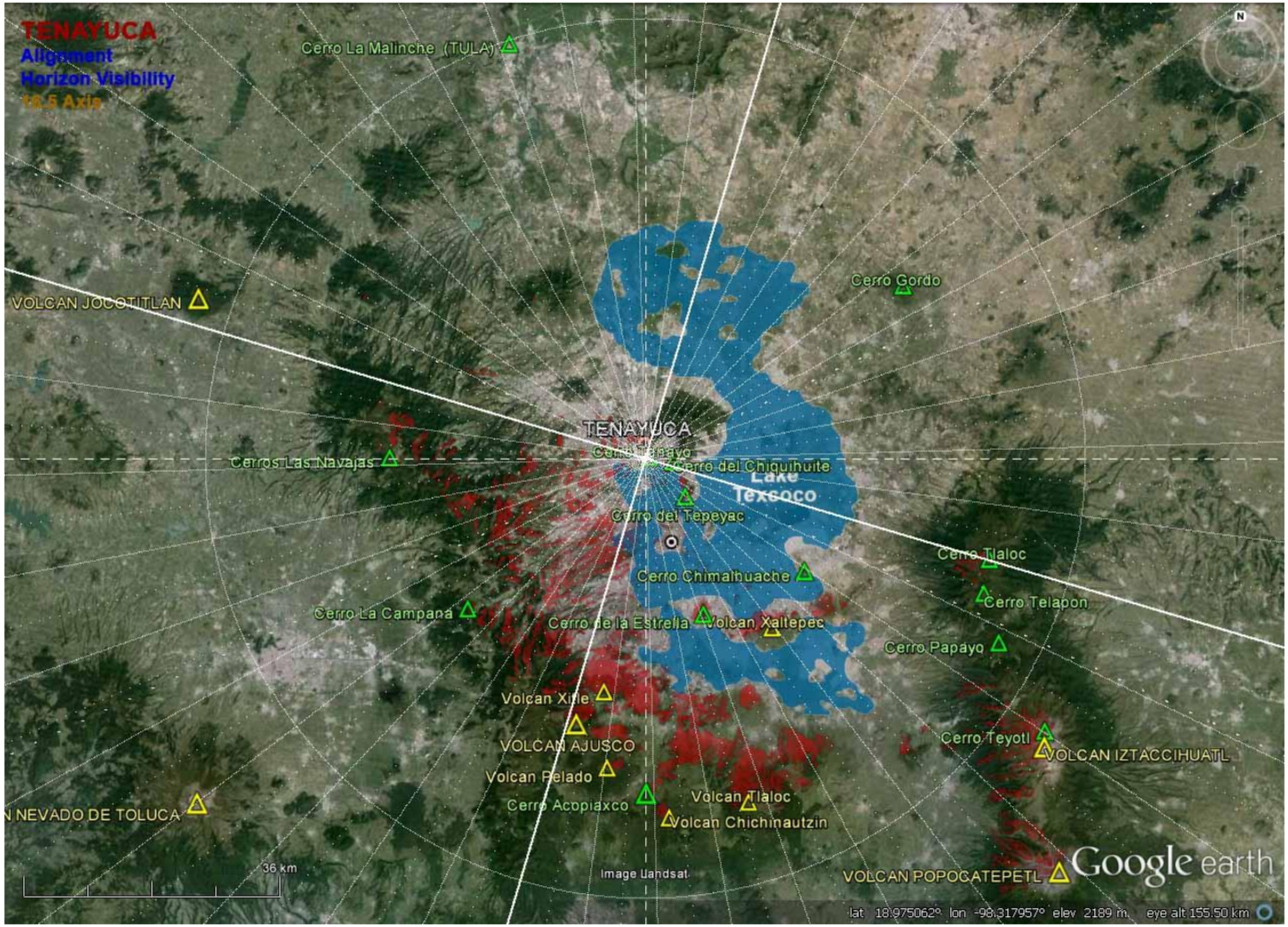


Figure 6.65. Alignment reference diagram superimposed on topographic landscape of Tenayuca. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

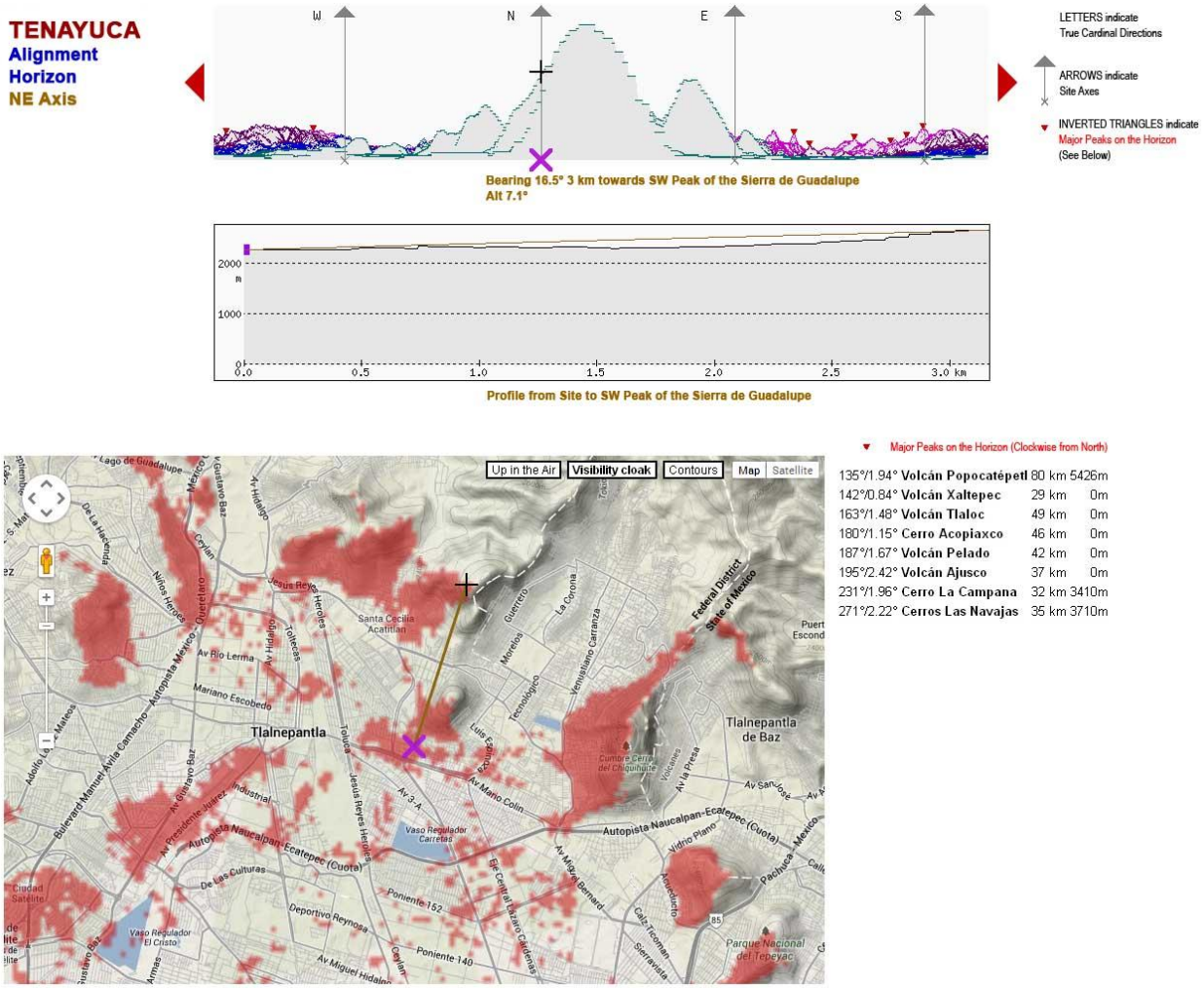


Figure 6.66. Alignment of Tenayuca to the Sierra de Guadalupe along its the urban north axis, marked on diagram as NW axis (Map data: Google Maps and TA).

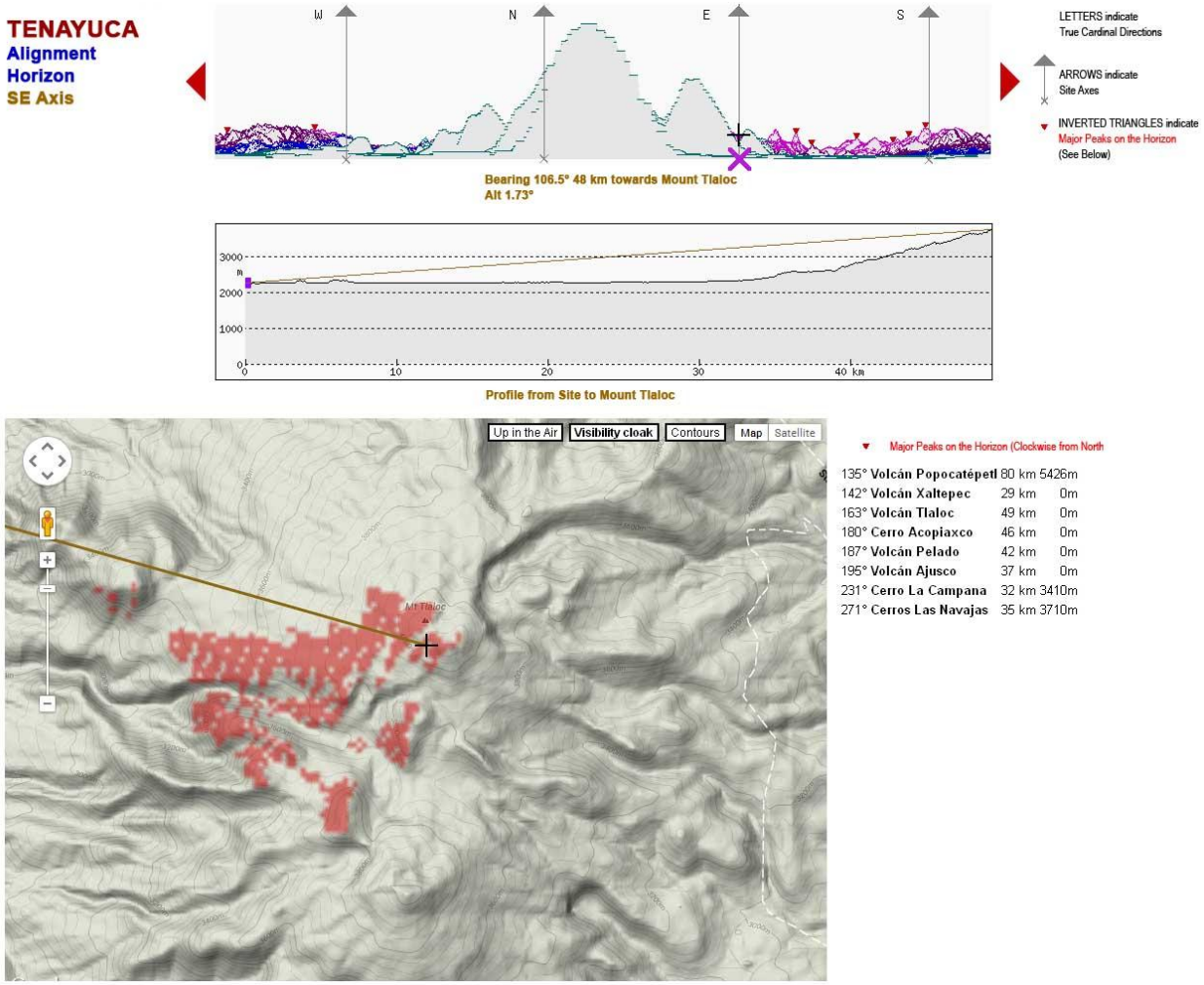


Figure 6.67. Alignment of Tenayuca to the concave space between Cerro del Chiquihuite (4 kilometers) and Cerro Zacatenco (6 kilometers) towards — but not exactly— the concave space between Cerro Tlaloc and Cerro Telapon (48 kilometers) along its the urban east axis, marked on diagram as SE axis (Map data: Google Maps and TA).

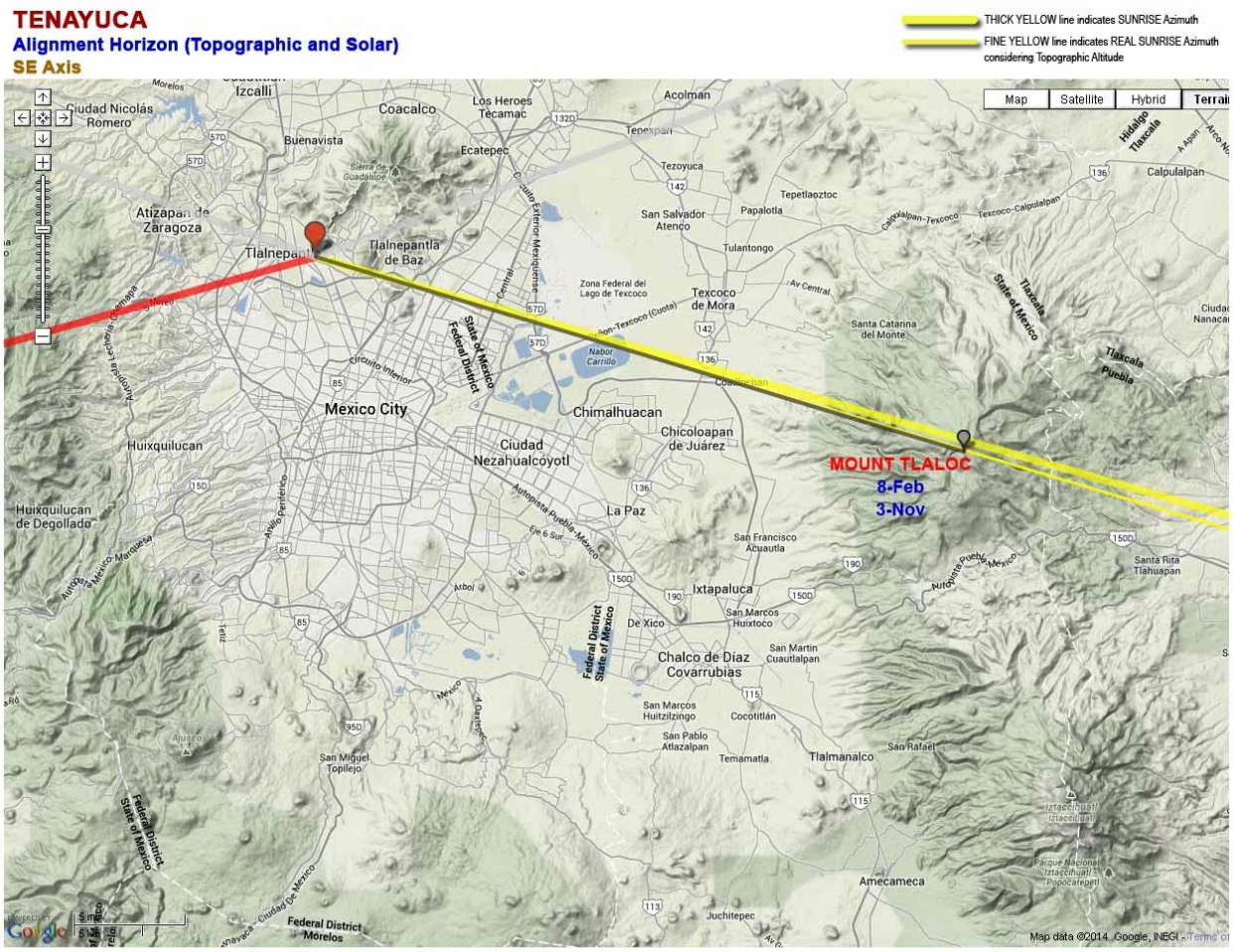


Figure 6.68. Position of the rising Sun along the 106.5° urban east-west axis of Tenayuca considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

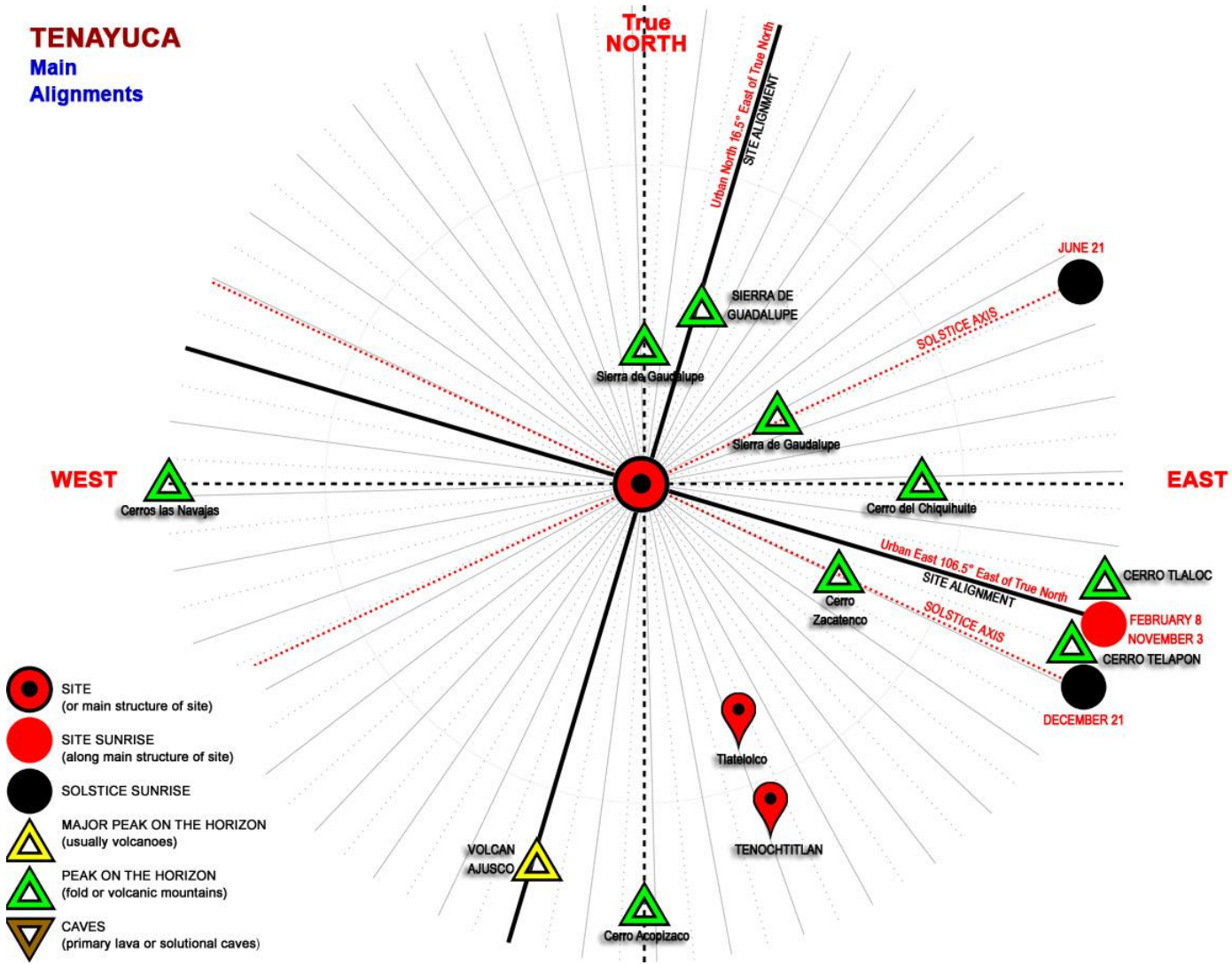


Figure 6.69. Main eastern alignments of Tenayuca. True cardinal directions are indicated as black dotted lines; the main urban axes of Tenayuca are indicated as black lines. The interactions between the *urban north-south-east-west axes* with the topography reveal the urban design principles of Tenayuca.

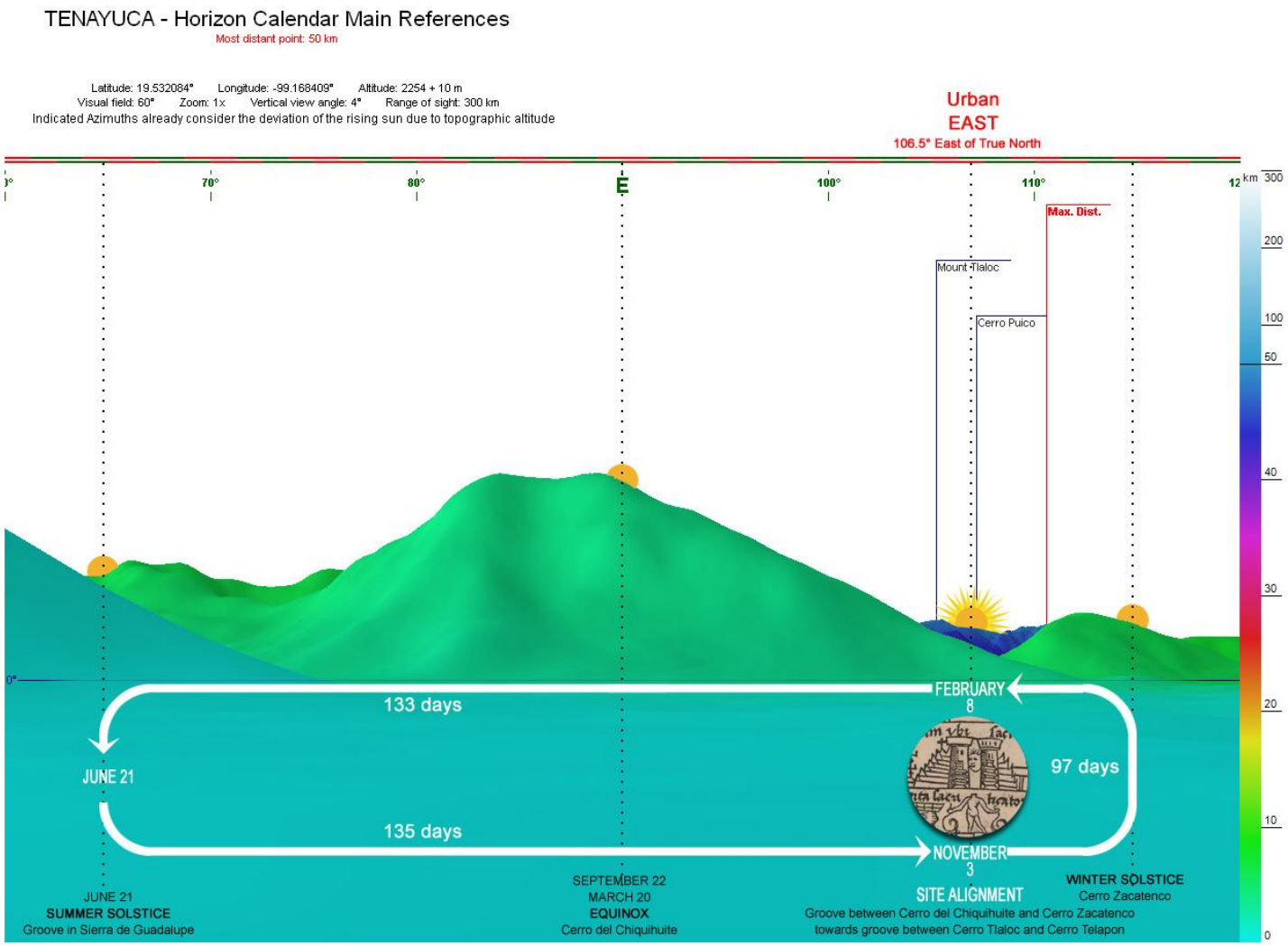


Figure 6.70. Main solar references on the 106.5° eastern horizon calendar of Tenayuca and calendar cycle (Map data: Google, INEGI and UDI).

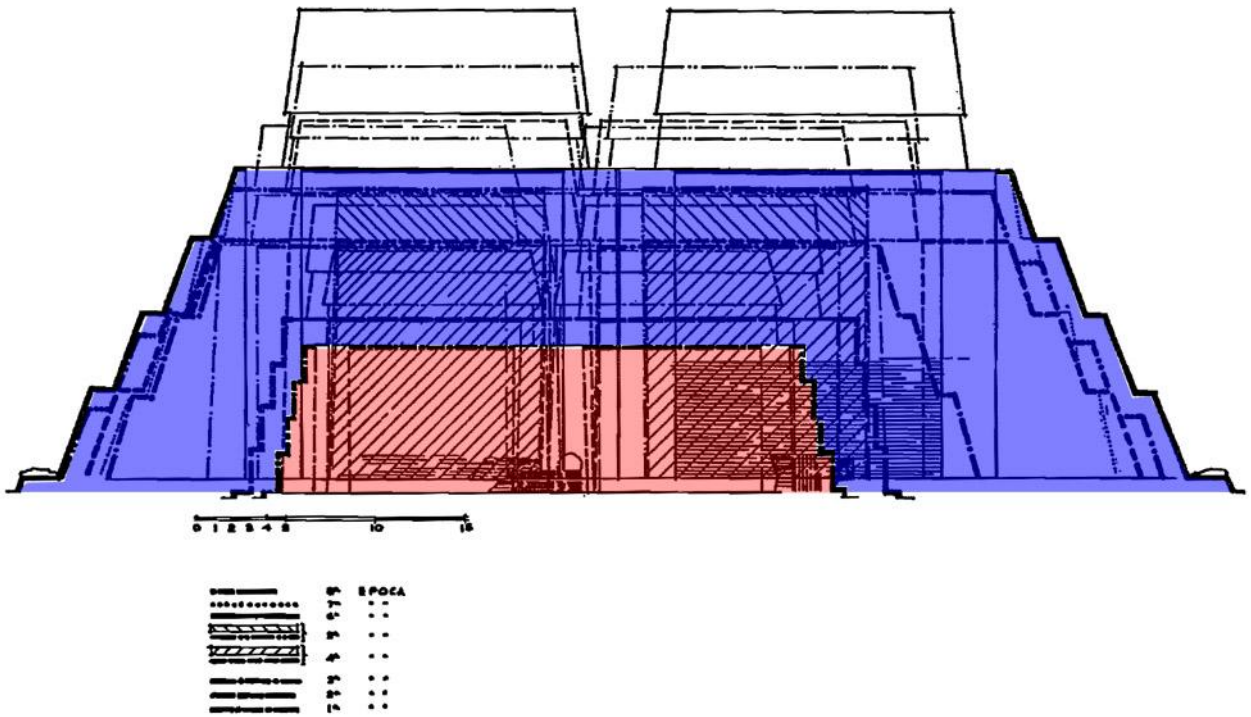


Figure 6.71. Drawing of the front view of the construction stages of the main double temple teocalli of Tenayuca where the observation made by Marquina that *"the temple on the north always stayed in the same place while the south temple was moved further south at each successive stage"* validates the theory proposed in this research that a single teocalli dedicated to Tlaloc was built first to align to Cerro Tlaloc on February 11/12, but that subsequent enlargements had to move and rotate south in order to align to the sacred concave space between Cerro Tlaloc and Cerro Telapon, the mythical space of birth of the Aztec Sun god Huitzilopochtli. This resulted in the offsetting of the architectural axes of the teocalli to the southeast and the site alignment dates from February 11/12 to February 8 (Drawing by Marquina 1964:Figure 50 modified by Rivera).

6.5.4 SANTA CECILIA ACATITLAN

6.5.4.1 Historical Background

The site of Santa Cecilia Acatitlan is located in the State of Mexico, 14 km northwest of Mexico City (Figure 6.72). The site lies on a flat area dominated by the mountains of the Sierra de Guadalupe. Even though it is within an area surrounded by colonial and modern buildings, only a double temple has been excavated (Smith 2008a:59-60) (Figure 6.73). Archaeological records indicate that Santa Cecilia Acatitlan was originally inhabited by Chichimecs, later occupied by the Mexica-Aztecs and converted into one of the several sites that were around Lake Tetzcoco (Aguilar 2007:240). Excavations— and restorations—in Santa Cecilia Acatitlan were undertaken around the 1920s by José Reygadas Vértiz. In 1962, Eduardo Pareyón Moreno led more excavations and reconstructed the two temples at different building stages based upon images in the codices. Currently, the site lies in the *Zona Arqueológica de Santa Cecilia Acatitlan* (Figure 6.74).

6.5.4.2 Previous Archaeoastronomical Research

In spite of the excavations and restorations performed by Reygadas and Pareyón, neither was adequately published (Smith 2008a:60). The only recorded theory to explain the 106.5±0.5° east of true north orientation of Santa Cecilia Acatitlan was offered by Tichy. According to him, this axis aligns to the setting Sun on May 17 and July 27, in other words, one day before the zenith passage and one day after the zenithal passage of the Sun (Galindo 1994:153). However, these dates are a rough approximation, as this axis really aligns to the setting Sun on May 3 and August 8.

6.5.4.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the analyses carried out in this research on Teotihuacan, Tula and Tenochtitlan, the analysis began by determining the coordinates of the main double temple, which were

defined as 19.552564,-99.173325. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of the Santa Cecilia Acatitlan from these coordinates.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.75). To this end, the azimuths of the main double temple were measured. The results were 16.5±0.5° east of true north for the urban north-south axis and 106.5±0.5° east of true north for the urban east-west axis. This alignment reference diagram was superimposed on Google Earth with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

The archaeoastronomical analyses of the urban north-south axis confirmed that it runs from the Sierra de Guadalupe in the north (Figure 6.76), to the Sierra Ajusco in the south, an area also characterized by its abundance of springs. This is similar topographic-urban relationship that Tenochtitlan has along its urban south axis from Pico Tres Padres to the Sierra Chichinautzin.

The archaeoastronomical analyses of the urban east-west horizon revealed that it runs from a nondescript topographic feature in the west, to the groove between the southeast corner of Sierra de Guadalupe and the Cerro del Chiquihuite (Figure 6.77), thus framing the rising of the Sun on February 8 and November 3. Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align to the position of the rising and the setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction. Due to the location of Santa Cecilia Acatitlan within an area dominated by mountains at a short distance, both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from the main double temple of Santa Cecilia Acatitlan, the urban east axis intersects the rising Sun on the local eastern horizon on February 8 and November 3 at a 106.5±0.5° azimuth, 3.65° altitude and a distance of 1 km (Figure 6.78); while the urban west axis intersects the setting Sun on the local western horizon on August 8 and May 3 at 286.5±0.5°azimuth, 1.16° altitude and a distance of 33 km. These analyses suggest that the most

feasible horizon calendar is to the east as the topographic features on the western horizon have similar shapes and altitudes.

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and the setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on June 21 (summit of southwest mountain of the Sierra de Guadalupe), September 22 (along the Sierra de Guadalupe), December 21 (summit of Cerro del Chiquihuite) and March 20 (along the Sierra de Guadalupe) on the eastern horizon. The same set of calculations was performed for the western horizon, but it became apparent that alignments to topographic features towards this direction were not easy to identify due to its similar altitude. This confirmed that Santa Cecilia Acatitlan had probably one functional horizon to the east that could have been used to mark the beginning of the Nemontemi days as discussed by Galindo (1994:153) and followed the main calendar of Tenochtitlan throughout the year.

Once all of the information was determined, it was summarized on a diagram (Figure 6.79) and a table which included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons. This table was utilized to plot the main solar reference points for the either the eastern (Figure 6.80) or western horizon calendar of Santa Cecilia Acatitlan. This information was also used to calculate the days between the alignment of Santa Cecilia Acatitlan and the solstitial and equinoctial solar dates, which resulted in the division of the year in three main intervals that resembled the 260-53-52 intervals in the calendar of Teotihuacan:

- Horizon calendar on the eastern horizon (106.5±0.5° urban E-W axis)

February 8 > 133 days > June 21 > 135 days > November 3 > 97 days > February 8

The results of this research suggested that —in spite of the location of Santa Cecilia Acatitlan surrounded by mountains to the east and the lack of knowledge whether it had more construction stages— the alignment and the symbolic meaning of the Sun coming out between two mountains

was still being kept in the urban design of the city. Similar to Tenayuca and Tlatelolco, the founders of the city only kept the alignments but not the connection to the synodic cycles of Venus, as the horizon calendar did not mark 73-day intervals. Even though these calendar references did not mark a 260-day interval like Teotihuacan, it was the best approximation given the design constraint to align the main east-west axis of the site between Cerro Tlaloc and Cerro Telapon. These findings also support the theory that the main double teocalli —or Great Temple— of Santa Cecilia Acatitlan could be viewed in the context of the architectural-urban-landscape interplay between the two double temples of Tlaloc and Huitzilopochtli and the space between two mountains from several possible viewpoints, which was the same symbolic and spatial relationship that Tenochtitlan had between their architecture and their sacred landscape. By founding Santa Cecilia Acatitlan in this location, the Aztecs demonstrated how they applied their profound knowledge of astronomy, topography, mathematics and geometry into their urban and architectural design.

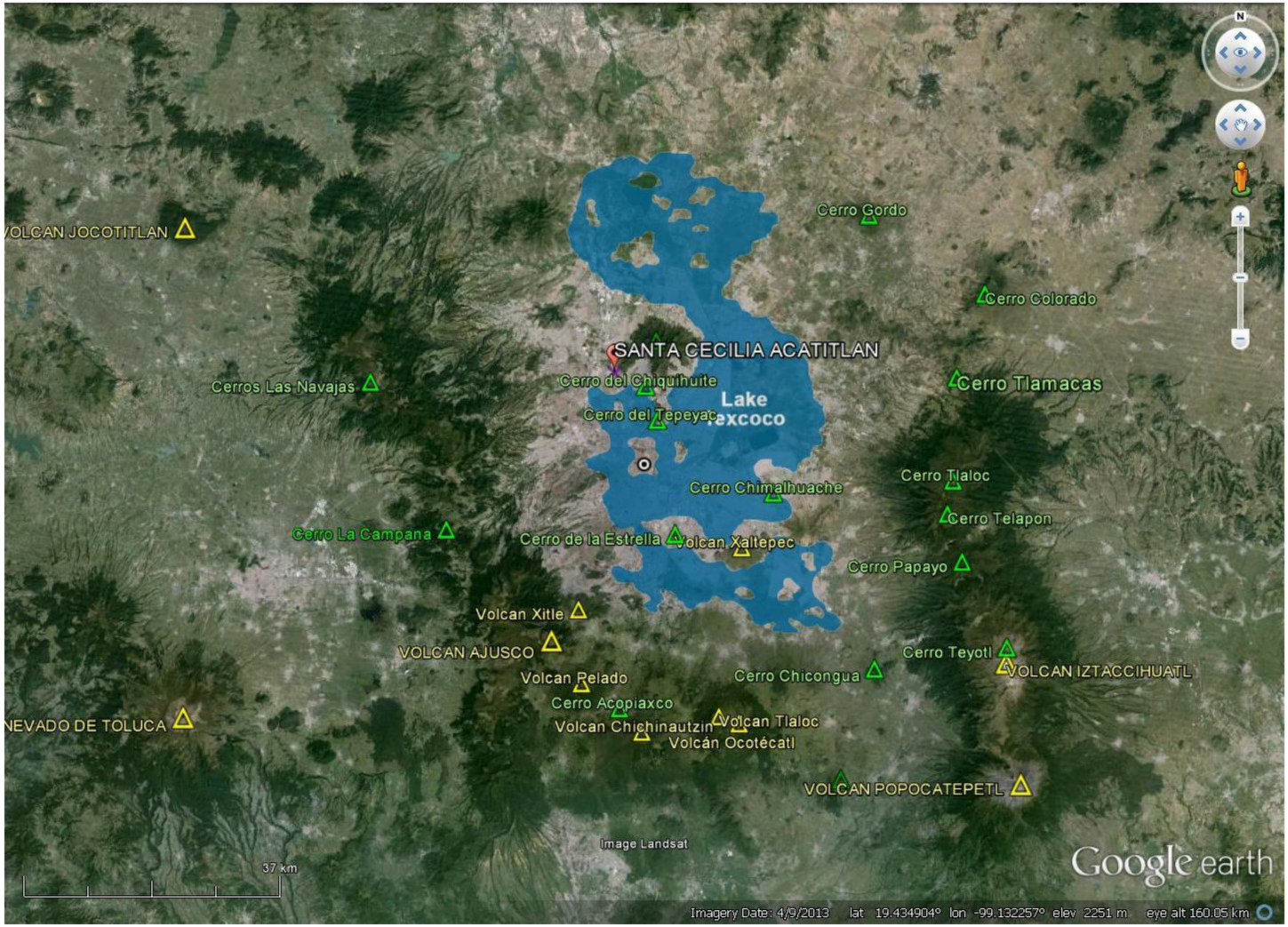


Figure 6.72. Location of Santa Cecilia Acatitlan indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

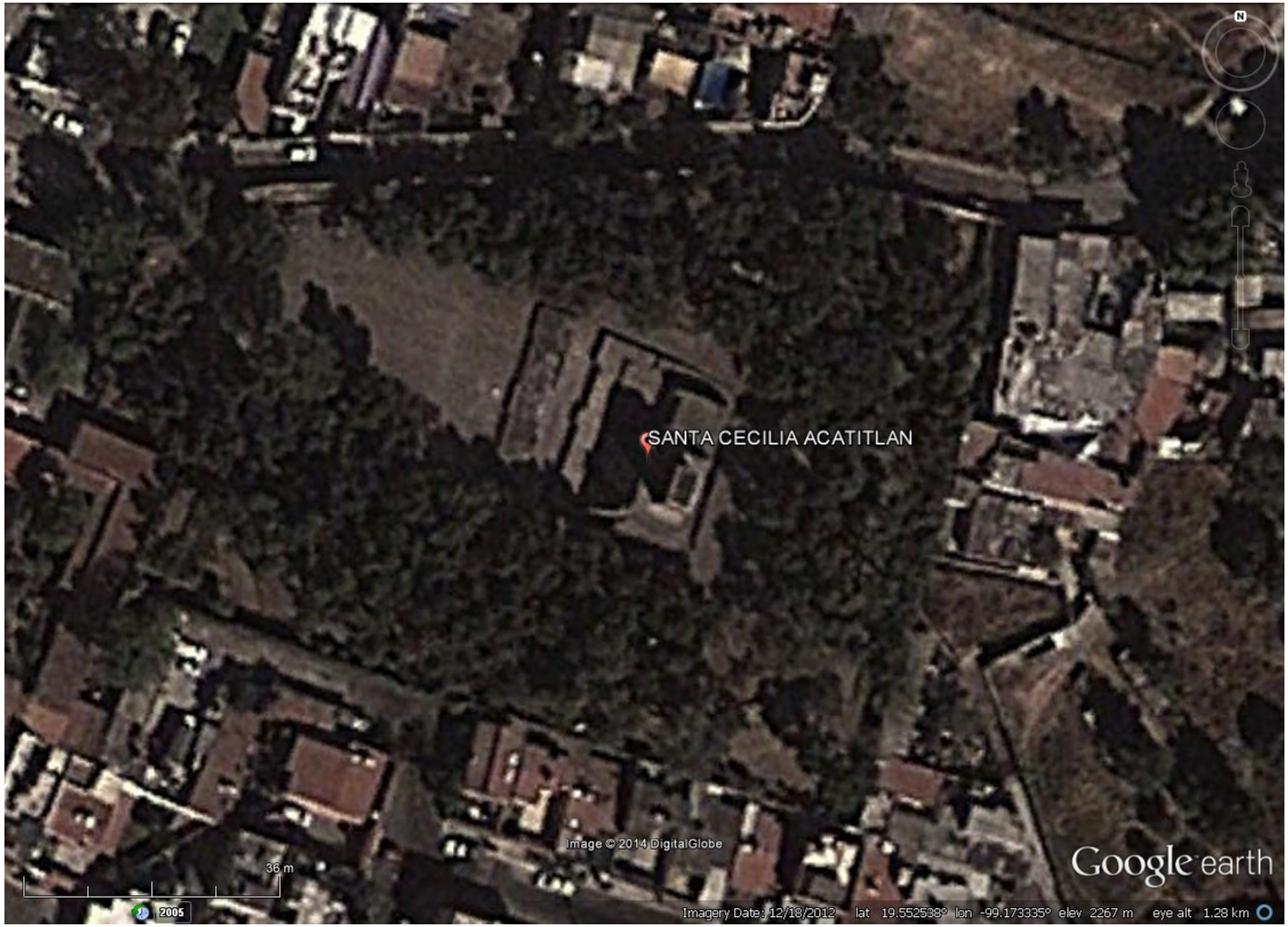


Figure 6.73. Aerial view of the archaeological remains of Santa Cecilia Acatitlan, scale 1:200 (Map data: Google Earth).

Figure 6.74. Google street view of archaeological remains of Santa Cecilia Acatitlan (Map data: Google Street View).

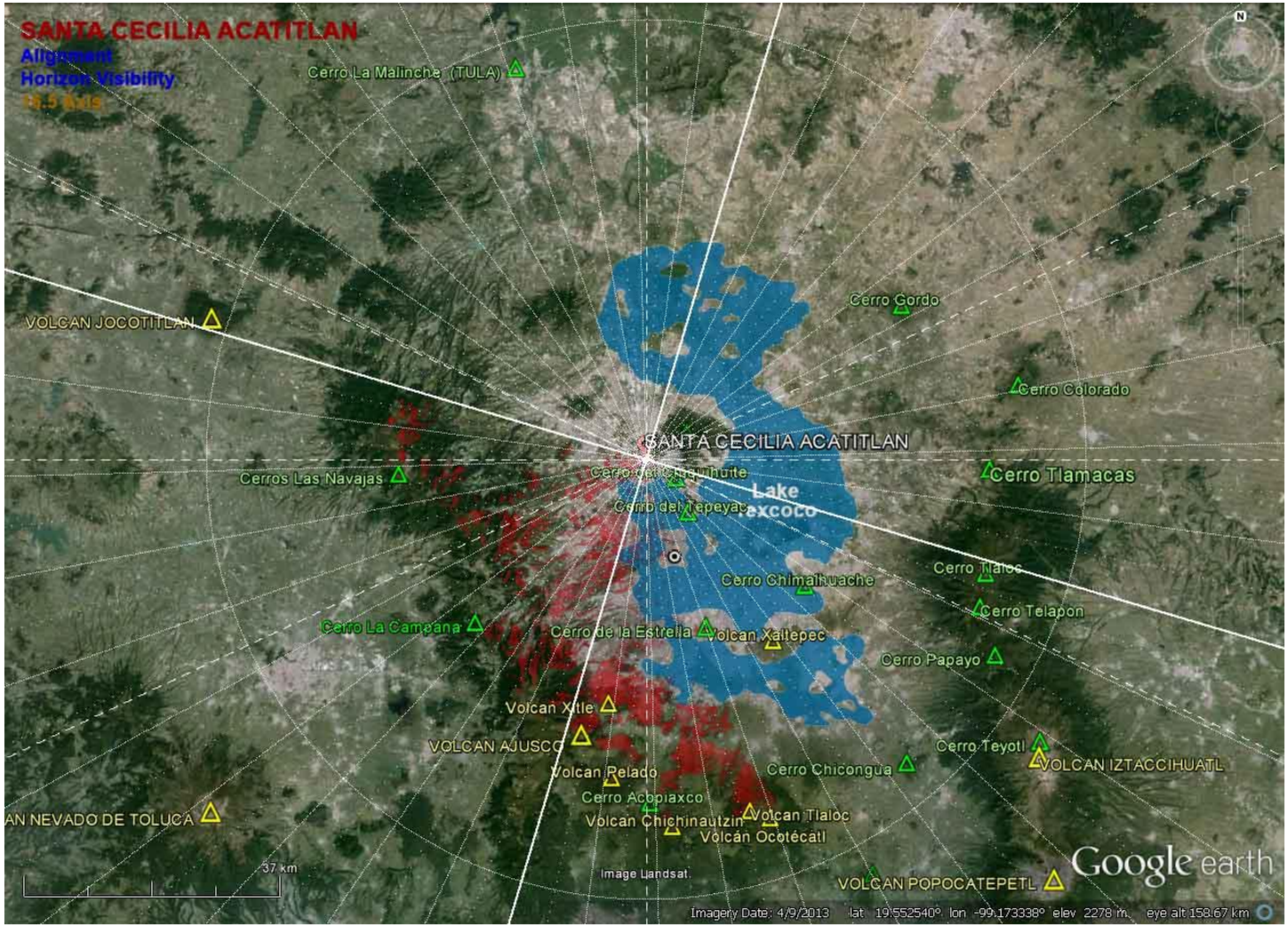


Figure 6.75. Alignment reference diagram superimposed on topographic landscape of Santa Cecilia Acatitlan. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

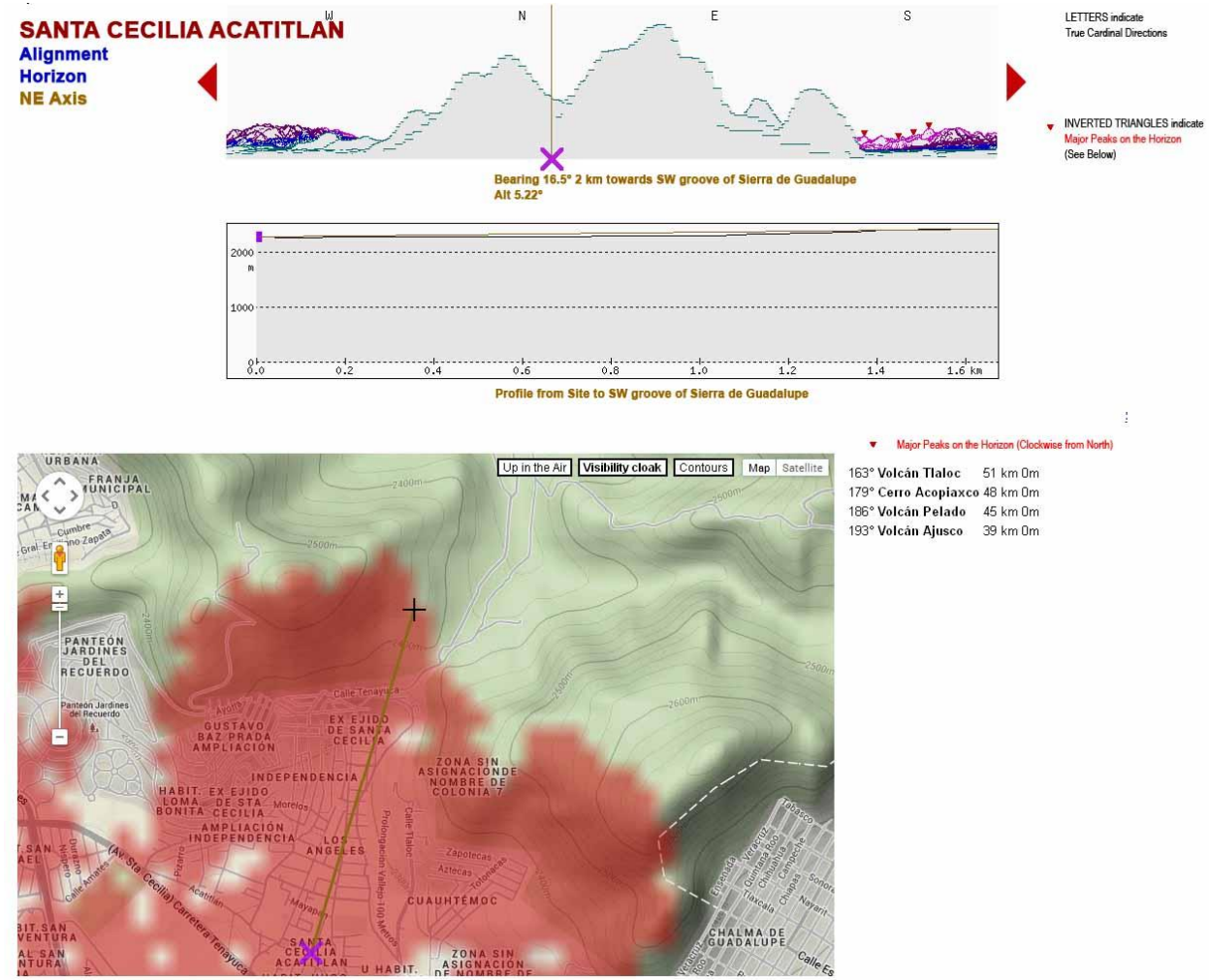


Figure 6.76. Alignment of Santa Cecilia Acatitlan to the Sierra de Guadalupe along its the urban north axis, marked on diagram as NW axis (Map data: Google Maps and TA).

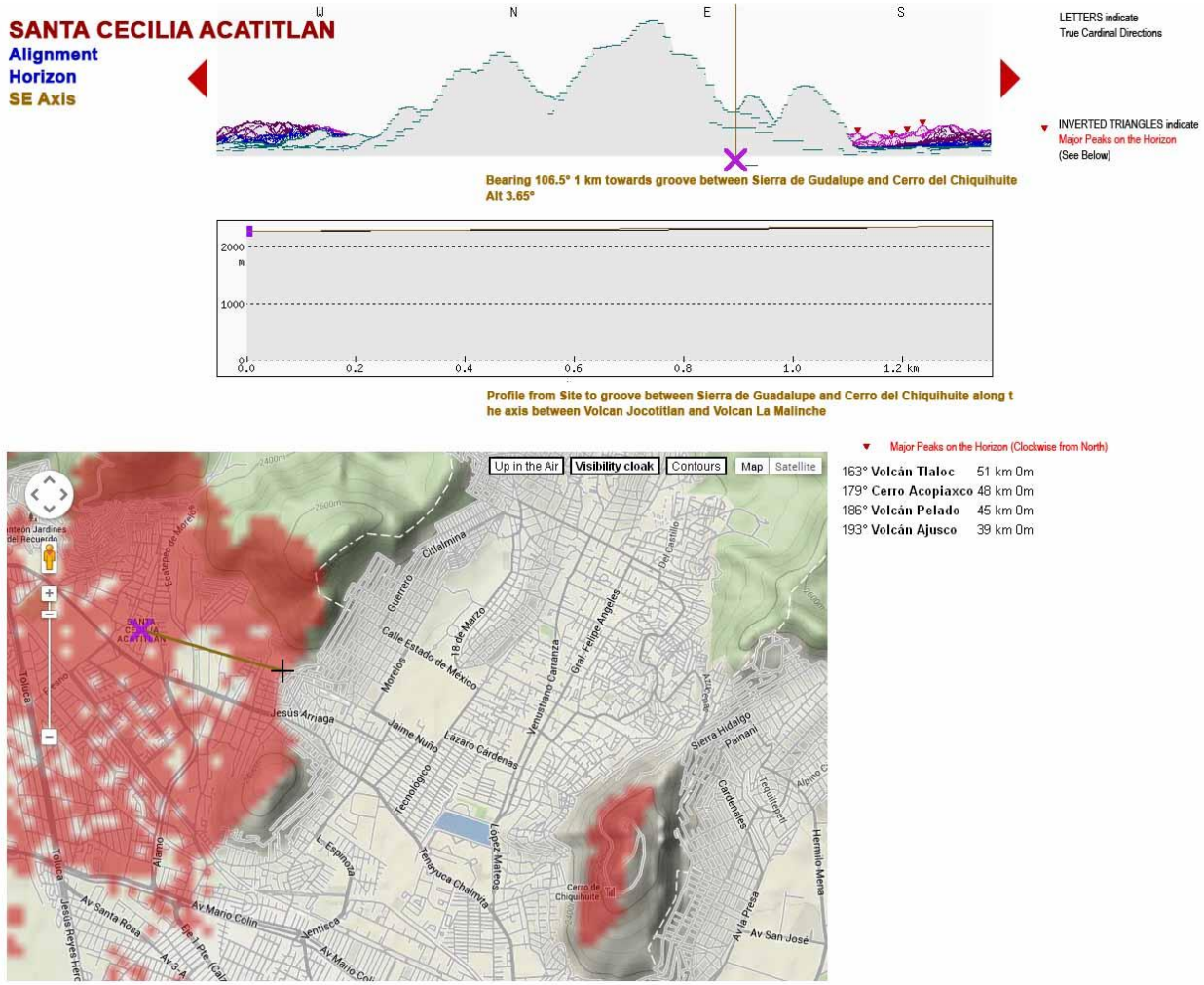


Figure 6.77. Alignment of Santa Cecilia Acatitlan to the concave space between Sierra de Guadalupe and Cerro del Chiquihuite towards —but not exactly— the concave space between Cerro Tlaloc and Cerro Telapon along its the urban east axis, marked on diagram as SE Axis. Since the view towards Cerro Tlaloc and Cerro Telapon was partially obstructed by Cerro del Chiquihuite, the founders of Santa Cecilia Acatitlan probably followed the orientation of Tenayuca, located approximately 4 kilometers to the southeast of Santa Cecilia Acatitlan (Map data: Google Maps and TA).

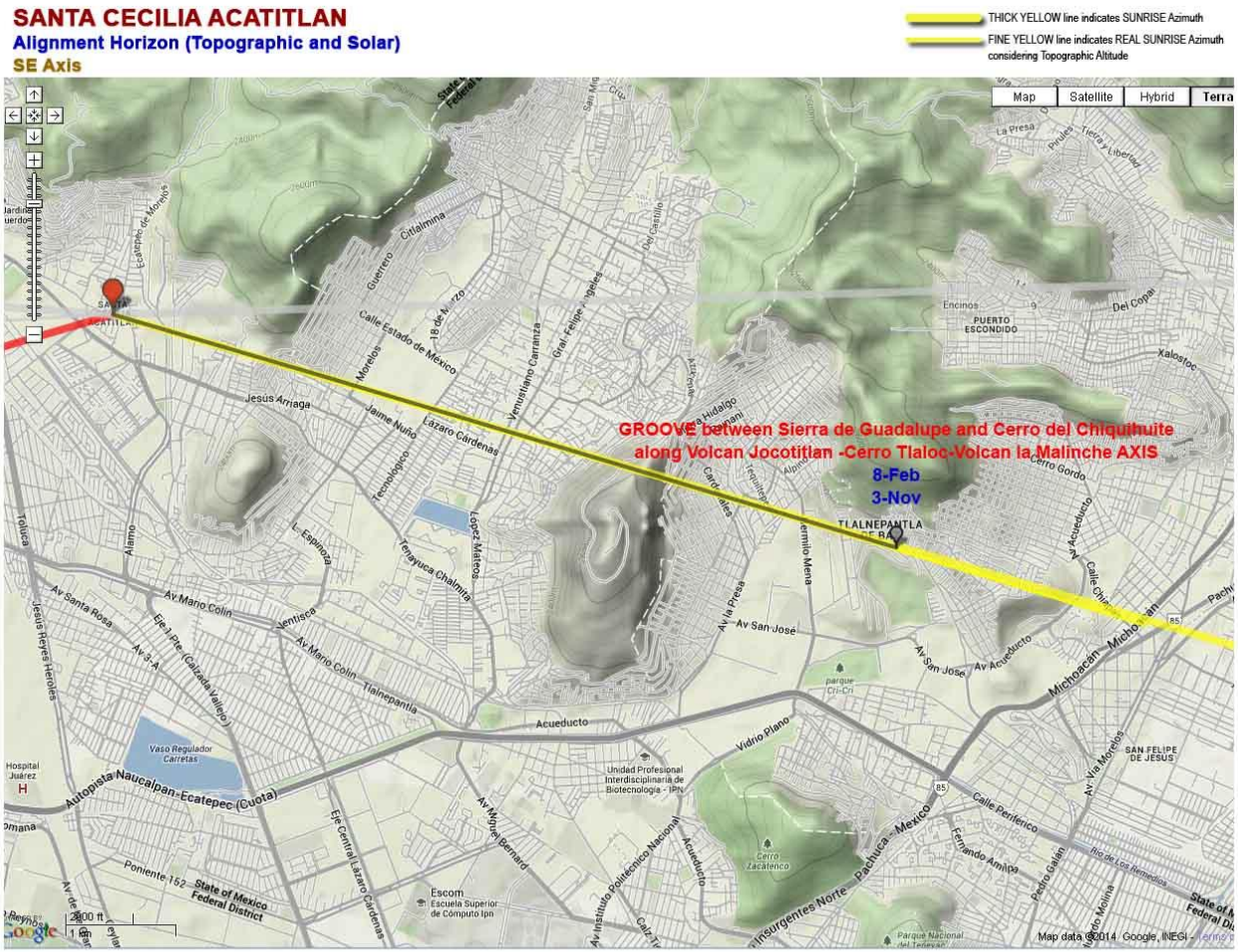


Figure 6.78. Position of the rising Sun along the 106.5° urban east-west axis of Santa Cecilia Acatitlan considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

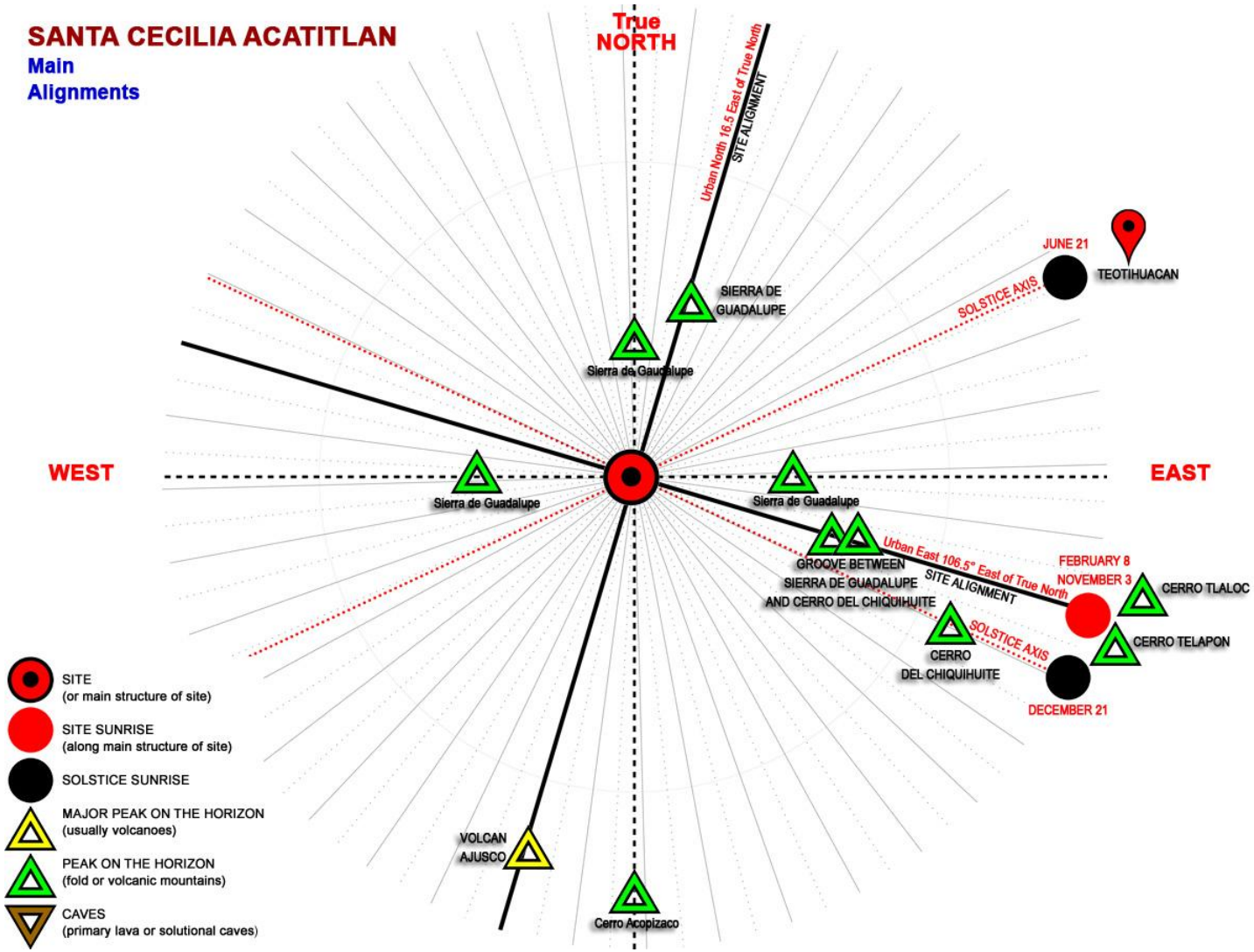


Figure 6.79. Main eastern alignments of Santa Cecilia Acatitlan. True cardinal directions are indicated as black dotted lines; the main urban axes of Santa Cecilia Acatitlan are indicated as black lines. The interactions between the urban north-south-east-west axes with the topography reveal the urban design principles of Santa Cecilia Acatitlan.

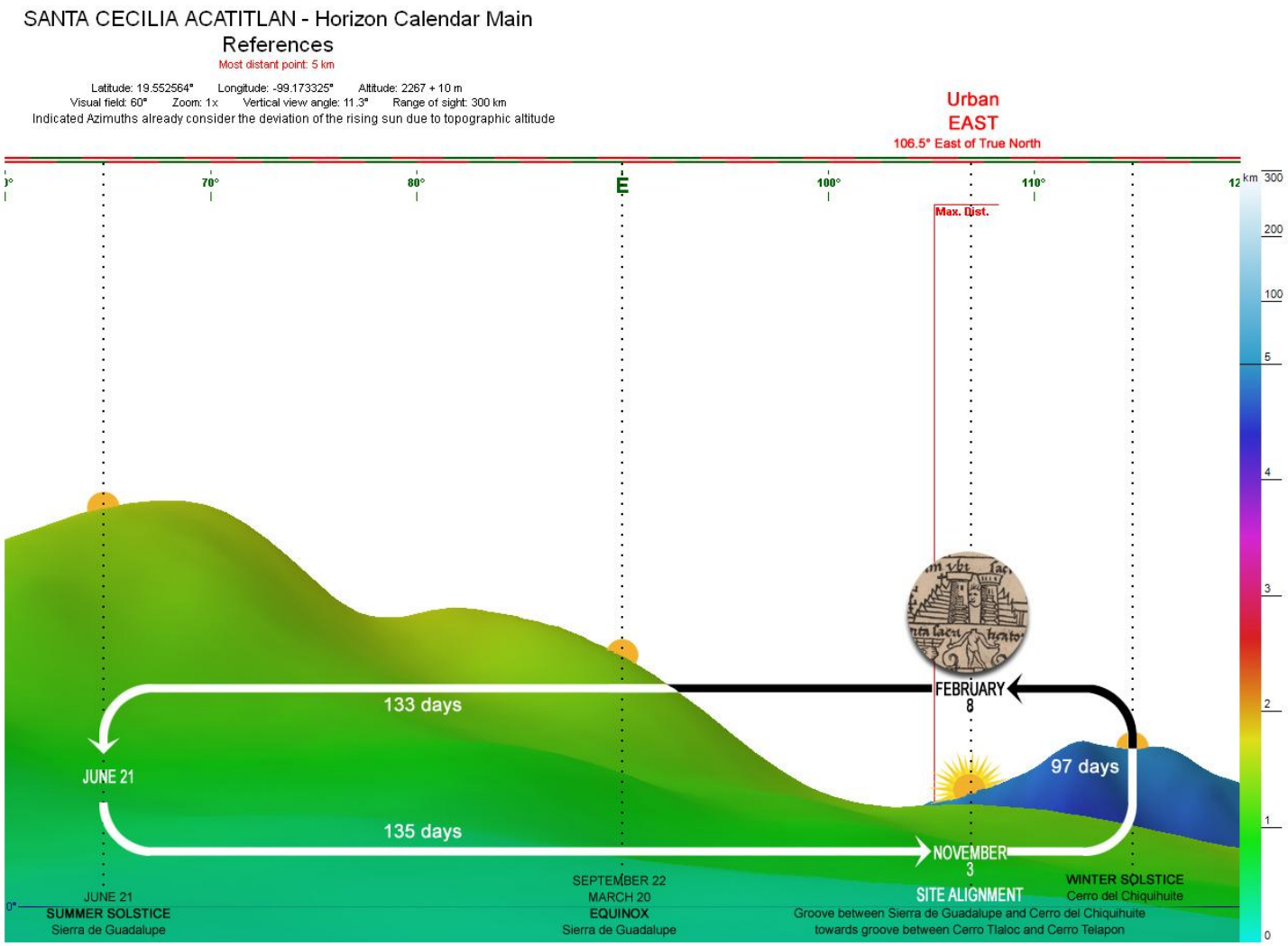


Figure 6.80. Main solar references on the 106.5° eastern horizon calendar of Santa Cecilia Acatitlan and calendar cycle (Map data: Google, INEGI and UDI).

6.5.5 TEOPANZOLCO

6.5.5.1 Historical Background

The site of Teopanzolco is located in the State of Mexico, 58 km south of Mexico City (Figure 6.81). The site lies on an area dominated by the Cerro Tres Cruces on the north and the Volcán Iztaccihuatl and the Volcán Popocatepetl on the east. Even though this area is surrounded by colonial and modern buildings in the modern city of Cuernavaca, it has one of the most complete urban centres of any Aztec site including a main double temple with two identified stages, several low platforms and possibly a palace (Konieczna 2005:2).

Teopanzolco was originally inhabited by the Tlahuica, but was later conquered by the Aztecs and incorporated into the Empire as a tributary province. According to Konieczna, the initial settlement was destroyed and new structures were built over the leveled buildings in a different layout from the original layout of the precinct (Figure 6.82). This new layout was similar to the design of ceremonial precincts of Tenochtitlan and Tlatelolco including a double temple pyramid and circular base platforms (2005:2).

Archaeological excavations have been undertaken in Teopanzolco since 1921 when the main double temple was discovered by accident when the vibrations caused by firing a cannon on a mound during the Mexican revolution shook loose dirt and revealed the walls of the structure. Caso and Reygadas excavated and restored this structure —the main double temple— in the 1920s. Intermittent excavations followed in the late 1950s and 1960s that revealed more structures organized around a central axial plan. In the 1970s. Jorge Angulo restored some of these buildings (Smith 2008:34). Exploratory work continued in other structures, and in 1982, Konieczna and Mayer discovered that the platform north of the main double temple had two stages. However, it was in the last decade that the remains of several structures beneath the plaza were detected. Currently, the main part of the city lies in the *Zona Arqueológica de Teopanzolco* (Figure 6.83).

6.5.5.2 Previous Archaeoastronomical Research

Although the excavations and restorations in Teopanzolco have not been adequately published, some archaeoastronomers have noted the slight clockwise azimuthal deviation of its urban axes from 0.72° in its urban north axis (Aveni and Gibbs 1976:512) to 92.62°±0.25° in its urban east axis (Šprajc 2001a:346). Apart from noting that it was one of the smallest azimuthal deviations that they had measured in ten Central Mexican ceremonial centres, Aveni and Gibbs did not discuss this peculiar orientation further (1976:515).

Šprajc measured the azimuthal deviations of both the main double temple and Temple II (the structure located behind the main double temple along its urban east axis). He reported that the main double temple was oriented to the setting Sun on Cerro del Aire on March 29 and September 14 in intervals separated by 169 days (13 trecenas), but he could not find "ideal" intervals for both directions with the same orientation. Hence, he proposed that the main double teocalli only marked the sunset dates while Temple II marked sunrise dates, so both of them could have been used simultaneously to mark relevant dates in the calendar (2001a:248). Even though this is a feasible proposal, the variables produced by having two viewing points might render both observations unreliable.

6.5.5.3 Discussion of Digital Archaeoastronomical Analysis and Research Findings

Building upon the analyses carried out in this research on Teotihuacan, Tula and Tenochtitlan, the analysis began by determining the coordinates of the main double temple, which were defined as 18.930391,-99.221989. The analysis proceeded to identify the prominent peaks on the horizon and to calculate the viewshed of Teopanzolco from these coordinates.

The creation of an alignment reference diagram followed in order to determine the main urban axes of the site (Figure 6.84). To this end, the azimuths of the main double temple and the excavated structures were measured. The results were 2.0°±.05° east of true north for the urban north-south axis and 92.0°±.05° east of true north for the urban east-west axis, consistent with those recorded by Šprajc. This alignment reference diagram was superimposed on Google Earth

with the viewshed data imported from the TA at different scales with the aim of exploring the spatial relationships of the site with the landscape at different distances.

The archaeoastronomical analyses of the urban north-south axis demonstrated that it runs from the Cerro Tres Cruces in the north (Figure 6.85) to non-descript topographical features on the south.

The archaeoastronomical analyses of the urban east-west horizon revealed that it runs from a nondescript topographic feature in the west, to the space between the closest mountain to the east and the Cerros de Yeganexchco (Figure 6.86), thus framing the rising of the Sun on March 13/14 and September 29. Once the topographic features along the urban axes were investigated, the next steps were to calculate the solar elevation and azimuth angles for the dates when the urban east-west axes align to the position of the rising and the setting Sun on the eastern and western horizons respectively, taking into consideration the viewshed of the site, curvature of the Earth and refraction. Due to the location of Teopanzolco, both the astronomical and local horizons had to be taken into consideration to get precise information for these alignments. Hence, the analyses indicated that, viewed from the main double temple of Teopanzolco, the urban east axis intersects the rising Sun on the local eastern horizon on March 13/14 and September 29 at a 92.0°±.05° azimuth, 0.9° altitude and a distance of 58 km (Figure 6.87), while the urban west axis intersects the setting Sun on the local western horizon on March 29 and September 13 at 272.0°±.05° azimuth, 3.3° altitude and a distance of 14 km. These analyses suggest that the most feasible horizon calendar is to the east, as the topographic features on the western horizon have similar shapes and altitudes.

The analyses proceeded to calculate the solar elevation and azimuth angles for the position of the rising and the setting Sun during the solstices and equinoxes, taking into consideration the viewshed of the site, curvature of the Earth and refraction. These analyses indicated that easily identifiable topographic features could be determined towards the rising Sun on June 21 (summit of the Volcán Iztaccihuatl), September 22 (Cerro Hueyapan), December 21 (Cerros Las Tetillas) and March 20 (Cerro Hueyapan) on the eastern horizon. The same set of calculations were performed for the western horizon, but it became apparent that alignments to topographic

features towards this direction were not easy to identify due to its similar altitude. This confirmed that Teopanzolco had probably one functional horizon to the east, and another to the west with fewer major references to adjust both calendars.

Once all of the information was determined, it was summarized on a diagram (Figure 6.88) and a table which included site alignments (true north-south-east-west and urban north-south-east-west axes) as well as solstitial and equinoctial solar positions on the local eastern and western horizons This table was utilized to plot the main solar reference points for the either the eastern (Figure 6.89) or western horizon calendar of Teopanzolco. This information was also used to calculate the days between the alignment of Teopanzolco and the solstitial and equinoctial solar dates, which resulted in the division of the year in three main intervals:

- Horizon calendar on the eastern horizon (106.5±0.5° urban E-W axis)

March 13/14 > 100 days > Jun 21 > 100 days > September 29 > 165 days > March 13/14

The results of this research suggested that —in spite of the location of Teopanzolco 58 km south of Tenochtitlan and consequently within a different topographic landscape— the alignment and the symbolic meaning of the Sun coming out in a space between two mountains was still being kept in the design of its ceremonial precinct. Similar to Tenayuca and Tlatelolco, the founders of the city only kept the alignments but not the connection to the synodic cycles of Venus, as the horizon calendar did not mark 73-day intervals. Even though these calendar references did not mark the 260-53-52 intervals in the calendar of Teotihuacan or the 219-73-73 intervals of Tenochtitlan, it marked 20-day calendrical intervals that could be followed with precision on the horizon. These findings also support the theory that the main double temple —or Great Temple— of Teopanzolco could be viewed in the context of the architectural-urban-landscape interplay between the two double temples of Tlaloc and Huitzilopochtli and the space between two mountains from several possible viewpoints, which was the same symbolic and spatial relationship that Tenochtitlan had between their architecture and their sacred landscape. By razing the original ceremonial precinct of Teopanzolco and building the new precinct on this location but only with a slight deviation to align to a birthplace *within the local landscape* for Huitzilopochtli between two mountains, the Aztecs demonstrated how they applied their

profound knowledge of astronomy, topography, mathematics and geometry into their urban and architectural design.

These findings also lead to the proposal of the theory that the initial location and orientation of the main complex of Teopanzolco was determined by the Tlahuica when they founded the city. This location was likely determined by the solstitial points, as they are clearly marked by the summit of the Volcán Iztaccihuatl on June 21 and Cerros las Tetillas on December 21. Since the deviation of the main urban east-west urban axis had to rotate clockwise 90° to 115° east of north in order to mark a sunrise at the nauhcampa cosmological space between the equinox and the winter solstice (see Chapter 6), then any axis between this range could have determined the main orientation of the initial site. Until further excavations of the razed structures underneath the plaza are performed, any of these hypothetical orientations could have been utilized by the founders of the city to build their ceremonial centre and their buildings, including 104.54 (February 12) or 96.86° (March 4).

However, when the Aztecs took over the city, it is possible that they did not want to build their main double temple with the same orientation as the original Tlahuica temple as it did not mark a space between two mountains where Huitzilopochtli could be born. Hence, they razed the ceremonial center and built their main double temple —Great Temple— towards 92.0°±.05°, the only direction between 90° and 115° (Figure 4.6) where there was a concave space on the horizon that could act as the landscape extension needed for this unique Aztec architectural type. Hence, this theory provided an explanation for the razing of the original site and a confirmation that the orientation of the Great Temple in major Aztec sites had to reproduce the main urban and architectural design principles of the Great Temple of Tenochtitlan, the centre of the Aztec world. This local reenactment of the birth of Huitzilopochtli, the patron deity of Tenochtitlan, could have served to assert their power on Teopanzolco.

Figure 6.81. Location of Teopanzolco indicating prominent peaks around the site, scale 1:10,000. Yellow triangles, indicating larger peaks, are identified as "volcán" (volcano), while green triangles, indicating smaller peaks, are identified as "cerro" (mountain), regardless of their geological origins (Map data: Google Earth).

Figure 6.82. Aerial view of the archaeological remains of Teopanzolco, scale 1:200 (Map data: Google Earth).

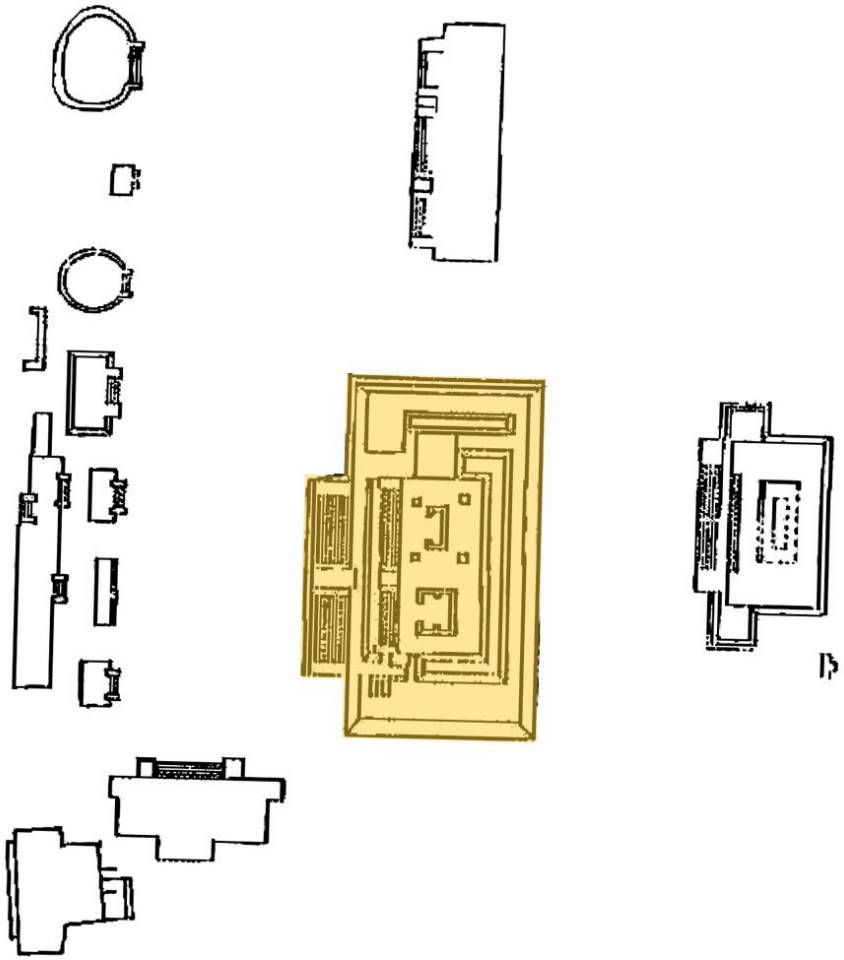


Figure 6.83. Plan of archaeological remains of Teopanzolco (Konieczna 2005:Figure 1).

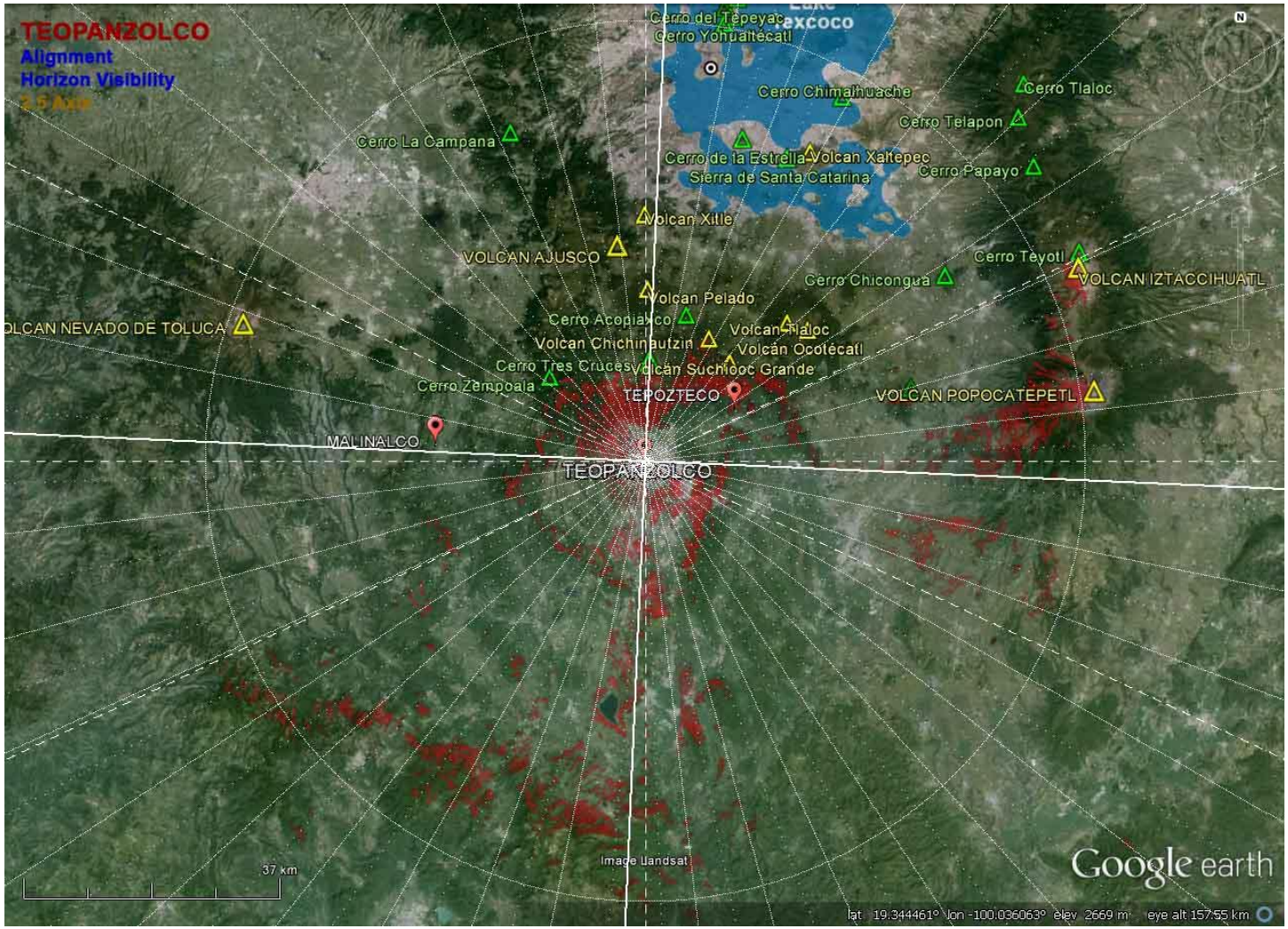


Figure 6.84. Alignment reference diagram superimposed on topographic landscape of Teopanzolco. Tentative alignments to prominent peaks on the horizon can be observed on solstitial/equinoctial and urban axes, scale 1:10,000. (Map data: Google Earth, AutoCAD, TA and CGA).

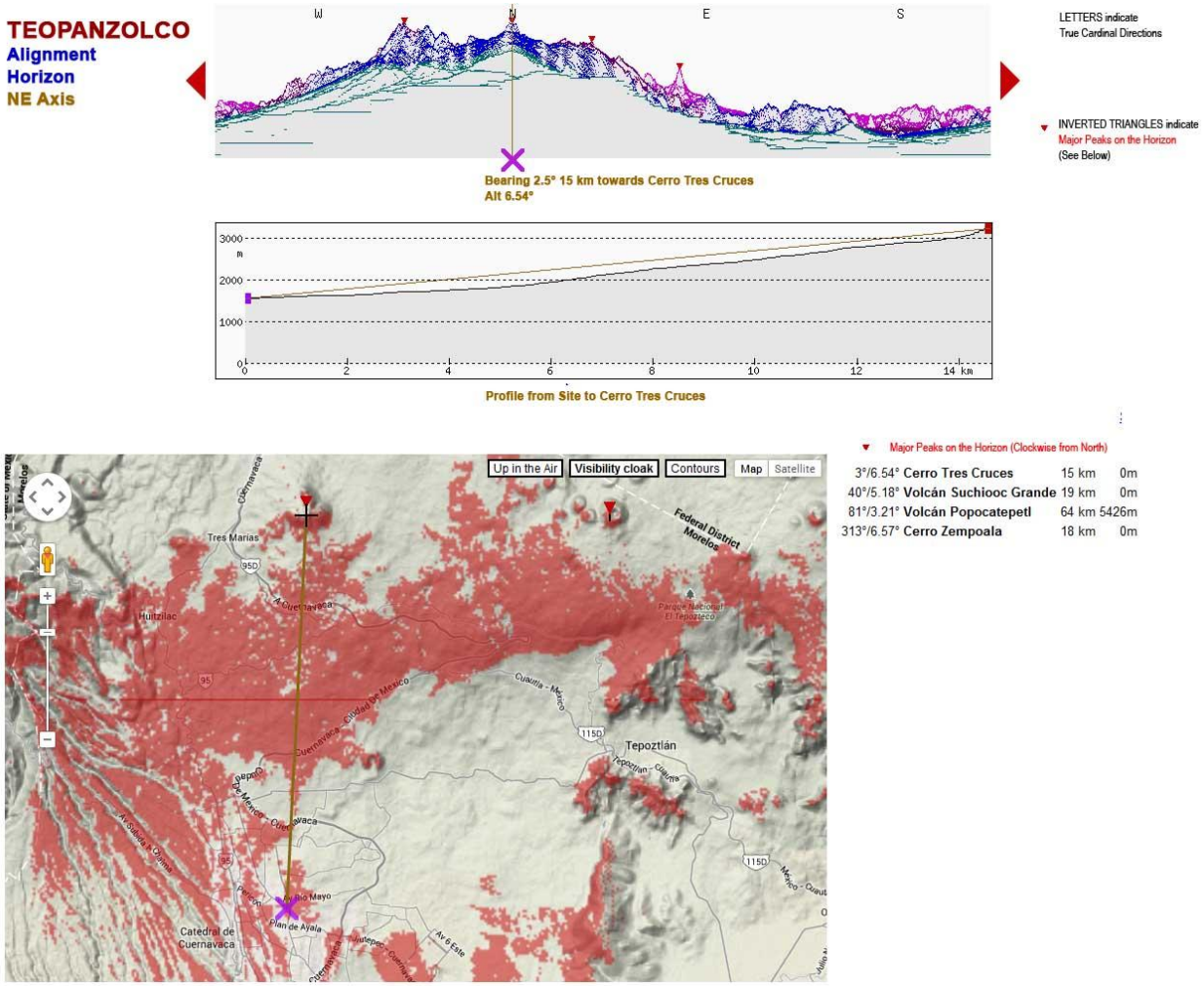


Figure 6.85. Alignment of Teopanzolco to Cerro Tres Cruces along its urban north axis, marked on diagram as NW Axis (Map data: Google Maps and TA).

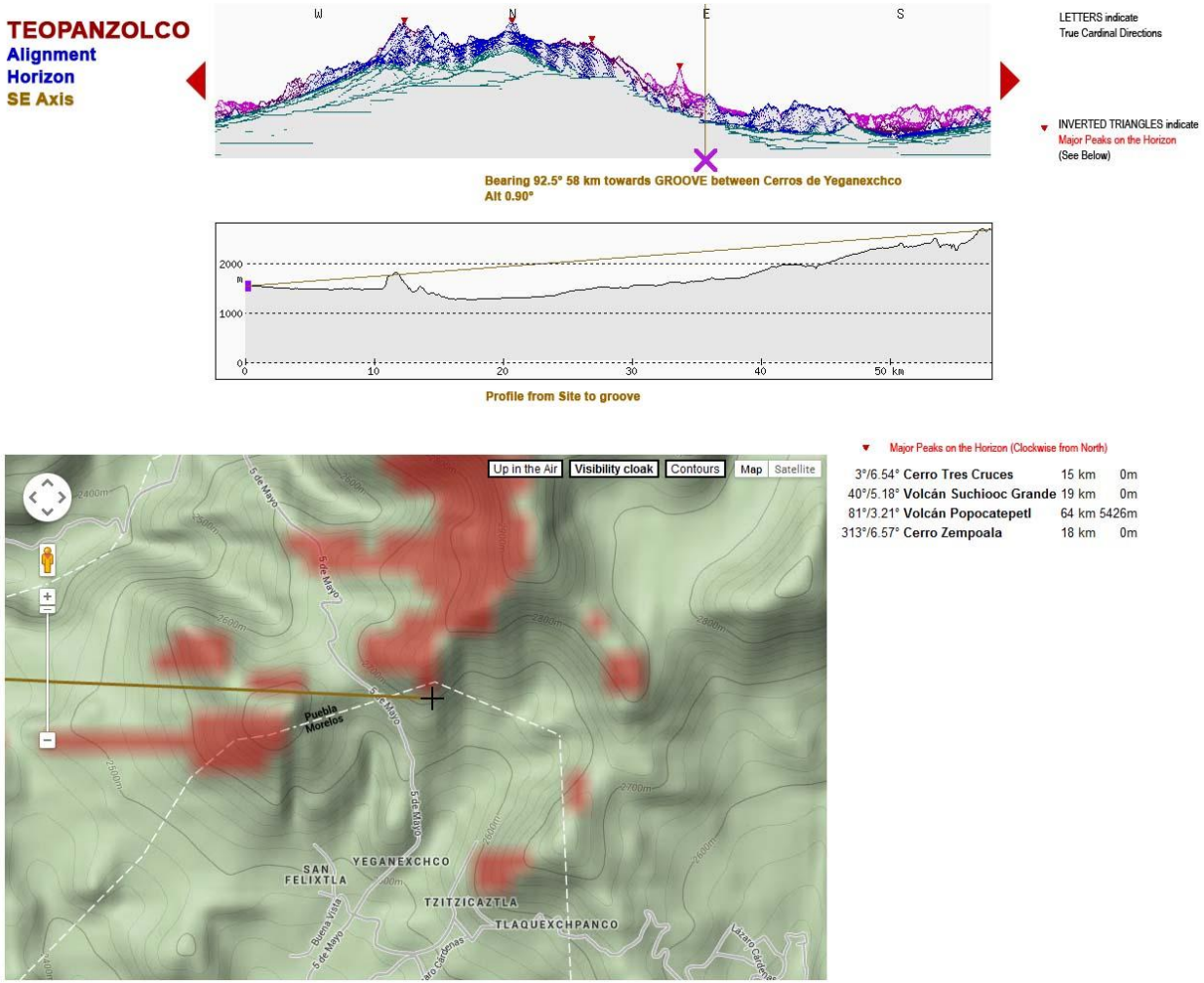


Figure 6.86. Alignment of Teopanzolco to the concave space between the closest mountains and the Cerros de Hueyapan at the base of Volcán Popocatepetl along its urban east axis, marked on diagram as SE axis. Before it was razed and rebuilt by the Aztecs to align to this direction, the axes of the ceremonial precinct at Teopanzolco probably aligned to the Cerros de Hueyapan during the equinox, a theory proposed in this research (Map data: Google Maps and TA).

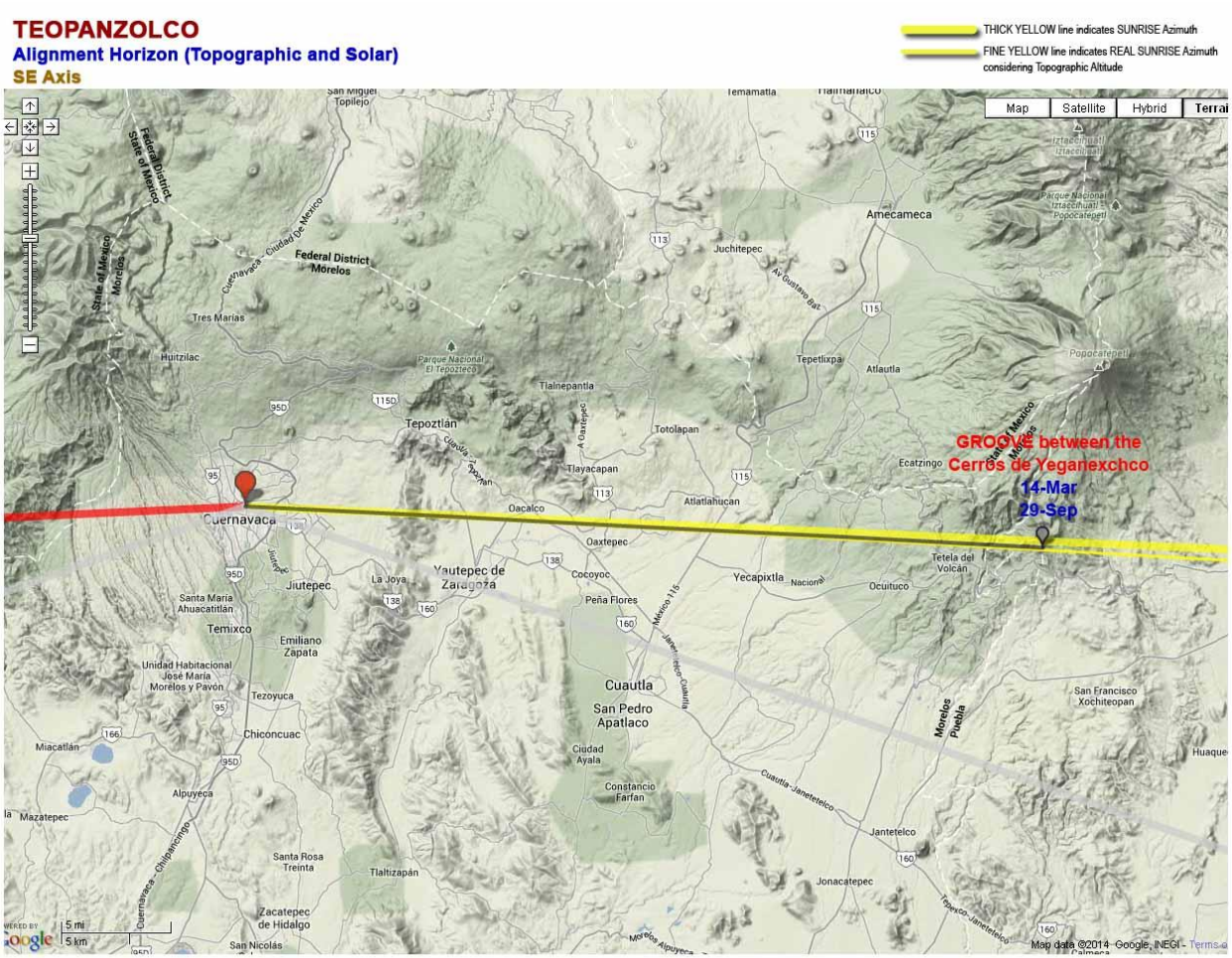


Figure 6.87. Position of the rising Sun along the 103.5° urban east-west axis of Teopanzolco considering topographic altitude and the curvature of the Earth. The thick yellow line indicates the sunrise azimuth in the astronomical horizon. The fine yellow line indicates the sunrise azimuth in the local horizon, which corresponds to the real position of the Sun viewed from the site (Map data: Google Maps, INEGI and SCA).

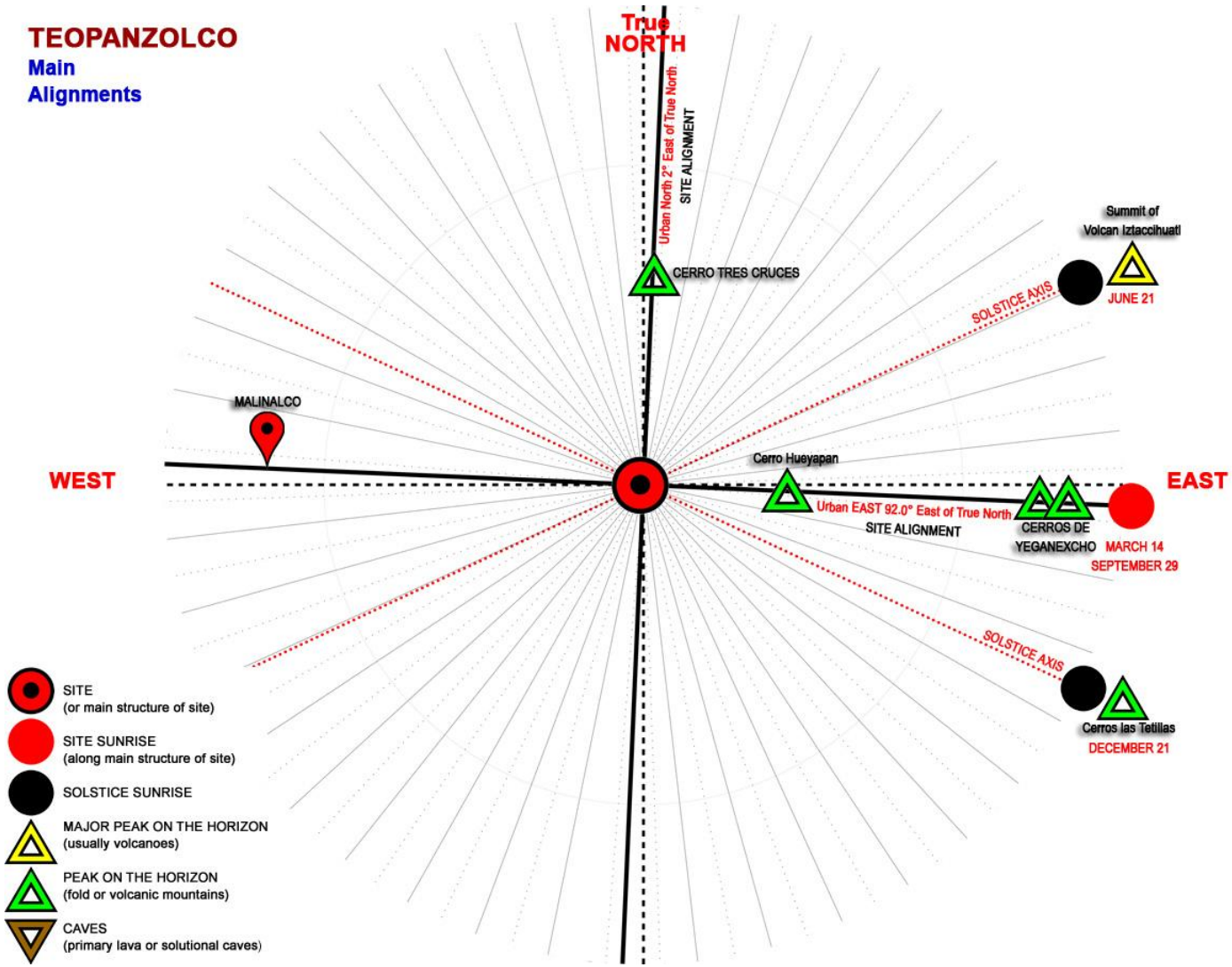


Figure 6.88. Main eastern alignments of Teopanzolco. True cardinal directions are indicated as black dotted lines; the main urban axes of Teopanzolco are indicated as black lines. The interactions between the urban north-south-east-west axes with the topography reveal the urban design principles of Teotihuacan.

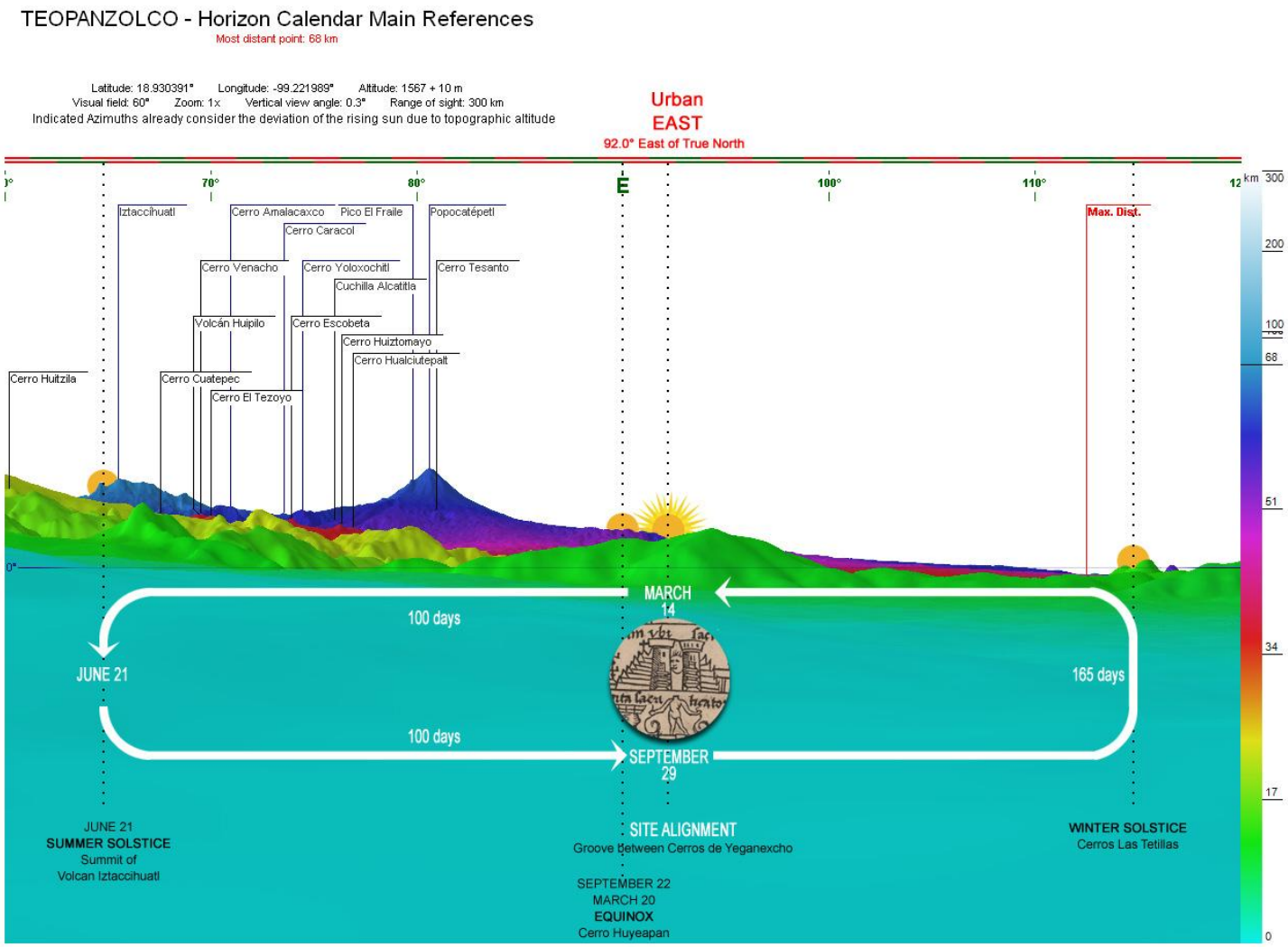


Figure 6.89. Main solar references on the 103.5° eastern horizon calendar of Teopanzolco and calendar cycle (Map data: Google, INEGI and UDI).

6.6 Chapter Summary

The archaeoastronomical analyses carried out in this chapter demonstrated how the Aztecs embedded their cosmovision in a set of architectural and urban design principles that were applied when they *founded* Tenochtitlan and Tlatelolco or when they *occupied and modified* the ceremonial centres and buildings of other cities that existed before the hegemony of the Aztec empire. In order to achieve an understanding of these principles, a systematic and replicable methodology was applied to pre-Aztec and Aztec sites that took into consideration: the cultural knowledge presented in previous chapters (religion, sacred topography, astronomy, mathematics and geometry); the dissimilar corpus of information available for each site as most scholarly work has focused on Teotihuacan and Tenochtitlan; and the topographic and solar information for each site. Since the same methodological steps were meticulously performed on each site, the research findings were expressed in the same format, thus allowing the comparisons of findings among sites. Similar to a puzzle where pieces are difficult to place if the overall image is not known, once the urban/landscape design principles of Teotihuacan and the architectural/urban/landscape design principles of Tenochtitlan and its Huey Teocalli were understood, the urban and architectural design principles of the other cities were revealed.

The main contributions of Teotihuacan were that the 15.5±0.5° and 105.5±0.5° deviations of its urban axes were the result of a combination of topographical and astronomical criteria where the north-south axis was defined by a mountain on the north and a cave to the south, and where the east-west axis was defined by the sunrises on February 11 and October 29 and the sunsets on August 13 and 29 April (dates in the Mesoamerican calendar that mark the four critical moments of the maize cultivation cycle separated by periods of 260 days, the length of the ritual calendrical cycle). The application of these design principles to architecture and urban planning resulted in buildings that were an integral part of the local horizon through a series of viewpoints along the urban north-south axis. This spatial relationship was supported by the proposed interpretation of the Tlalocan mural of Tepantitla and the Mapa Saville (a pictorial-administrative document) as well as by a series of viewpoints captured through the manipulation of several parameters in Google Street view.

The main contributions of the urban design of Tenochtitlan were that its 7.0±0.5° and 97.0±0.5° deviations of its urban axes were the result of a combination of topographical, astronomical, religious, mathematic and geometric calculations. The findings of this research demonstrated that the city was founded at the precise location where the urban north axis —marked by the highest point of Pico Tres Padres, known in Nahuatl as *Cuauhtepec*, "the Mountain of the Eagles" in the north— intersects with the urban east axis —marked by the concave space framed by the binary volcanic system of Cerro Tlaloc and Cerro Telapon in the east— on March 4 and October 9 (dates that allow the division of the year in 73-day intervals related to Venus) in order to commemorate the date of the birth of Huitzilopochtli depicted in the Codex Azcatitlan. The definition of this location was supported by the passage in the Crónica Mexicayotl and the geometrical exploration that was performed for this research so as to identify the location where these axes intersected along a circular arc given two points in a diametric cord. This exploration resulted in the proposal of a new theory to explain the slight rotation of the urban axes of Tlatelolco (8.5±0.5° and 98.5±0.5°) as opposed to the deviation of Tenochtitlan (7.0±0.5° and 97.0±0.5°) in spite of their close proximity, a matter that has intrigued scholars for a long time. This theory demonstrated that the urban axes of Tlatelolco were rotated to align to Pico Tres Padres to the north and Cerro Tlaloc and Cerro Telapon to the south. The location of Tlatelolco at this intersection was confirmed by the geometrical exploration, as this city also lay along the same circular arc as Tenochtitlan.

A major contribution regarding the architectural principles of the Huey Teocalli (the main double temple teocalli in Aztec ceremonial precincts) was that the multilayered symbolism, embedded in its stepped truncated pyramids form, not only represented the centre of the Aztec world —where the plane inhabited by humans intersected the thirteen levels of the heavens and the nine levels of the underworld— and the Hill of Coatepec where Huitzilopochtli was born, as scholars have established, but *also* that the twin temples on the upper platform represented the thighs of Coatlicue in squatting birth position, from which Huitzilopochtli was born. This theory was supported by the analyses of the symbols embedded in monumental sculptures, such as the Teocalli de la Guerra Sagrada and the Templo Mayor Tlaltecuhtli, as well as by depictions of the founding of Tenochtitlan within ethnohistorical sources. Consequently, every time the Sun came out in the eastern horizon on the alignment date —March 4 in the Huey Teocalli of Tenochtitlan,

March 1st in Tlatelolco, February 8 in Tenayuca and Santa Cecilia Acatitlan, and March 14 in Teopanzolco— the *birth of Huitzilopochtli was reenacted*. However, it was only in Tenochtitlan that this event happened on the exact date of the birth of the Sun god. These dates confirmed that Tenochtitlan was founded before Tlatelolco, as they both have alignment dates in March, but that sites like Tenayuca and Santa Cecilia Acatitlan were founded before Tenochtitlan, as their initial alignment dates are in February. This difference explains the slight rotation and offsetting of the Huey Teocalli of Tenayuca as it was initially a temple dedicated to Tlaloc aligned to Cerro Tlaloc on February 8, as well as the reason behind the razing of the ceremonial centre of Teopanzolco; the destruction of its buildings was necessary to build the Huey Teocalli so as to align to the *concave space* between the closest mountains and the Cerros de Yeganexchco. Even though the *physical spatial relationships* of the Huey Teocalli with Pico Tres Padres and the concave space between Cerro Tlaloc and Cerro Telapon could not be replicated exactly due to the distinct topographic conditions of each site, the *symbolic spatial relationships* of the Huey Teocallis in other Aztec cities with the landscape could be reproduced in a concave space between two mountains in order to represent the space between the thighs of Coatlicue-mother Earth from which Huitzilopochtli the Sun god could be born.

Chapter 7: Conclusion

This dissertation was set out to understand Aztec architecture and urban planning and has identified the design principles that the Aztecs applied when they laid out their cities and temples. The general literature on this subject—specifically in the context of Central Mexico—has been scarce, as scholarly works have largely focused on other aspects of Aztec culture such as art, history, literature and religion, to name a few. However, this major cultural aspect had never been thoroughly studied. Aztec architecture had only been addressed in a limited number of general studies on Mesoamerican architecture and few publications that had examined their physical, symbolic, economic and political characteristics from the point of view of archaeologists or historians. Therefore, this dissertation sought to answer a straightforward question: What were the main design principles embedded in Aztec architecture and urban planning from the point of view of an architect?

In order to answer this question, a radial methodology was proposed, since Aztec cultural knowledge in several disciplines —archaeology, art, history, astronomy, geography, geometry, mathematics and religion— had to converge and overlap in the archaeoastronomical-topographic analyses of each site. Even though these different cultural aspects were continuously cross-referenced, they were presented in a linear form. In spite of the limitations of this format, the contributions of each chapter can be synthesized and integrated into the key architectural and urban findings of this research as follows:

Chapter 1, Introduction, provided a summary of the biases of the researcher as a practicing architect and academic.

Chapter 2, Sources for the Study of Aztec Architecture and Urban Planning, evidenced the number, scope and variety of traditional and non-traditional sources. Traditional sources —comprised of pictorial manuscripts, eyewitness accounts by the Conquistadores, chronicles compiled by the missionaries and archaeological evidence— provided the visual and written material from which depictions of architectural types and urban forms were extracted; while non-traditional sources—comprised of pictorial administrative manuscripts, monumental sculpture,

urban and architectural models and oral history— demonstrated their relationship with other cultural aspects such as religion, astronomy and mathematics, as well as with architecture and urban planning. The material compiled from these sources contributed to other chapters in different ways: first, it supplied pictographic representations for the typological compilation; second, it provided the visual material that was utilized in the explanations about religion, time, astronomy, mathematics and geometry; and, third, it served to illustrate the findings revealed in the archaeoastronomical and topographic analyses.

Chapter 3, Aztec Typology, argued for the necessity of a study of Aztec architectural types within their Latin-American cultural context and presented a visual sample of the inventory that was compiled for this research since it served as a valuable tool to understand Aztec architecture and urban planning. This inventory was based on *the ICOMOS Principles for the Recording of Monuments, Groups of Buildings and Sites* that included: Nahuatl name, form, cultural functions and examples of a pictographic depiction, a physical representation as well as a plan and photograph of archaeological remains of that building type. Besides recognizing that the Aztecs appropriated the form and meaning of several Mesoamerican building types, this inventory validated the double temple teocalli as a distinct architectural type only present in seven main Aztec cities: Tenochtitlan, Tlatelolco, Tenayuca, Santa Maria Acatitlan and Teopanzolco as archeological remains, and in Texcoco and Tlacopan as pictorial representations in ethnohistorical sources. In relation to urban forms, this chapter discussed the influence of the urban planning principles of Teotihuacan and Tula in the layout of Tenochtitlan argued by several scholars. These principles included: the clockwise east of north deviation of the urban axes; the orthogonal planning of the urban grid; the organization of the main buildings into a central axial plan; the utilization of common Mesoamerican architectural types; and the orientation of the larger teocalli along the east-west urban axis. Hence, the architectural and urban knowledge obtained from these studies, contributed the criteria that was applied in the archaeoastronomical and topographic analyses: on one hand, they centred on the Huey Teocalli (main double teocalli) of each site; and on the other hand, they prompted a focus on the archaeoastronomical and topographic analyses on the urban north, south, east and west axes.

Chapter 4, The Aztec Cosmological Concept of Space and Time, explained the multilayered relationship between cityscape/landscape/skyscape and Aztec cosmovision, as the research carried out in the ethnohistorical sources (Chapter 2) and the typological studies (Chapter 3) had suggested. Hence, to fully understand the symbolism embedded in Aztec architecture and urban planning, it was necessary to comprehend both the physical space and the Aztec multifaceted religious system that consisted of various, and at times, contradictory myths, as well as a multiplicity of gods who were sometimes venerated as multiple personifications of the same gods. Hence, it first described the concept of Aztec cosmovision, an understanding of the world where time and space were ritually represented and enacted in architecture, particularly in the Huey Teocalli according to ample research done in this area of Aztec scholarship. This description narrated two fundamental stories in Aztec religion and mythology: the creation of the world and the birth of Huitzilopochtli —god of Sun, fire, war and patron deity of the Aztec— and the relationship of these myths with the four directions, the movement of the Sun across the sky and the symbolic meaning of mountains. Then, it showed how these concepts were integrated into a complex calendar system that counted the days on site-specific horizon calendars where the annual course of the Sun was tracked on the local topography; hence the concept of sacred landscape was introduced. Lastly, it highlighted the importance of mountains, caves and bodies of water within this sacred landscape revealed by research carried out by high mountain archeologists, and emphasized the significance of Tlaloc — god of rain, water and lighting— and the rituals performed on Cerro Tlaloc. Therefore, the religious, spatial, calendric and topographic cultural knowledge obtained from research done in these fields, contributed the basis for the archaeoastronomical and topographic analyses, since they not only established the symbolic importance of Huey Teocalli, but also the understanding of the Aztec calendar, the utilization of horizon reference systems and the religious and cultural significance of Cerro Tlaloc.

Chapter 5, Aztec Concepts of Astronomy, Mathematics and Geometry, provided an overview of Aztec astronomy, mathematics and geometry with the purpose of understanding how these disciplines were applied to Aztec architecture and urban planning, as this knowledge was necessary to create the horizon reference system to track the Sun at calendrically significant intervals within the solstitial points (Chapter 4), as well as to lay out their urban centres and

architectural structures (Chapter 3). In contrast to the material presented in Chapter 4 which had a large body of established research in Aztec scholarship, the material in this chapter included research from relatively new fields such as archaeoastronomy, to fields with barely any research such mathematics, geometry and building practice. The discussion on archaeoastronomy or "cultural astronomy" included an explanation about its astronomical, mathematical and cultural foundations and its application in the study of archaeological sites; an overview of Aztec astronomy; and a technical explanation about charting the movement of the Sun. The explanation of Aztec mathematics included a description of Aztec numerical systems and linear and angular measuring units. The discussion on Aztec geometry graphically demonstrated the underlying design principles that were utilized in sculpture and architecture. Finally, this chapter presented an overview of Aztec building practice and demonstrated the existence of a sophisticated design and construction system that allowed the Aztecs to lay out their urban centres and architectural structures. Hence, the information from the fields of astronomy, mathematics and geometry contributed the tools for the archaeoastronomical and topographic analyses. First, it established the movement of the Sun as a determinant of the orientation of a site; second, it presented the symbolic importance of the Sun rising between the temples of the Huey Teocalli of Tenochtitlan; third, it introduced the utilization of linear and angular systems; and lastly, it demonstrated the application of design principles and regulating lines, knowledge that was essential for the construction of their buildings and cities.

Finally, Chapter 6, Archaeoastronomical Analyses of Selected Pre-Aztec and Aztec Sites, acted as the core of the radial methodology where the accrued knowledge from Chapter 2, 3, 4 and 5 converged and overlapped in the archaeoastronomical analyses so as to achieve an understanding of the design principles of Aztec architecture and urban planning. To this end, it first demonstrated through a case study the methodology that was developed for this research, and then it presented a summary of the archaeoastronomical-topographic analyses that was performed in two Pre-Aztec sites —Teotihuacan and Tula— and five Aztec sites —Tenochtitlan, Tlatelolco, Tenayuca, Santa Cecilia Acatitlan and Teopanzolco. Since this methodology had to consider cultural information that ranged from religious, mathematic and geometric cultural knowledge to specific topographic and solar information distinct to each site, the analyses followed the same format even though the amount of cultural information varied

from site to site. In spite of this imbalance, the topographic and solar information of each site always included: the seasonal-and-hourly positional changes of the Sun throughout the year; the rising and setting times of the Sun during the solstices, equinoxes and alignment dates; the altitude and azimuth of the Sun in these dates; and finally, the topographic features in the local horizon of each site such as mountains, caves and springs. Hence, the archaeoastronomical-topographic analyses of each site included: a historical background; a summary of previous archaeoastronomical research and theories that have been proposed to explain its orientation; a discussion of the digital archaeoastronomical analyses and research findings; and a selection of images to illustrate the analyses at the end of each section so as to allow a continuous reading flow. Furthermore, this chapter presented the *main contributions of this research to Aztec scholarship*, which included:

- Demonstrating that the main urban north-south (15.5±0.5°) axis along the Avenue of the Dead in Teotihuacan was determined by not only Cerro Gordo as scholars have argued, but also by the Cuevas de Xometla. This theory provided an additional interpretation of the Tlalocan mural of Tepantitla and the Mapa Saville.
- Demonstrating that the main urban north-south (7.0±0.5°) and east-west (97.0±0.5°) axes of Tenochtitlan were the result of a combination of topographical, astronomical, religious, mathematic and geometric calculations. This theory proved that the city was founded at the precise location where the urban north axis —marked by the highest point of Pico Tres Padres, known in Nahuatl as Cuauhtepec, "the Mountain of the Eagles," in the north— intersects with the urban east axis —marked by the concave space framed by the binary volcanic system of Cerro Tlaloc and Cerro Telapon in the east— on March 4 and October 9 (dates that allow the division of the year in 73-day intervals related to Venus) in order to commemorate the date of the birth of Huitzilopochtli depicted in the Codex Azcatitlan.
- Demonstrating that the architectural principles in the multilayered symbolism embedded the form of the Huey Teocalli not only represented the centre of the Aztec world and the Hill of Coatepec where Huitzilopochtli was born, as scholars have already claimed, but also the twin temples on the upper platform represented the thighs of Coatlicue in squatting birth position from which Huitzilopochtli was born. This theory was supported by the analyses of the symbols embedded in monumental

sculptures such as the Teocalli de la Guerra Sagrada and the Templo Mayor Tlaltecuhtli, as well as by depictions of the founding of Tenochtitlan within ethnohistorical sources. Furthermore, it provided an additional interpretation of the main symbol of the Mexican nation included even in the flag: an eagle holding a snake in its beak.

- Demonstrating that once the urban/landscape design principles of Teotihuacan and the architectural/urban/landscape design principles of the Tenochtitlan and its Huey Teocalli were understood, the urban and architectural design principles of the other cities were revealed. Hence, new theories were proposed that were able to explain some architectural and urban aspects that had intrigued scholars for a long time in other Aztec cities as well. In the case of Tlatelolco, its slightly different orientation from Tenochtitlan and its foundation date were understood, as the founders of the city had to rotate the main axes of their Huey Teocalli in order to align to Pico Tres Padres and the concave space between Cerro Tlaloc and Cerro Telapon; in case of Tenayuca, the rotation and offsetting of its axes was understood, as the initial single teocalli had to be enlarged and rotated in order to align to Pico Tres Padres and the concave space between Cerro Tlaloc and Cerro Telapon; in case of Santa Cecilia, its rotation similar to that of Tenayuca, was understood as they just followed the orientation of Tenayuca because the view to Cerro Tlaloc and Cerro Telapon was partially obstructed by topography; and finally, in case of Teopanzolco, the razing and rebuilding of its ceremonial precinct, was understood as they had to modify their initial axes to align to a concave space in the landscape where Huitzilopochtli could be born.
- Lastly, demonstrating that the main design principles of Aztec architecture and urban planning were a physical manifestation of the myth of the birth of Huitzilopochtli. In Tenochtitlan, this event was reenacted at the ceremonial precinct where the Sun god was born between the two temples of the Huey Teocalli (located in the east of the ceremonial precinct), killed her sister Coyolxauhqui at the feet of temple, and then returned to mother Earth through the sculpture of the Tlaltecuhtli (located west of the Huey Teocalli), just to come back the next day and repeat this eternal cycle as long as the humans paid their debt to the gods. Consequently, when an Aztec city was laid

> out —or occupied— the "wise men" described by Sahagún [architects and urban planners] had to work in conjunction with priests [astronomers, mathematicians, geographers] to determine a space within the concave space within the sacred landscape [local topography] bounded by the solstitial points.

The implications of these research findings in Aztec scholarship are twofold. On one hand, they contributed a greater understanding of the Aztec architecture and urban planning supported by ethnohistorical sources, archaeological evidence and precise solar and topographic calculations. On the other hand, they contributed a series of theories to explain the location and orientation of Teotihuacan and Tenochtitlan and other Aztec cities that will be a valuable addition to Aztec scholarship, as the understanding of these principles might aid in the interpretation of other Aztec cultural manifestations. For example, once these principles were understood, the interpretation of the female Tlaltecuhtli sculptures was straightforward. In the same way, once the symbolic relevance of the landscape was established, this topographic form was easily identifiable in pictorial manuscripts such as *the Historia de las Indias de Nueva España y islas de Tierra Firme.*

This research also validated the utilization of digital resources for scholarly research, as it not only utilized numerous software applications and databases originally designed for other technical disciplines, but it also took advantage of the unprecedented amount of cultural material that had remained inaccessible to the public in multiple museums and libraries around the world as it has now been become "repatriated" through digitization. In the past it would have been very difficult to analyze original sources, particularly after fellow Mexican José Luis Castañeda stole the Codex Aubin from the *Bibliothèque Nationale de France* in 1982. This event caused a major diplomatic incident between France and Mexico, as Castañeda was seen as a national hero who had returned what originally belonged to Mexicans. This incident also highlighted the lack of accessibility of these documents to researchers, particularly Mexican nationals who did not have the means to access these resources. In 1999, this situation led to one of the first partnerships of its kind between the *Centro de Investigaciones y Estudios Superiores en Antropología Social* (CIESAS) and the *Bibliothèque Nationale de France*. They collaborated on the *Amoxcalli* ("house of books" in Nahuatl) project to digitize the Mexican resources in their collections. Other

institutions worldwide, such as *Biblioteca de la Real Academia* de Historia and the University of Oxford Bodlelian Library, have followed suit and the quality of the digitized material is improving. Digital scans with specialized equipment have allowed meticulous analysis of details only possible with magnifying glasses for jewelers.

Even though a portion of this research was done with traditional library material and multiple visits to archaeological sites in Central Mexico, the level of sophistication expected from ethnohistorical sources changed. Rather than relying on photographic reproductions, facsimiles or material translated into English, the researcher increasingly started turning to the digitized originals. This was particularly true when looking for material specifically related to architecture and architectural building practice, as translators were not familiar with architectural terms. In a time when we, as Indigenous peoples, are asserting ourselves and exploring our cultures, access to original material completely changes our ability to interpret it. Indigenous scholars no longer have to utilize sources that have been reinterpreted and published over and over again (frequently reproducing the same inaccuracies), but we are now able to interact directly with the original sources. Moreover, we have access to the entire source, not just fragments of it, which represented a huge obstacle when scholars were researching a particular aspect of a culture, in this case, Aztec architecture.

One of the benefits of reclaiming these digitized cultural resources as part of cultural heritage in our scholarly pursuits as Indigenous people is to consider its social uses with a more complex vision of how society appropriates its history, which can involve new sectors of society:

> [Cultural heritage] does not need to reduce itself to a matter of specialists of the past: it is of interest of public officials and professionals occupied of building the present, of Indigenous people, of peasants, of migrants and all sectors whose identity is upset by the hegemonic uses of culture. In as much as our study and promotion of heritage accepts the conflicts that accompany them, it can contribute to the consolidation of the nation, but not as something abstract, but as something that unites and connects a historical project that supports social groups concerned about the way they inhabit their space and conquest their quality of life (García Canclini 1997:28).

Only by repatriating our past in our collective memory will we be able reclaim our identity in the future.

Finally, the potential for further research in Aztec architecture and urban planning is ample, as ethnohistorical sources and the ubiquitous archeological remains in Central Mexico have been barely studied from an architectural point of view. A promising field of study is the exploration of architectural and urban depictions in traditional sources such as pictorial manuscripts — particularly pictorial-administrative manuscripts— as they offer a wealth of stylistic, astronomic, topographic, mathematical and geometric information. The quantity of these ethnographic sources is increasing with projects such as the *Mapas, Planos e Ilustraciones del Archivo General de La Nación* that has digitized more than 4975 illustrations, and the availability of this kind of material will likely expand with the additions of other digitization projects. Another promising field of study is Aztec mathematics and geometry in monumental sculpture and architecture, since Aztec measuring units and regulating lines underlay in their formal compositions.

However, the largest potential for further research lies in applying the methodology designed for this research to topographic and archaeoastronomical analyses in the multiple Aztec sites that lie scattered in Central Mexico. Since these sites are located in very different topographic conditions, the results of this potential analyses can lead to more theories and achieve a deeper understanding not only of Aztec architecture, but also of Mesoamerican architecture and urban planning.

The implications of this research reach beyond Aztec scholarship as it provided a replicable methodology that can be applied to the archaeoastronomical analysis of ancient settlements and ceremonial structures anywhere in the world.

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