A Comparison of Vector Based and Raster Based Analyses of Historic Records for the Identification of Archaeological Sites

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at George Mason University

by

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Spring Semester 2015
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DEDICATION

This is dedicated to my husband who has supported me and believed in me and to my mother who always encouraged me to follow my passion.

ACKNOWLEDGEMENTS

I would like to thank my family, friends and supporters who have made all of this possible. My mother, Rosemary, always pushed me to work hard and pursue my dreams. My husband, Jesse, assisted me with editing and provided me with the supported I needed to focus on my work. Drs. Houser, Luzzadder-Beach and Mattietti provided me with invaluable opportunities, resources and advice. I would also like to thank the Department of Geography and Geoinformation Science for providing excellent facilities, resources, and assistance; The Department of Geography and the Environment, College of Liberal Arts at The University of Texas at Austin for the funding that made the fieldwork in Belize possible; and the Maya Research Program for providing me with the use of their field camp while in Belize.

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LIST OF ABBREVIATIONS AND/OR SYMBOLS

Advanced Spaceborne Thermal Emission and Reflection Radiometer ..... ASTER
Digital Elevation Model ..... DEM
Environmental Systems Research Institute ..... ESRI
Electronic Atlas of Ancient Maya Sites ..... EAAMS
Geographic Information System ..... GIS
Global Positioning Systems ..... GPS
Satellite Pour l'Observation de la Terre ..... SPOT

ABSTRACT

A COMPARISON OF VECTOR BASED AND RASTER BASED ANALYSES OF HISTORIC RECORDS FOR THE IDENTIFICATION OF ARCHAEOLOGICAL SITES

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This thesis compares a vector based analysis and a raster based analysis of observations and photographs from an historic aerial survey to identify Mayan archaeological sites. The first relies on the distance measurements taken during the original survey to select likely points from a comprehensive database of known Mayan sites while the second relies on the structural features of the landscape to identify likely sites. The two analyses indicate that neither method offers definitive results when used exclusively. The distance measurements cannot be relied upon as absolute due to errors in calculations and the accuracy of the site database. Instead, the distances offer a starting point for a landscape based search. The result is a multi-media model that uses a wide variety of overlapping data in order to utilize the unique information available in historic records for archaeological prospection.

1. INTRODUCTION AND PURPOSE

Often, historical records are overlooked because of a lack of location or site data. However, they may hold valuable information that could be used to study landform change, environmental change, mass wasting, deforestation or historic preservation; to name a few. This thesis attempts to fill in that missing information for one particular expedition by mapping the sites and features that were observed and photographed during an aerial survey as well as identifying sites unknown at the time. The process relies on a comprehensive geographic database of known Mayan archaeological sites as well as the results of Oliver Ricketson and Alfred Kidder's 1929 aerial survey; which includes a flight map, descriptions from their article published in 1930, and a collection of aerial photographs.

This thesis tests two methods for the identification of sites. The first relies on the distance measurements included in the original article and the second on the structural features of the landscape. The effectiveness of these methods will then be compared in order to determine which might best serve future research.

1.1 Aerial Photography in Archaeology

Archaeologists noticed the value of aerial photography in 1899 when the first European archaeological photo of Rome was taken by Giacomo Boni from a hot air balloon in (G. J. J. Verhoeven 2009). Since then, archaeologists have used many different platforms to acquire aerial photographs ranging from balloons to masts and even

unmanned aerial vehicles (UAVs) (Reeves 1936; G. J. Verhoeven et al. 2009). In 1919, G.A. Beazeley used aerial photographs to survey the city of Eski in Baghdad and found that he could discern the outline of ancient structures better from the photographs than from the ground. He was able to see forts, roads, irrigation systems, and the remains of the canal regulators (Beazeley 1919).

In 1929, Charles Lindbergh, Oliver Ricketson and A.V. Kidder conducted an aerial survey of the ancient Mayan landscape of the Yucatan Peninsula. They were able to identify several known temple sites as well as many possible smaller complexes that had not yet been identified (Ricketson and Kidder 1930). This came about a year after a successful survey of Chaco Canyon, Canyon de Chelly and the Grand Canyon at the request of A.V. Kidder and John C. Merriam (Berg 2004). Today, archaeologists primarily use aerial photography to assist with fieldwork, generate more accurate maps, view patterns across wide areas that are not visible from the ground and create an archive to study land cover change.

The use of satellite photography gained ground with the 1995 release of the classified photography collected by the Corona spy satellite (Ruffner et al. 1995). Corona was the first in a series of earth observing satellites including French satellite *Satellite Pour l'Observation de la Terre* (SPOT); privately owned, commercial satellites like Ikonos and Quickbird; and the Landsat series. They have been popular sources of data for a wide range research. Imagery from all of these systems has been effective in the identification and study of archaeological resources whether it be through visual analysis (Ur 2003), spectral signatures (Urquizu and Saturno 2012) or feature extraction (De Laet,

Paulissen, and Waelkens 2007); however, satellite imagery only extends as far back as the Corona mission in the 1960s which had spatial resolutions too coarse to identify most archaeological features. This makes satellite photography a very limited technology when analyzing change over time or recreating past environments. Since aerial photography was used long before satellite systems, it has the ability to reach back even farther in time and the chance of capturing archaeological remains and environments before they were first identified, excavated, or altered.

1.2 The Carnegie Institution's Maya Research Program

The Carnegie Institution of Washington (now known as the Carnegie Institution for Science) was founded by Andrew Carnegie in 1902 and devoted to scientific discovery. Though the institution now focuses primarily on biological, geological, astronomical and ecological studies; it originally encompassed a wider range of specialties including archaeology ("Carnegie Institute of Science" 2007). The institution's Maya Research Program was proposed and founded by the renowned Mayanist Sylvanus Morley. Under his control, the program conducted yearly expeditions and excavations throughout the Maya world, with a special emphasis on Chichen Itza. When Alfred Kidder became the director, he expanded the scope of the research to include socio-cultural investigations of modern populations in addition to the ancient Maya. He proposed that Lindbergh assist in an aerial reconnaissance flight across Mexico's Yucatan peninsula, Belize and Guatemala ("Artstor Archive: Carnegie Institution of Washington Photographs of Mayan Excavations (Peabody Museum of Archaeology and Ethnology, Harvard University)" 2010; "Carnegie Institute of Science" 2007).

1.3 The Lindbergh Flight

In the October of 1929, Alfred Kidder led a joint expedition between the Carnegie Institution and Pan American Airways to survey the Yucatan Peninsula from the air with the explicit purpose of documenting Mayan structures. Previous surveys elsewhere in the world revealed that identification of archaeological features was greatly increased by the aerial perspective. Alfred Kidder and Oliver Ricketson both believed that an aerial survey over the forests of the Yucatan would be especially valuable due to the cost and limited results that come from ground surveys. Ricketson described conducting ground surveys in his part of the world as:

> "Slow and laborious travel, a hot, humid climate, swarms of insects, and prevalence of tropical diseases have greatly retarded exploration of the Maya country. Even in such parts of it as can be reached the traveler is so buried in the "bush," so shut in and engulfed by the mere weight of vegetation that he can literally never see more than a few feet or yards and so is almost totally in the dark as to the topography of the regions he is examining. A rise of ground crossed by the trail may, for example, be an isolated hill or part of an extensive ridge; it may be the highest land in the vicinity or a saddle in an important divide. It is almost always impossible to reach any point for extended views over the terrain. (Ricketson and Kidder 1930)"

Charles Lindbergh and his wife flew Ricketson and Kidder on a five day path extending from the southern end of Belize (then known as British Honduras), through the northeastern corner of Guatemala to the northern coast of the Yucatan peninsula. Along the way they took photographs of significant Mayan structures, local communities, and environmental regions. They photographed the temples at Tikal; structures and mounds at Uaxactun; the ruins of Chichen Itza; Lakes Chichancanab and Yaxha; Lake Peten, on which sits the town of Flores; the temple ruins at Tulum; and the islands off the coast of

Belize (Ricketson and Kidder 1930). Along with these previously identified sites, they also found new areas of interest including unknown temples and mounds.

Following their flight, they published a fairly detailed record of their observations in the *Geographical Review* in 1930. The article included dates, times, distances, altitudes, locations and observations of features that could be used to identify, exact or at least estimated locations of significant features. For example, on page 183, they observe the ruins of "two temples facing each other on an artificially raised terrace" 56.8 miles north of Uaxactun. They proposed that it is either the site of Yeso or Rio Bec but were unable to confirm that assumption (Ricketson and Kidder 1930). It may be possible to identify which structure they actually saw by georeferencing the flight path, measuring the distance indicated, and comparing the physical characteristics they describe with known sites in that area. In addition to studying ancient Mayan structures, their observations and photographs could be used for a variety of other analyses such as landscape change, urban growth by expanding the historic record of populated areas such as the town of Flores; and more(Ricketson and Kidder 1930).

1.4 The Photographs

The Carnegie Institution of Washington's Maya Research Program lasted from 1913-1957. It was officially ended when the launch of Russia's Sputnik satellite spurred the institution to devote more time and resources to biological, ecological, earth and planetary sciences with a special focus on nuclear technology. The entire Mayan collection was then given to Harvard University's Peabody Museum of Archaeology and Ethnology. The museum collaborated with Artstor digital library to digitize all the 44,337

photographs taken during the program's lifetime and in 2010 they were made available online. The collection includes everything from artifacts to site photographs as well as the aerial photographs taken during the 1929 flight ("Artstor Archive: Carnegie Institution of Washington Photographs of Mayan Excavations (Peabody Museum of Archaeology and Ethnology, Harvard University)" 2010). The flight collection consists largely of black-and-white oblique aerial photographs but also includes some ground level photographs from the rare occasions when they landed the plane for close ups (Figure 1).

In this thesis, the photographs will not necessarily be analyzed for content since the purpose is to identify locations. However, generalizations about the subject matter of the photographs and their potential applications to other research were be made when possible.

Figure 1 Aerial photograph of Uaxactun taken during the Ricketson Survey in 1929 (O. Ricketson and Kidder 1930).

2. METHODOLOGY

Throughout the article, Ricketson and Kidder describe archaeological sites that they observed in relation to other known features based both on distances as well as landscape characteristics. These have been separated into two test groups. The first set, or the distance method, was observed during the first flight on October 6, but very little landscape information was included in the descriptions. Since aerial surveys were still very new to archeological research, they began their survey with essentially no training in how to make observations. At the beginning they relied heavily on the aircraft's instruments as their primary base for reference. However, as their expedition progressed they began to understand the features of the landscape better.

> "Our results were, of course, less full and less precise than could be wished, but it must be remembered that both the writers were entirely unpracticed in air observation. We improved, however, with every hour and toward the last found ourselves able to see and to record not only the principle features of the country we were passing over but a considerable amount of detail.(O. Ricketson and Kidder 1930 p. 204)"

This improvement in observational skills makes the second method, the landscape analysis, possible. The second set of features was observed during the third and fourth flights and includes considerably more information regarding the landscape characteristics than the first set, which supports their own description of improvement. The increase of information for these sites allows for a search to be conducted that does not rely solely on distance measurements that could include errors or miscalculations. The landscape method uses the flight path and known locations as general references to

begin the search but relies primarily on the landscape features to pinpoint possible sites rather than distances alone. This way, any discrepancies in the distance calculations should not hinder the search.

2.1 Article Features

The first step in this project was to careful review the 1929 article by Ricketson and Kidder. The anecdotal descriptions; including departure and arrival time, date, altitude, speed, cardinal direction, reference features, site description, names and more; were extracted and parsed into discrete categories in Microsoft Excel (Appendix A). This resulted in a database for the article which allowed for a better selection process by making the information sortable and searchable.

Known and verifiable features were then extracted and used to create a point feature class in ArcGIS for refining the georefencing of the flight map (to be discussed in the next section). This is called the Known Sites feature class and includes such locations as cities and towns as well as monumental/iconic Maya sites that were known at the time of the survey (Table 1). Known sites that were not flown directly over but viewed from a distance were not included.

2.2 Electronic Atlas of Ancient Maya Sites

The Electronic Atlas of Ancient Maya Sites (EAAMS) (Brown and Witschey 2010) is a collection of over 6,000 sites compiled from a variety of sources such as research articles, survey maps and even exact Global Positioning Systems (GPS) coordinates when possible. It was designed to be used in Google Earth but can be easily converted into a data layer compatible with ArcGIS. The sites are ranked by size and complexity into

layers that become visible at different spatial scales in Google Earth. The ranking system is based on "courtyard count, volumetric assessments of architecture, and number of monuments" (Witschey and Brown 2010).

The database was last updated in 2010; however there are still some significant errors in regards to the exact location for many of the sites. This may be due to a variety of reasons including relatively abstract regional maps; smaller sites that are not visible in imagery, which makes verifying their locations difficult; and possibly even purposeful discrepancies meant to protect the sites from looting.

2.3 Photo Alignment

Google Earth was used to identify the location of the photographs taken during the survey. Google earth is particularly useful for this because it contains imagery for many years at varying levels of resolution which assists with identifying features. More importantly, it has the ability to adjust the viewpoint based on altitude, angle and cardinal direction allowing the view to match that of the photographs. The view in Google Earth was lined up as close as possible to that of the photographs to help narrow down the precise location of the airplane. This was done for four locations including one photograph each for the Rio Hondo, Yaxha, Lake Chichancanab and the Keys; two for Tayasal; three for Flores; and seven for Chichen Itza (Appendix B). All of these locations were then added to the Known Sites feature class to be used to refine the georeferencing of the flight path.

2.4 Yo Chen Lagoon

The alignment of one of the photographs of the Rio Hondo is a good example of how this process can aid other research. The photograph was aligned in Google Earth and the coordinates of the lagoon it pictures were recorded (Figure 2 & 3). Not only are the lagoons still visible in modern imagery but the markings in the wetlands are also present. The knowledge that those lines through the wetlands still exist 85 years later can be used in modern land cover change analysis and may prove useful in archaeological site prediction models as well as the study of wetland agriculture of the ancient Maya. I then traveled to the location of the coordinates for the lagoon, where I was then able to take photographs of the present day environment (Figure 4). The closest I came to the exact coordinates of the lagoon from the historic photo was approximately 1.75 miles (Figure 5), due to the lack of named roads in this part of Belize but another attempt could bring me closer. The lagoon is being referred to here as the Yo Chen lagoon because the closest accessible town to that area is that of Yo Chen, Belize. This process could be repeated for other photographs and analyses made to determine environmental change over the past 85 years.

Figure 2 Aerial photograph of the Rio Hondo taken during the Ricketson Survey. The lagoon and marks in the vegetation were used to identify the location of the photograph in Google Earth ("Carnegie Institution of Washington Photographs of Mayan Excavations (Peabody Museum of Archaeology and Ethnology, Harvard University)" 2010).

Figure 3 Google Earth image of the location of the Rio Hondo photograph taken during the Ricketson Survey.

Figure 4 Ground truth photograph of the Rio Hondo taken by me during my visit in the summer of 2014.

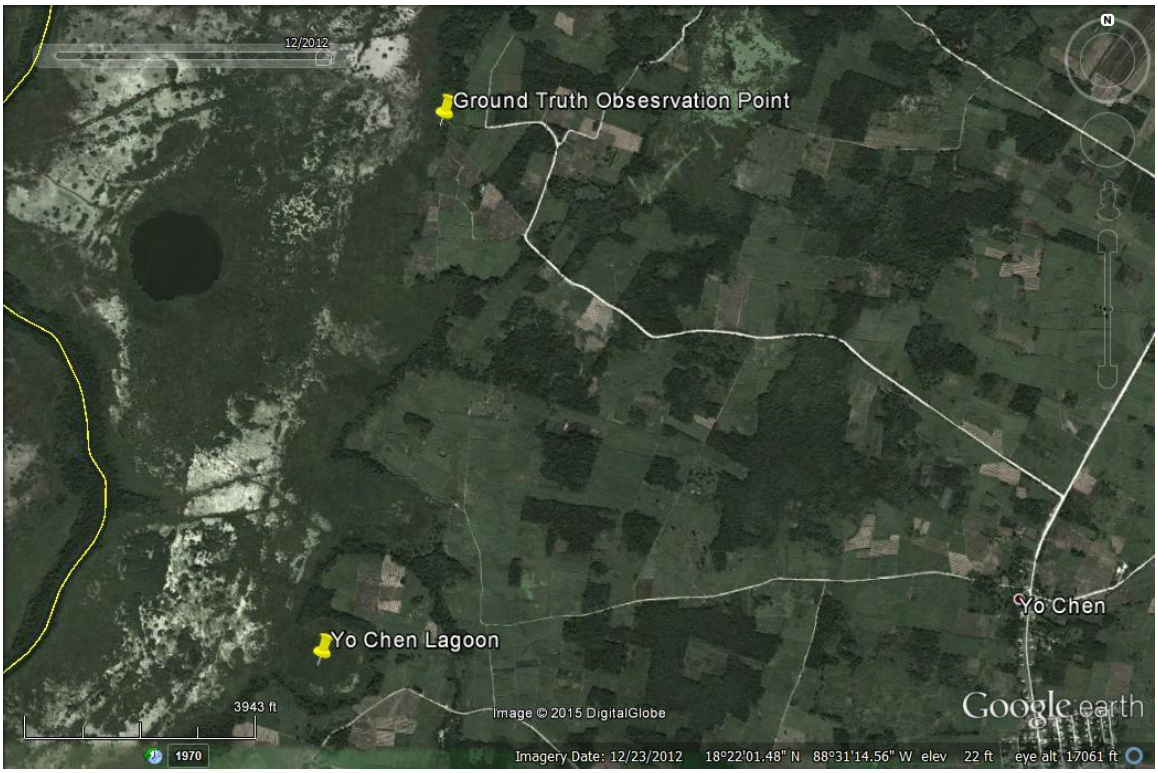


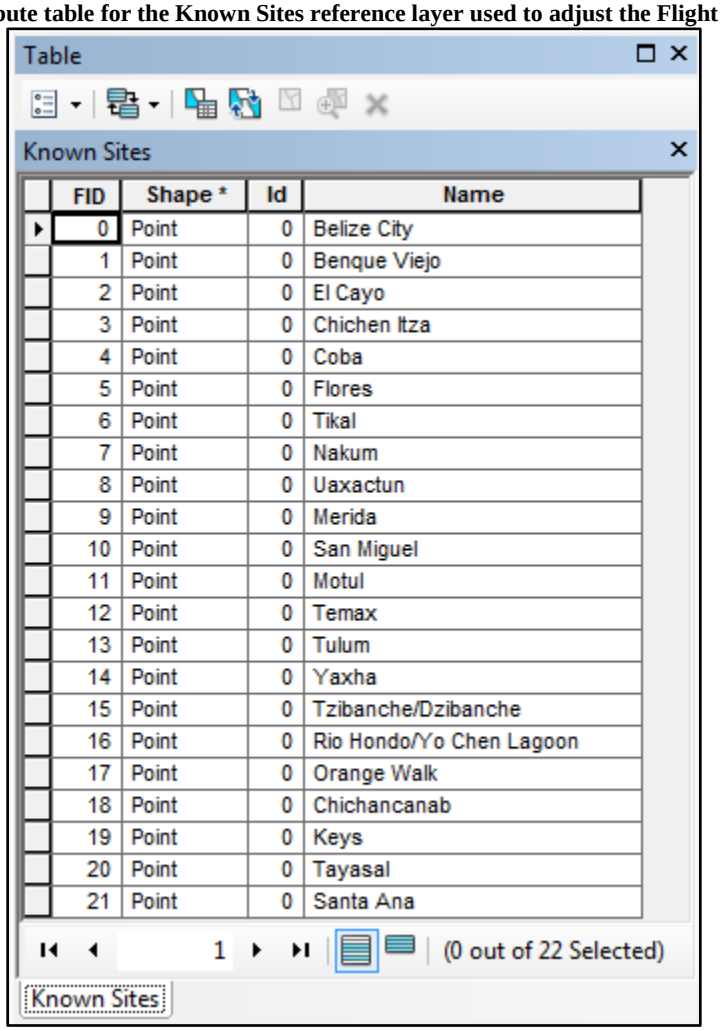
Figure 5 Google Earth image of the location of Figure 4 in relation to the lagoon pictured in the Ricketson photograph.

2.5 Georeferencing

The first step in the alignment process was to georeference the flight map from the Ricketson and Kidder article to the world imagery basemap available in ESRI ArcGIS 10.2. Next, the flight path was digitized and refined based using the Known Sites feature class that was created in ArcGIS using the location of the known features from the article as well as the locations for the aligned photographs. It consists of places such as Belize City, Belize and Merida, Mexico as well as archaeological sites such as Tikal and Uaxactun and locations of the aerial photographs. In all, 20 locations were digitized

(Table 1) and used to edit the flight path by snapping the vertices along the line to the corresponding Known Location points.

Table 1 ArcGIS attribute table for the Known Sites reference layer used to adjust the Flight Path line feature.



FID	Shape *	Id	Name
0	Point	0	Belize City
1	Point	0	Benque Viejo
2	Point	0	El Cayo
3	Point	0	Chichen Itza
4	Point	0	Coba
5	Point	0	Flores
6	Point	0	Tikal
7	Point	0	Nakum
8	Point	0	Uaxactun
9	Point	0	Merida
10	Point	0	San Miguel
11	Point	0	Motul
12	Point	0	Temax
13	Point	0	Tulum
14	Point	0	Yaxha
15	Point	0	Tzibanche/Dzibanche
16	Point	0	Rio Hondo/Yo Chen Lagoon
17	Point	0	Orange Walk
18	Point	0	Chichancanab
19	Point	0	Keys
20	Point	0	Tayasal
21	Point	0	Santa Ana

3. DISTANCE MEASUREMENTS ANALYSIS

3.1 Introduction

The first flight of the expedition began at Belize City, Belize and ended at Merida, Mexico. Along the way they passed the towns of El Cayo (now known as San Ignacio), Benque Viejo, Temax and Motul and surveyed the archaeological sites of Yaxha, Tikal, and Uaxactun. Once they left Uaxactun, they did not encounter another known archaeological site till they reached Temax near the northern coast of the Yucatan peninsula. However, they did noticed three possible ancient sites along the way. The article includes brief descriptions of these structures and their distances from Uaxactun, a known and verifiable location. Ricketson and Kidder indicate the sites they encountered as Ruin I located 56.8 miles north of Uaxactun, Ruin II at 125 miles, and Ruin III at 196 miles.

The Distance Measurements Analysis takes advantage of these observations by searching for archaeological sites at those points along the flight path. This was accomplished by buffering the Uaxactun known reference point by each the distances indicated above. Next, a point feature was created at the intersection of the edge of each of the buffers and the flight path. All the EAAMS points that fell within a 5 miles radius of the intersection points were selected and investigated for structural characteristics similar to the descriptions in the article (Figure 6). This process resulted in 12 possible sites for Ruin I and 5 for Ruin III. No sites fell within 5 miles of the intersection point for

Ruin II. Instead, the closest sites to the intersection point were selected: Triumfo at 9.25 miles away from the intersection point and Xpaicheil at 9.8 miles (Table 2). Finally, the George Mason Library, Mesoweb, and Google Web Search were queried for any references to these sites.

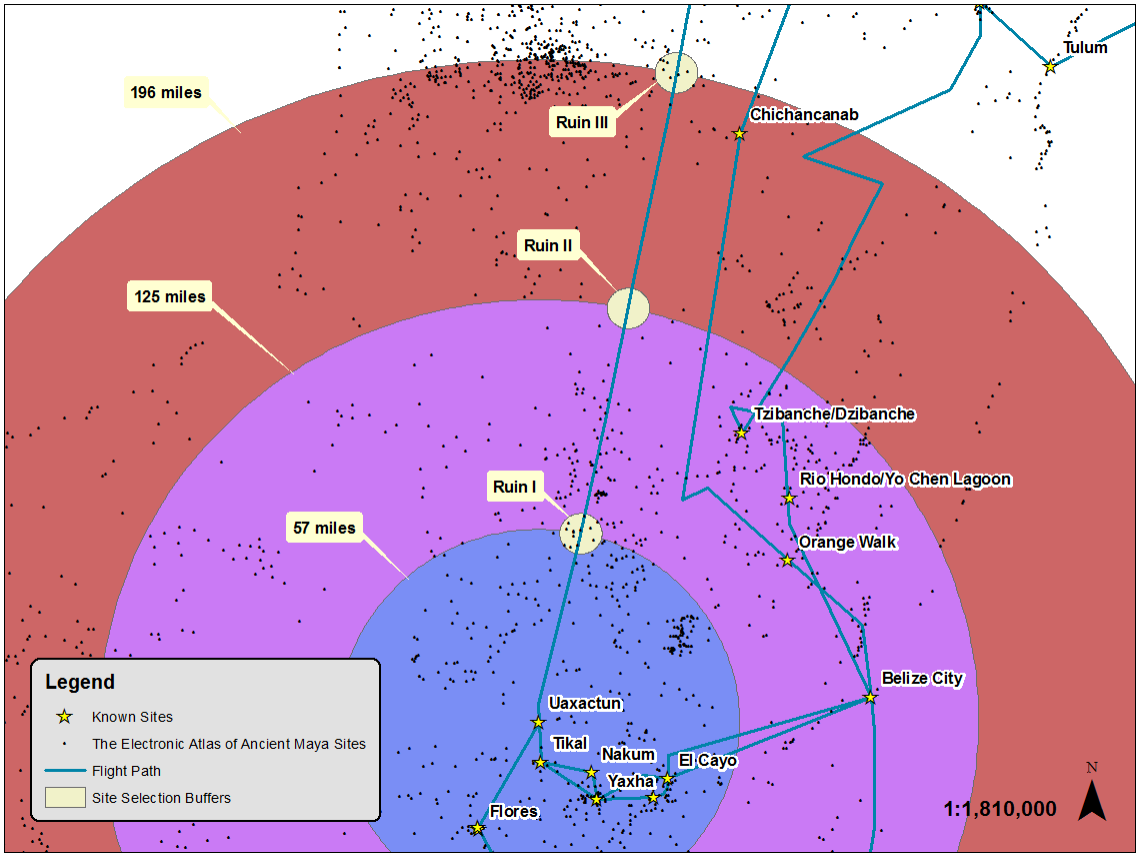


Figure 6 Distance Analysis buffers. The blue, purple and read buffers indicate 57, 125, and 196 miles from Uaxactun respectively. The small beige buffers indicate 5 miles from the intersection points of the previous buffers with the flight path. All of the EAAMS sites that fall within those buffers were selected as candidates.

Table 2 Results of the Distance Method; includes the site results from the spatial search as well as the results of the literature search.

Method 1: Distance Measurements Results			
Ruin	Distance (miles)	Results	Research Results
I	56.8	Aktunkin	No results
		Aktunkin Cave	cave
		El Carmen	No results
		El Porvenir	No results
		La Tortuga	No results
		La Victoria	No results
		Noche Buena	No results
		Placeres	Referenced but no site description
		Pueblo Viejo	No results
		Ramonal	Referenced but no site description
		Xanantun	No results
		Yeso	Referenced but no site description
II	125	No sites within 5 miles. Triumfo at 9.25 miles. Xpaicheil at 9.8 miles	No results
III	196	Ek Balam	Results
		Rancho Bolon	No results
		San Isidro Buleb	No results
		Sisbic (Tizizbic)	Referenced but no site description
		Tixmehuac	No results
		Tzitz	No results

3.2 Ruin I

Ricketson and Kidder describe the first ruin as:

> "At 56.8 miles the plane passed over and circled what was obviously a Mayan ruin, consisting of two temples facing each other on an artificially raised terrace. It was possible to make out some of the stone construction in the rear walls of the southernmost temple. What the actual extent of the ruin may be is impossible to state, but it may be inferred that it is large, for the small ones, which must be present in this region, were not visible during the flight. This ruin may be that called Yeso which is shown on the Blom-

> Ricketson map as about 57 miles north and slightly east of Uaxactun, but it seems more probable that it is Rio Bec, a site discovered by R. E. Merwin of the Peabody Museum."

The 57 mile intersection buffer selected 12 possible sites from the EAAMS, however, little information has been found for these sites. The George Mason University library, Mesoweb, and Google were used to search for any mention of these candidates. Only three were mentioned in other articles but were only mentioned as a reference during the discussion of a different site or simply included in maps. None were accompanied by any structural description that could be used for identification. The rest have not yet been identified in other sources.

Rickeston and Kidder assumed this site was either Yeaso or Rio Bec. The EAAMS places Yeso at approximately 53 miles from Uaxactun and Rio Bec at almost 70 miles. Though Yeso does qualify as one of the candidates, no description of the site has been found that would corroborate their claim.

Rio Bec, however, does have some physical characteristics that could coincide with their description. Rio Bec Group B was discovered in 1912 by Robert E. Merwin and Clarence L. Hay. The primary structure has two large towers on either end of the building (Figure 7) (Thomas and Campbell 2008). If this was viewed from the air while still mostly covered by the forest canopy, it could look like two temples on a raised plaza but without an aerial photo available it is difficult to make a reliable comparison between the descriptions.

The term Rio Bec is also used to indicate a particular architectural tradition throughout central Yucatan. It consists of structures with towers much like that at Group

B (Potter 1976). This means that the style is common throughout the area, which could make it even more difficult to narrow down which one they might have seen.

Figure 7 Photograph of Rio Bec Group B taken in 1973 (Thomas and Campbell 2008).

3.3 Ruin II

Ricketson and Kidder describe this ruin as:

> "At about 125 miles from Uaxactun we passed a stream, the first noted, running from northwest to southeast. Just before a small Maya pyramid was sighted on a cleared piece of ground.(O. Ricketson and Kidder 1930 p.187)"

Since no EAAMS points were located within 5 miles of this intersection point, the closets sites (Triumfo and Xpaicheil) were investigated instead, but like Ruin I a search of the literature returned no information of for these sites. A visual survey of Google

Earth for the area around Triumfo shows several milpas (agricultural fields) and possible creek beds, but no visible signs of a pyramid. Ricketson and Kidder describe Ruin II as a pyramid but they do not clearly state if there was any masonry visible. Throughout the article they seem to use the terms pyramid, mound and temple interchangeably, which makes it difficult to tell precisely what kind of feature they saw. Without more information it is not possible to identify this site.

3.4 Ruin III

Ricketson and Kidder describe the first ruin as:

> "At 1:24 p. m., or about 196 miles from Uaxactun, a small Maya temple was sighted in a clearing. Part of the vault of the roof remained, and the walls appeared fairly intact.(O. Ricketson and Kidder 1930 p.190)"

The buffer at 196 miles selected six possible candidates. Again, the George Mason University Library, Mesoweb, and Google were used to search the literature for any reference of these candidates. Four did not return any results and one was referred to but no site description was included. The only one to have some information was Ek Balam, a large Mayan complex, yet the area surrounding this point in the EAAMS shows no indication of an ancient Mayan structure. The map included in the article about Ek Balam indicates that it is actually located much farther to the northeast than EAAMS would indicate (Figure 8) (Bey, Hanson, and Ringle 1997). I then searched EAAMS for the name Ek Balam and found that a second point with the same name exists approximately 77 miles northeast of the first. When the area surrounding this point was viewed in Google Earth, a large complex could be seen that fits the description in the article. Google Earth also indicates that there is a small modern time in close proximity to the EAAMS point for Ek Balam that was selected by the buffer. This would seem to indicate

the EAAMS includes modern towns along with archaeological sites which could be the cause for the limited literature results.

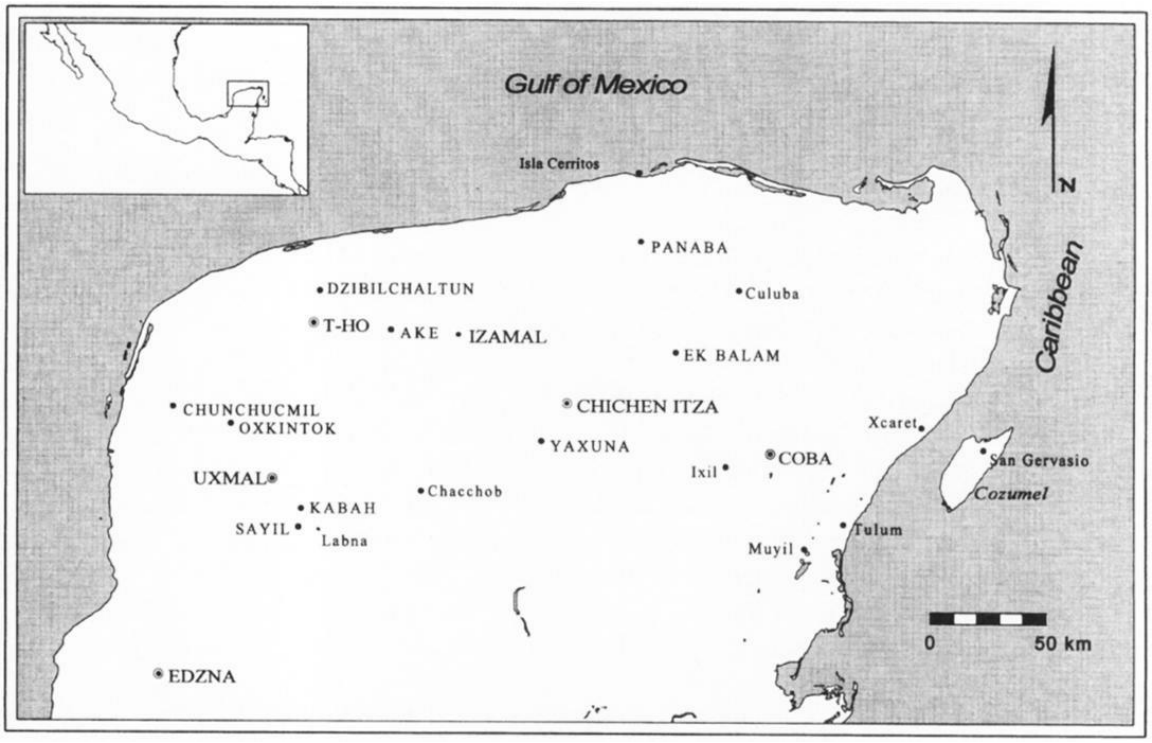


Figure 8 Figure 8 Map that indicates that Ek Balam is located much farther away from the EAAMS point (Bey, Hanson, and Ringle 1997)

3.5 Adjusted Distances

It is possible that the distance measurements from the article were incorrect. In the article, they posited that the structural characteristics of Ruin I are consistent with that of Rio Bec and claimed to have seen it at 57 miles from Uaxactun. However, EAAMS places Rio Bec at approximately 70 miles from Uaxactun (confirmed with Google Earth

imagery). If it is accepted that they did in fact pass over Rio Bec, then the buffers can be adjusted to make up for the discrepancy in measurements.

If they did actually see Rio Bec that would mean that their measurements are only 81% of the true distance traveled. Therefore, Ruin II would actually be about 154 miles from Uaxactun instead of 125 and Ruin III at 242 miles instead of 196. To test this theory, the Distance Analysis was repeated with the new measurement. Uaxactun was buffered for these new measurements and feature points were created for each of these new locations. The new points are designated Ruin IB (Rio Bec), Ruin IIB, and Ruin IIIB. All EAAMS sites within 5 miles of the new points were selected and resulted in no sites within 5 miles of Ruin IIB (the closest is Chumul at 15.6 miles to the north) and 10 sites within 5 miles of Ruin IIIB (Table 3). Again the candidate sites were searched for in the George Mason library, Mesoweb, and Google. Nothing was found for Chumul. However, two of the sites for Ruin IIIB, Chalamte and Tzalam, offered some possible results.

Chalamte is mentioned in an article discussing the architectural styles of early Christian churches. Chalamte is an open ramada style church common throughout the Mayan lowlands. They were built during the early Christian mission movement across the Yucatan (Targa 2004). Near the EAAMS point in Google Earth there is a hacienda with a cemetery entrance that closely resembles the style of these early missions (Figure 9). This could be all that remains of an old mission and more was still standing during the Ricketson and Kidder survey.

Tzalam is a small town in northern Yucatan. Google Earth offers streetview throughout out most of Mexico including many small, rural towns. Streetview made it possible to look around Tzalam and see that the ruins of an old stone building near the edge of town farthest from the main road (Figure 10).

There is no way to determine the age of either of the remains from these images alone but their similarity to the architectural style of those early missions could serve as a starting place for future research. This method could be used as a preliminary survey technique for other archaeological sites.

Table 3 Results of the adjusted distance analysis.

Features from Flight 1			
Ruin	Distance (miles)	Description	Results
IB	70	Two temples facing each other on artificially raised plaza. Yeso or Rio Bec	Rio Bec
IIB	154	Mayan pyramid before stream	No sites within 5 miles. Closest is Chumul at 15.6 miles away.
IIIB	242	Small Mayan temple in clearing. Walls and part of vaulted roof intact.	Acun Camino a Kanab Nohcal Piris Santa Catalina Tocbatz or Chalamte Tzalam Uitzil Xbolin Xcolac II

Figure 9 Photograph of Hacienda entrance near the EAAMS point for Chalamte. This photograph was uploaded into Google Earth by user name jetxea.

Figure 10 Google Earth streetview of stone ruins in Tzalam.

3.5 Problems

3.5.1 Distance measurements

The lack of results for this search method may be attributed to an inaccuracy of the distance measurements from the article. Ricketson and Kidder even address this problem by stating that "map locations in this practically unknown region are to be regarded as subject to great error (O. Ricketson and Kidder 1930 p. 186)". For example, with Ruin I they mention that the map they were referencing placed Yeso at about 57 miles away from Uaxactun yet, based on their observations of the structure of the site, what they saw was more likely Rio Bec which is approximately 70 miles from Uaxactun (based on Google Earth measurements).

3.5.2 Spellings

Another factor that could be limiting the search results is the spelling of the site names. For example Sisbic, one of results for Ruin III, was mentioned in an article by Amara Solari (2010), alongside the alternate spelling Tizibic. It can be assumed that this is not the only occurrence of spelling variation. Without knowing the alternate spellings of other sites, further research of the literature will be limited.

4. LANDSCAPE BASED ANALYSIS

4.1 Introduction

The landscape based analysis focuses on three archaeological sites mentioned in the article that had little or no distance measurements associated with them but instead included descriptions of the landscape that could help pinpoint their location. The landscape descriptions include features such as lakes, ridges and the general layout of the site. This method relies on the imagery available in Google Earth, the ArcGIS basemaps, the EAAMS database, as well as ASTER Digital Elevation Models (DEMs) to better visualize the landscape.

4.2 Feature I

The first site investigated with this method is different from the others because there were no archaeological features visible during the flight. It is a cave and was chosen because of the cultural significance that cave hold for many Mesoamerican traditions. To the ancient Maya, caves "represent passageways to the interior of the living earth, and are orifices of the earth as a living being (Evans 2008)" therefore they are often associated with archaeological remains of ritualistic practices.

Ricketson and Kidder also felt it was significant enough to warrant future research calling it "well worthy of future investigation (O. Ricketson and Kidder 1930 p.194)". Therefore, it seemed appropriate that it be included and an attempt made to identify the whether or not it is among known sites.

This sight was seen during the third day of surveying. They began that flight by retracing the steps of their first till they reached Uaxactun but instead of going north from there they turned southwest on a heading that would take them to Lake Tayasal and the town of Flores. On their way Ricketson and Kidder passed by a cave that they described as the following:

> "At 11:34 the plane crossed a large oval swampy savanna, full of water under tall reedy looking grass. On its north rose a very sharp limestone escarpment, sufficiently steep in two places to show perpendicular cliffs rising 50 to 75 feet. In one of the cliffs was an apparently deep cave some 50 feet long by 15 or 18 feet high. Situated as this grotto is, in the heart of the Old Empire region, it is well worthy of investigation (O. Ricketson and Kidder 1930 p.194)."

To visualize the landscape around this portion of the flight, an ASTER DEM was retrieved from EarthExplorer and processed in ArcGIS to accentuate the structural characteristics. First, the Hillshade tool was run on the DEM then it was overlaid with the original DEM symbolized using a standard elevation color ramp set at 50% transparency. This highlights the primary features of the terrain (Figure 11) and shows the flight path passing over a large valley bordered by steep cliffs along the northern edge.

To better accentuate the structures, the DEM was then processed for slope based on 'percent rise'. This highlights the ridges and cliffs that could have been the ones observed during the flight. When this is also combined with the 50% transparent DEM as before the features become even more apparent (Figure 12).

These maps show that there is a long steep cliff near the center of the map northwest of the flight path. South of this range is a large valley in which sits a small deeper depression. The EAAMS indicates that there are several candidate sites in this

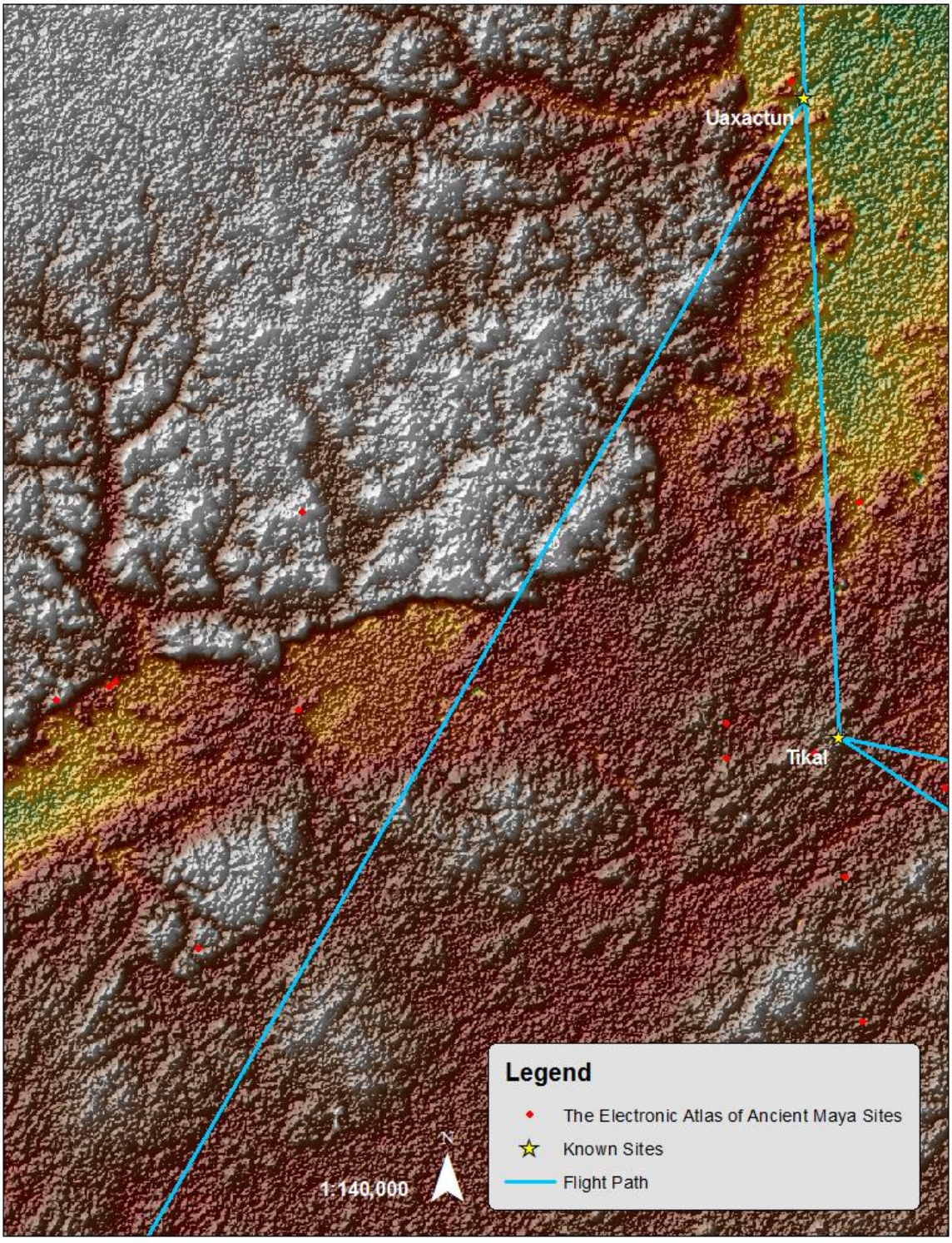


Figure 11 Ricketson and Kidder flight path with the ASTER DEM overlaid on the hillshade layer.

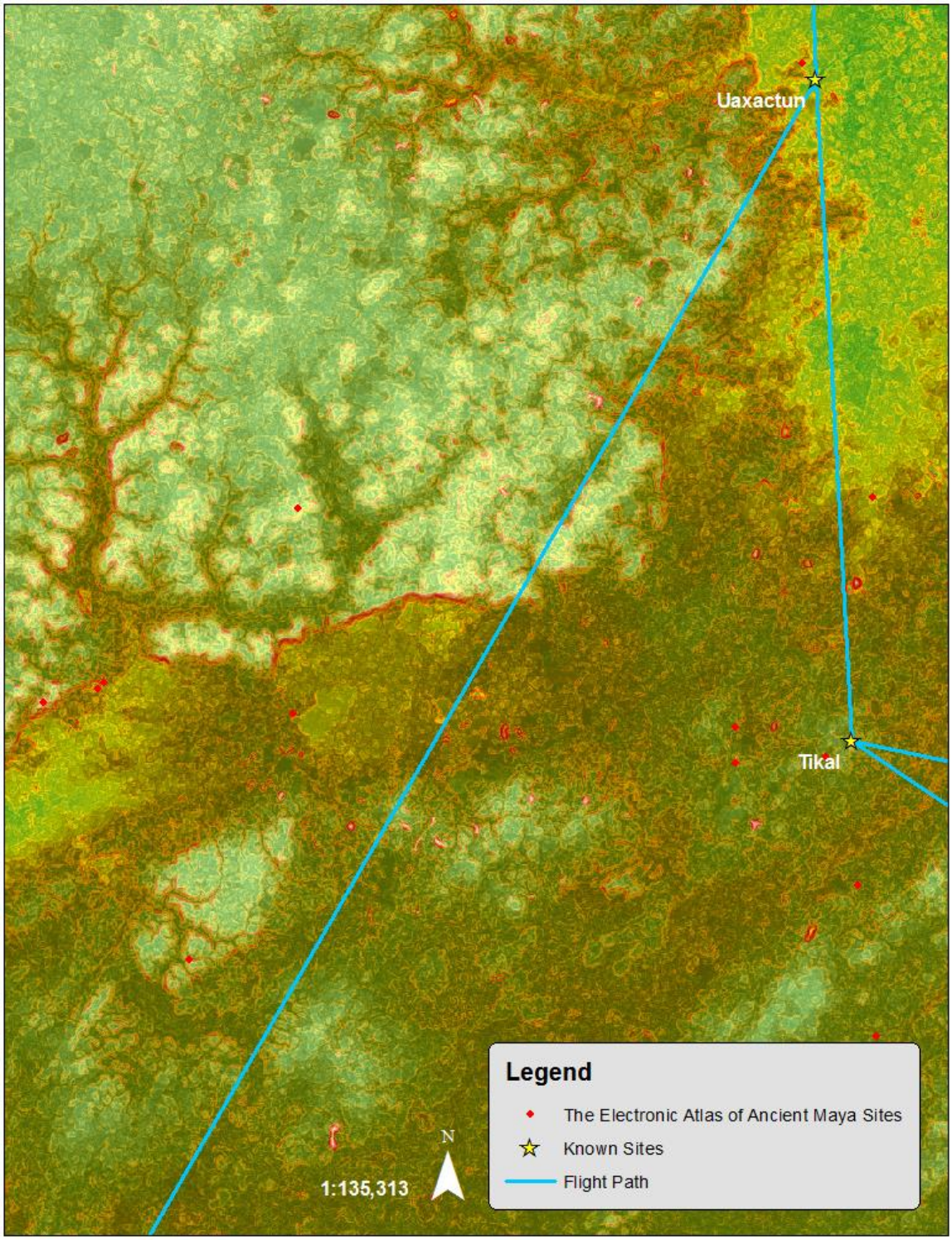


Figure 12 Slope output for the ASTER DEM.

area. El Zotz, El Diablo and Las Palmitas are located along those cliffs and El Palmar is located on the western edge of the smaller depression in the valley (Figure 13).

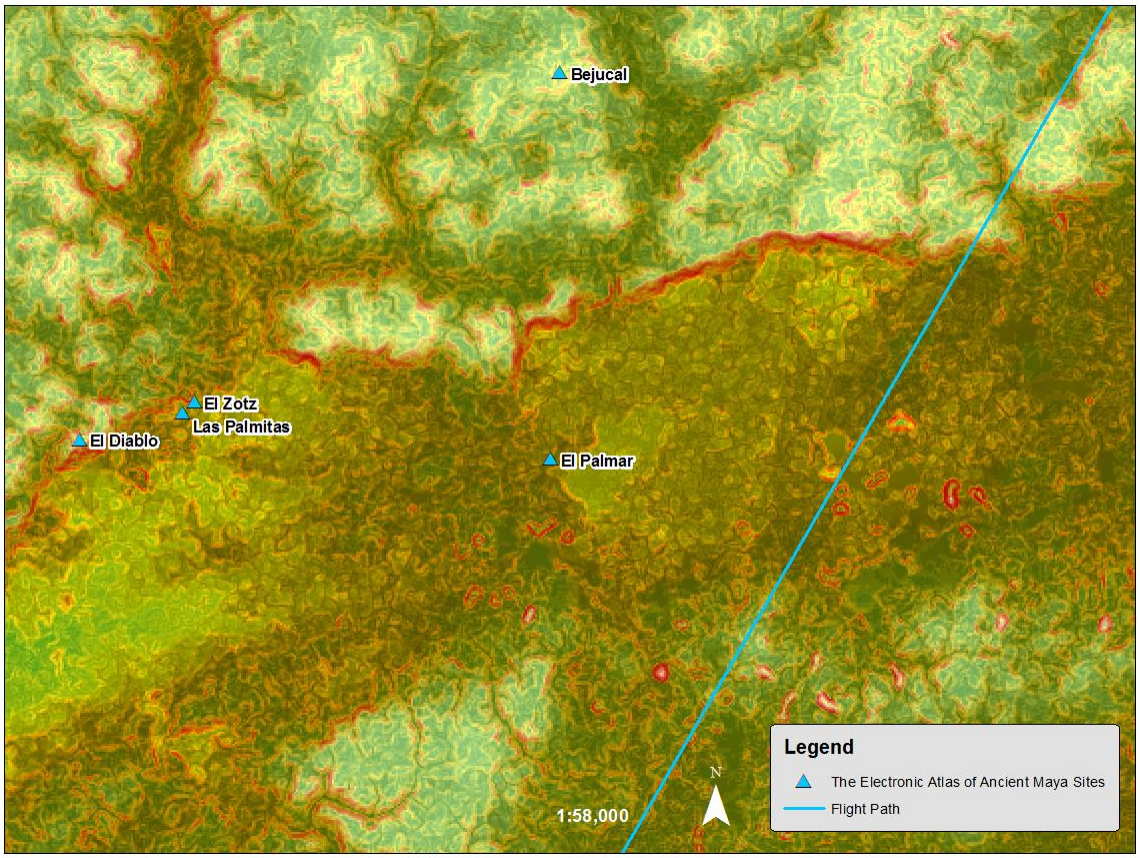


Figure 13 Close up of the study area in the slope output for the ASTER DEM. The bright red area indicates the steep slope that they may have viewed during their survey. To the left are the EAAMS points that indicate the candidates investigated in this study. The lake can be seen as a depression in the center of the map next to the EAAMS point for El Palmar.

When the same area is viewed using the ArcGIS Basemap, it shows that this depression is in fact a body of water (Figure 14). This could be the "large oval swampy

savanna, full of water under tall reedy looking grass" that was described in the article. The next step was to research these sites to determine if any of them are cliff-side caves.

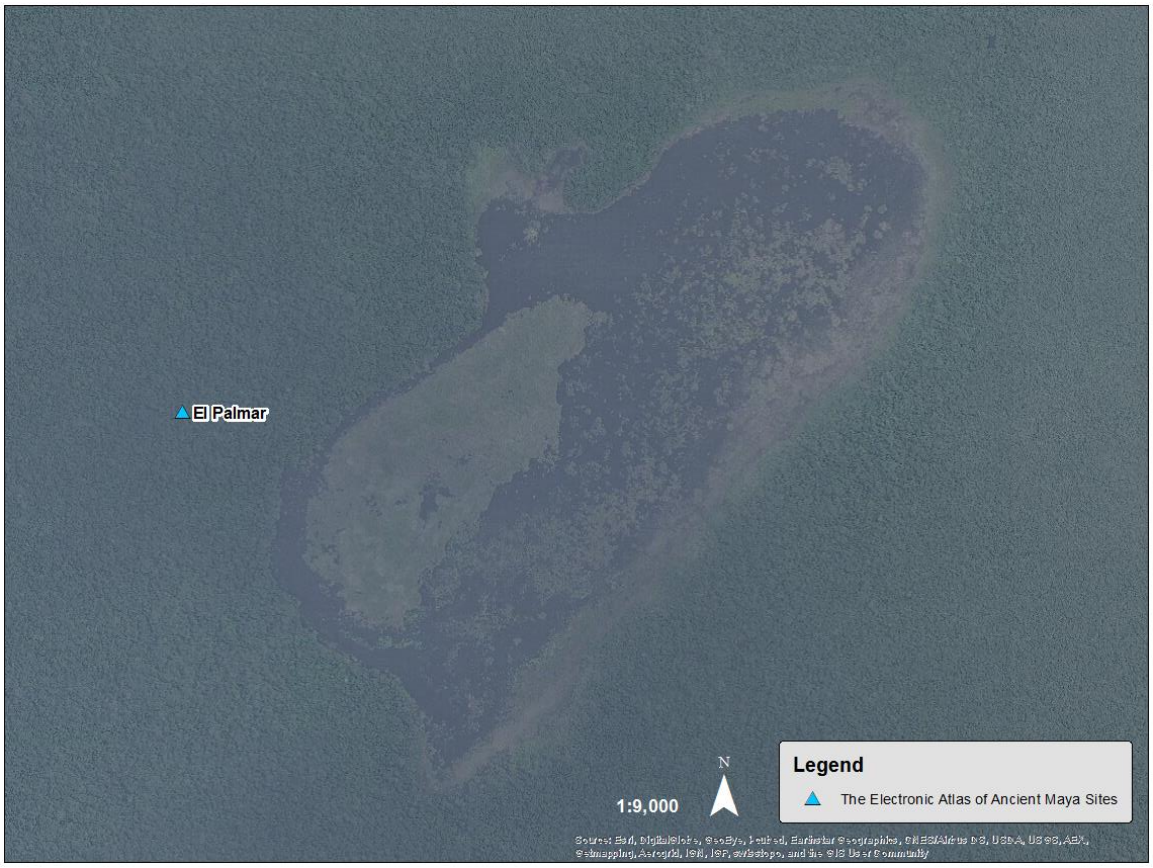


Figure 14 Imagery of the lake near El Palmar as seen in the ArcGIS basemap.

El Zotz, discovered in 1977 by Marco Antonio Bailey, is a large settlement complex with 49 buildings. The name refers to a nearby cave that houses a large population of bats but recent research of the glyphs found at the sites indicates that it was originally known as pa'-chan which means "broken sky" (Figure 15) (Leiva and Houston 2008).

El Diablo, or Devil's Lookout, is a small settlement 1km west of El Zotz. It consists of an enclosed courtyard and temple that sits at the summit of a substantial elevation from which Tikal is visible (Leiva and Houston 2008; Skidmore 2015). The structure and location indicate that it may have been a defensive site (Figure 15) (Leiva and Houston 2008).

Las Palmitas is located on an artificially leveled hill approximately a mile north of El Zotz. It is a large temple and palace site made up of 11 structures (Figure 15) (Leiva and Houston 2008).

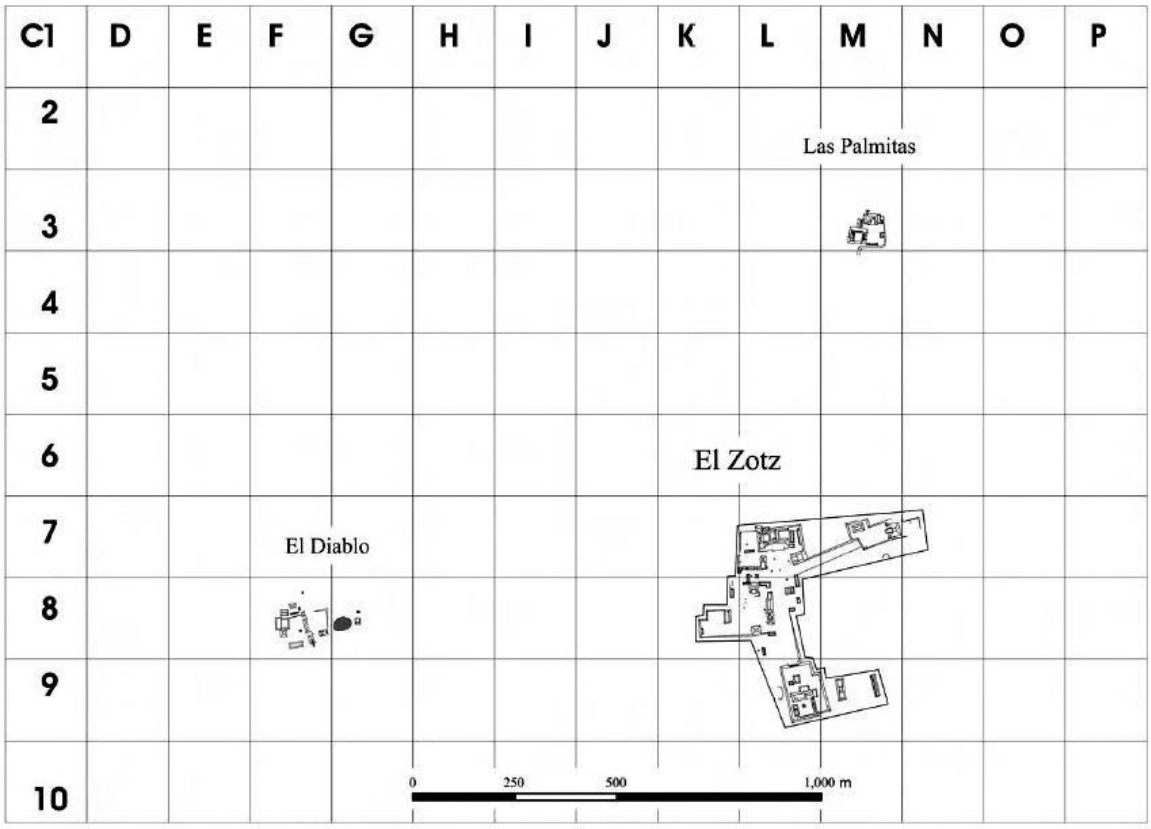


Figure 15 Site maps for El Zotz, El Diablo an Las Palmitas (Leiva and Houston 2008).

Finally, El Palmar is a monumental, pre classic, plaza site located 5.5 km east of El Zotz on the western edge of the body of water mentioned earlier that may have been the one observed during the Ricketson flight (Figure 16) (Doyle 2013; Leiva and Houston 2008).

One of the photographs from the Ricketson survey may be of this cave feature. It is titled Limestone Cliffs but it does not include many details as to the location beyond Peten, Guatemala, and Central America (Figure 17). Without more information it is hard to make a definitive statement but further research may be able to extract more information. Different image analysis software could be used on the photograph to extract the mountain structures or directly reviewing the original prints and notes from the flight could help illuminate its location.

Because EL Zotz is known to be associated with a cave, it is the most likely of these candidates to be the one they observed. However, there is not enough information for a definitive statement to be made. It is possible that they saw any of a number of caves that may exist along this range of cliffs. It is also not possible to definitively state that the photograph of limestone cliffs is referring to this range; however, they do not discuss another range like this in the article. It would probably require another flight through this area in order to make a one-on-one comparison of the mountain range's structure.

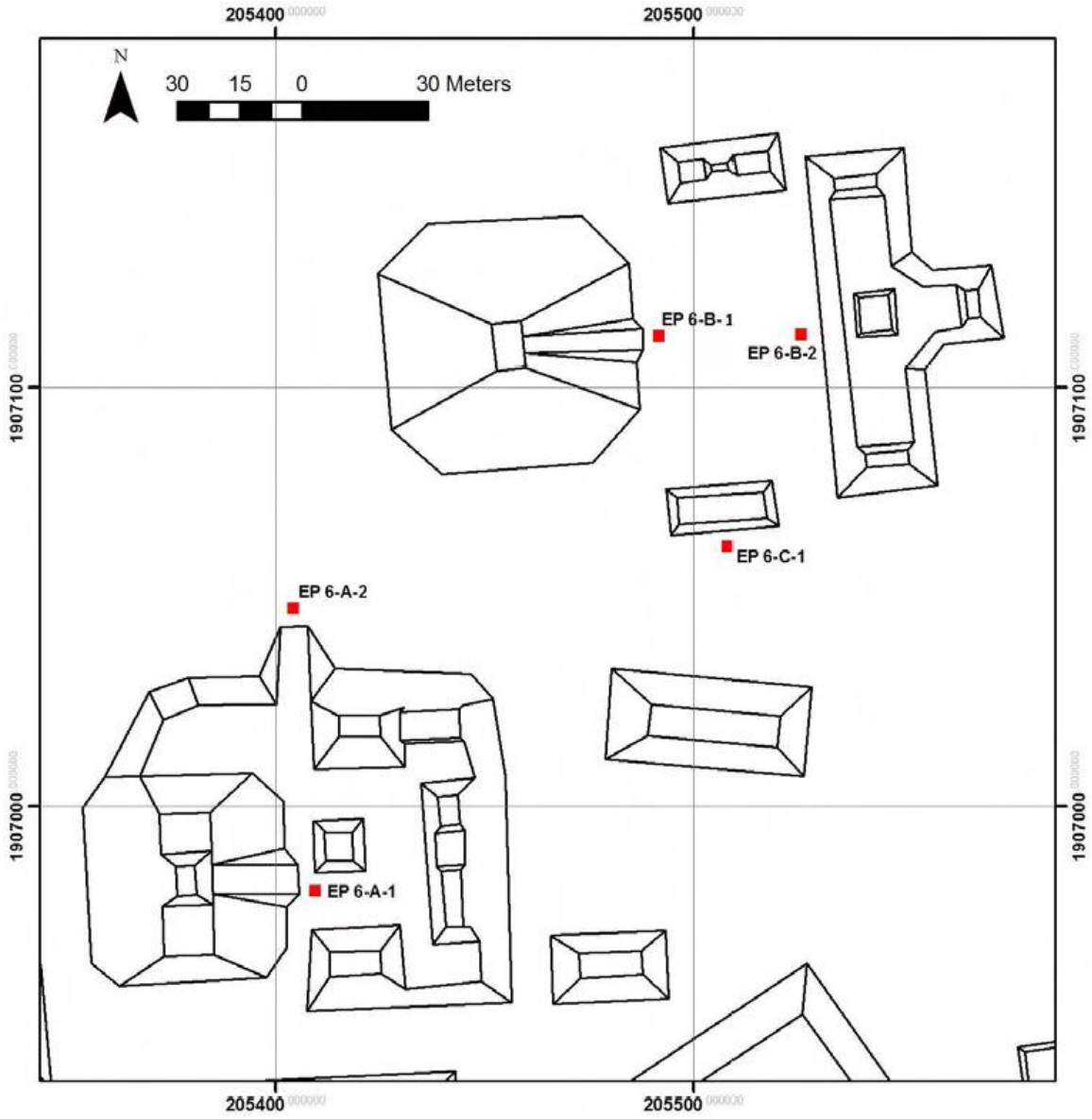


Figure 16 Site map for El Palmar (Leiva and Houston 2008)

Figure 17 Aerial photograph of limestone cliffs taken during the Ricketson and Kidder aerial survey in 1929. Artstor catalog # AHARVARD_10310435063.

4.3 Feature II

The second feature was observed on October 9th during the fourth flight on. It was described as:

> "About 15 minutes, 21 miles, west of [Lake] Bacalar and five miles west of the western edge of the *bajo* was a pronounced north-south whaleback ridge, perhaps five miles long. Three miles north of its northern end in flat, densely forested country we came over a group of five mounds (Ruin II), the tallest about 50 feet high and showing among the trees that shrouded its summit a fragment of masonry wall… a small *aguada* lay close to the mounds (O. Ricketson and Kidder 1930 p. 198)."

They also indicate that a whaleback ridge is located between Feature II and Dzibanche so the search began by downloading an ASTER DEM for the area surrounding Dzibanche in order to identify that whaleback ridge. The DEM was

processed using the same techniques as Feature 1 in order to better illustrate the location of the ridge (Figure 18). Ricketson and Kidder measured the ridge as approximately 5 miles long yet the pronounced elevation seen in the DEM is only about 2.5 miles long, which means that they may have included the lower hills surrounding the ridge in their calculations. Even though, Feature II was supposedly located an equal distance from the northern end of the ridge as Dzibanche is from the southern end. Using the measurement tool, Dzibanche is located almost 2 miles southwest of the southern end of the ridge.

To include as much area and as many sites from EAAMS as possible, Dzibanche was buffered to 11 miles based on the distances in the article. All the points within that buffer and in the general path of the flight line were selected and investigated. Feature 18 shows that there are no named sites in that area however there are two sites indicated as placemark nearby. This seems to lead to a dead end since there is no way to research the placemarks. Instead another database, called MayaMap (CIRCA 2015), was referred to in an attempt to find out what sites might lay there. It is an online only database that includes sites from Honduras all the way to southern Mexico and is overlaid on a topographic basemap. MayaMap includes some of the same unnamed points as EAAMS but also has a point labeled Ichkabal approximately 2.5 miles northeast of the northern end of the ridge (Figure 19). A site named Ichkabal was also found in EAAMS but it is over 37 miles to the northeast of Dzibanche.

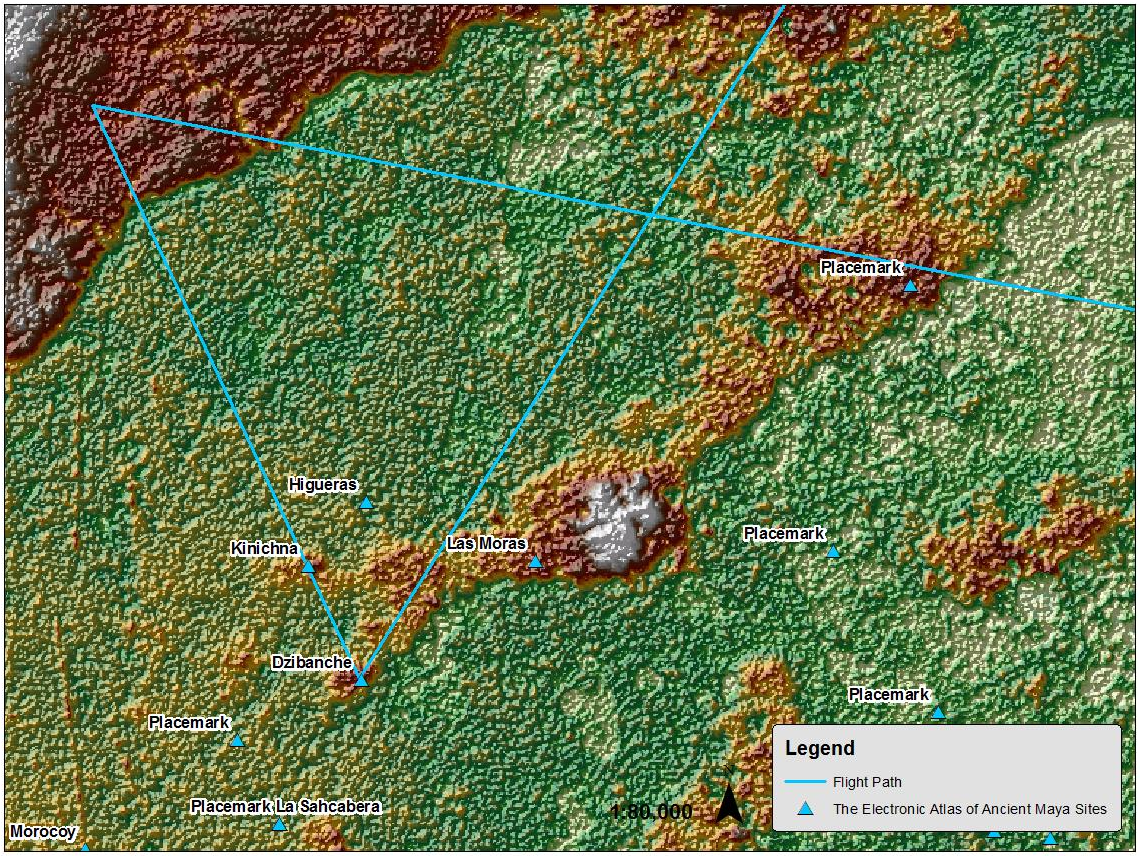


Figure 18 ASTER DEM overlaid on a hillshade layer for the area surrounding Dzibnche. The higher elevation in the center is likely the whaleback ridge described in the Ricketson and Kidder article. The flight path was adjusted to the Dzibanche point in the EAAMS, however, the rest of the path may not be accurate due to the lack of other verifiable locations in this section of the flight path.

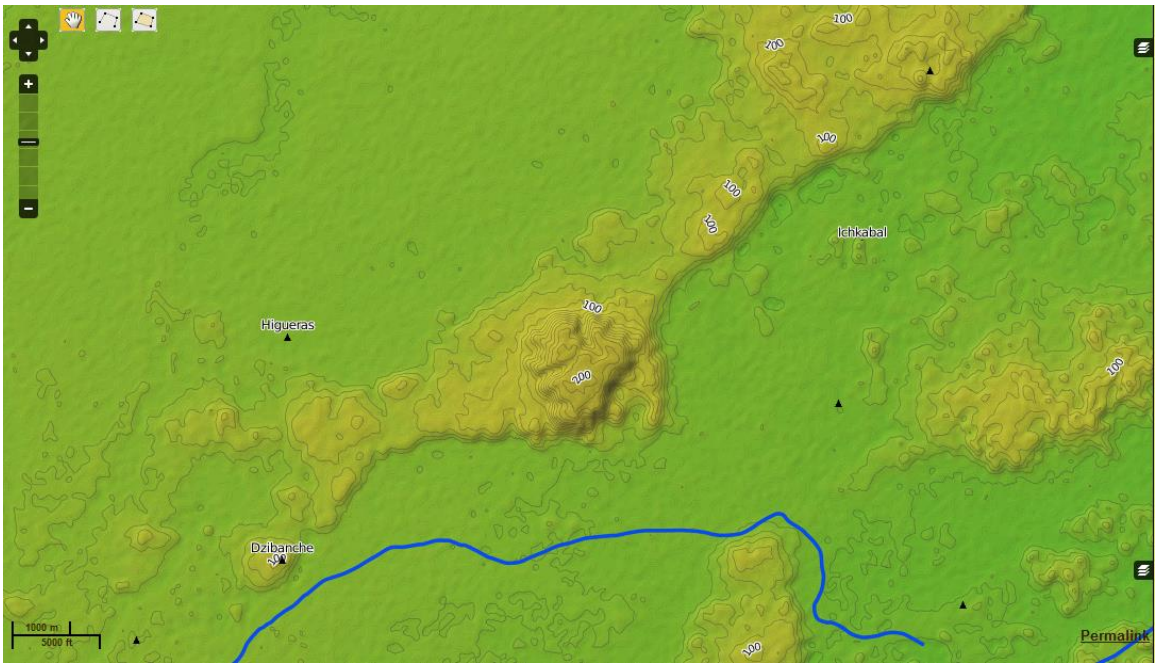


Figure 19 MayaMap view of the same location from Figure 15. Unlike Figure 15, a point labelled Ichkabal can be seen in the top right quarter of the map.

Ichkabal was officially discovered in 1995 and excavations started in 2009. The site consists of 6 architectural groups made up of large structures, the tallest of which measures 46 meters (Instituto Nacional de Anthropologia e Historia 2010). Because it is in the early stages of research there are few published works about the site, however, there is a video documentary of the site that describes it as consisting of several large pyramid structures with many smaller mounds and shows the landscape to be consistent with Ricketson's description including the rectangular body of water close to the mounds (Instituto Nacional de Anthropologia e Historia 2011) (Figure 20). It is also located 10 kilometers to the northeast of Dzibanche (Instituto Nacional de Anthropologia e Historia 2013).The location of Ichkabal taken from MayaMap combined with the features seen in the video allowed this site to be verified in Google Earth (Figure 21).

Figure 20 Image of Ichkabal taken from the video documentary of the site. Several mounds and the rectangular body of water are visible (Instituto Nacional de Anthropologia e Historia 2011).

It is very likely that Ichkabal is the site observed during the 1929 survey based on the general proportion of distances. Even though the distance measurements in the article are not very reliable, they indicate that Dzibanche is the same distance from the southern edge of the whaleback ridge as Feature II is from the northern edge. The measurements in ArcGIS indicate that Dzibanche is approximately 2 miles from the southern end and Ichkabal is approximately 2 miles from the northern end of the lower hills. This would indicate that though their measurements are different the proportions are the same and the general structure and understanding of the landscape is correct.

Figure 21 Google Earth view of the features seen in the video documentary of Ichkabal. Like Figure 17, several mounds and a rectangular body of water are visible.

4.4 Feature III

The final site is also from the fourth flight. At 12:59 on October 9th the team flew over a ruin that was not on their map. They designated it as Ruin VI and described it as,

> "… a steep high mound set slightly back from the tip of an inconsiderable natural elevation. The stonework of a ruined temple could be made out, and nearer the end of the ridge were two or three lesser mounds. A slough lay just north of the high ground and beyond it a large milpa." (O. Ricketson and Kidder 1930 p. 199-200)"

They estimated its location to be approximately 30 miles east of Lake Chichancanab though they did not fly from the lake to this site so the measurement has to be used only as a general reference. The search began by buffering the Known Sites point for the lake by 30 miles but no EAAMS sites exist at 30 miles from the lake. The two closest include Yo'okop and La Aguada at 15 and 19.5 miles to the east of the lake respectfully.

No information has yet been found regarding a site named La Aguada. It is likely, however, that this is referring to a feature within the Yo'okop complex, an assumption that will be clarified later.

As for Yo'okop, a 2010 article by Johan Normark includes a site map that shows two groups of structures and a small body of water, possibly the slough mentioned in the Ricketson article (Figure 22). Google Earth was then searched for any similarly shaped body of water in the area surrounding the database location of Yo'okop and one was found approximately one mile east of the La Aguada point feature.

The DEM analysis conducted for features 1 and 2 was repeated on an ASTER DEM for this area. The results indicate that there are subtle rises in elevation surrounding a slight depression (Figure 23). This coincides with the structures and water body from the Normark map as well as a modern road visible in the imagery. In this case the features are very subtle because the ASTER DEM, with a spatial resolution of 30 meters, is too coarse to extract the more detailed variations within the site itself. Therefore, the ASTER DEM is useful for a general understanding of the landscape but cannot be used to identify the finer Mayan structures. Instead, Google Earth and ArcGIS imagery was used to analyze the site.

The most distinct features in the imagery are the aguada (water body), Group A, Group B and Sacbe 2B. An aguada is manmade water reservoir that relies on rainfall for replenishment though they are sometimes created naturally when sinkholes become sealed by sediments. Sacbe is a term commonly used in Mayan studies to describe an

ancient road or causeway. It comes from the Yucatec word sakbe meaning “white road”(Normark and Göteborgs universitet 2006).

Also available in the Normark (2006) article is an intensity map for the site (Figure 25). It shows several large structures situated on the edge of a small ridge overlooking a body of water much in the same way as the description of Ruin VI from the Ricketson article.

All of this information combined would indicate that this is likely the true location of Yo’okop even though the EAAMS point is almost 6 miles to the southwest. This serves as another example of the spatial error present in the EAAMS. Based on the structural comparison presented here, it is very likely that Yo’okop it the site Ricketson and Kidder observed during their aerial survey.

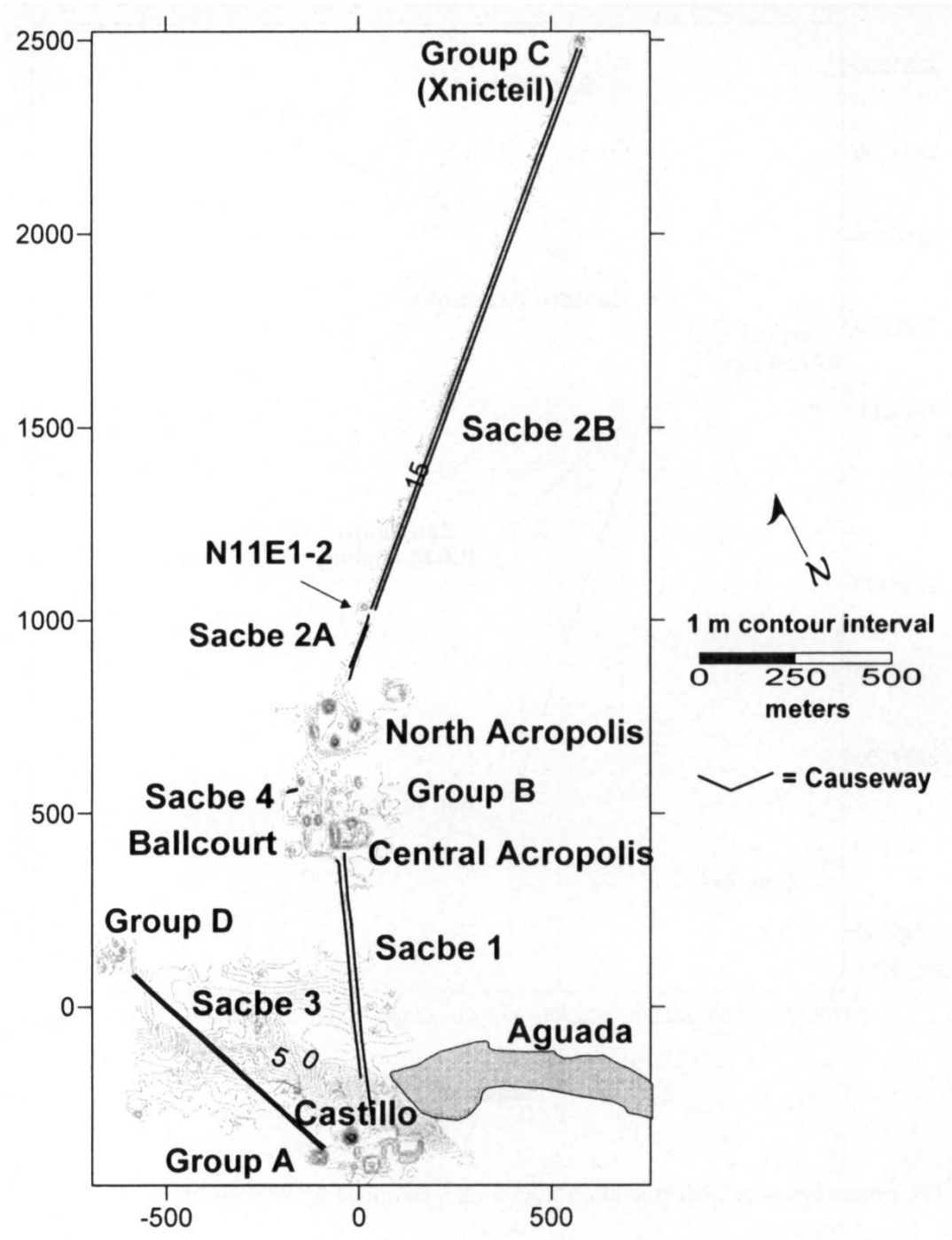


Figure 22 Site map of Yo'okop (Normark 2010).

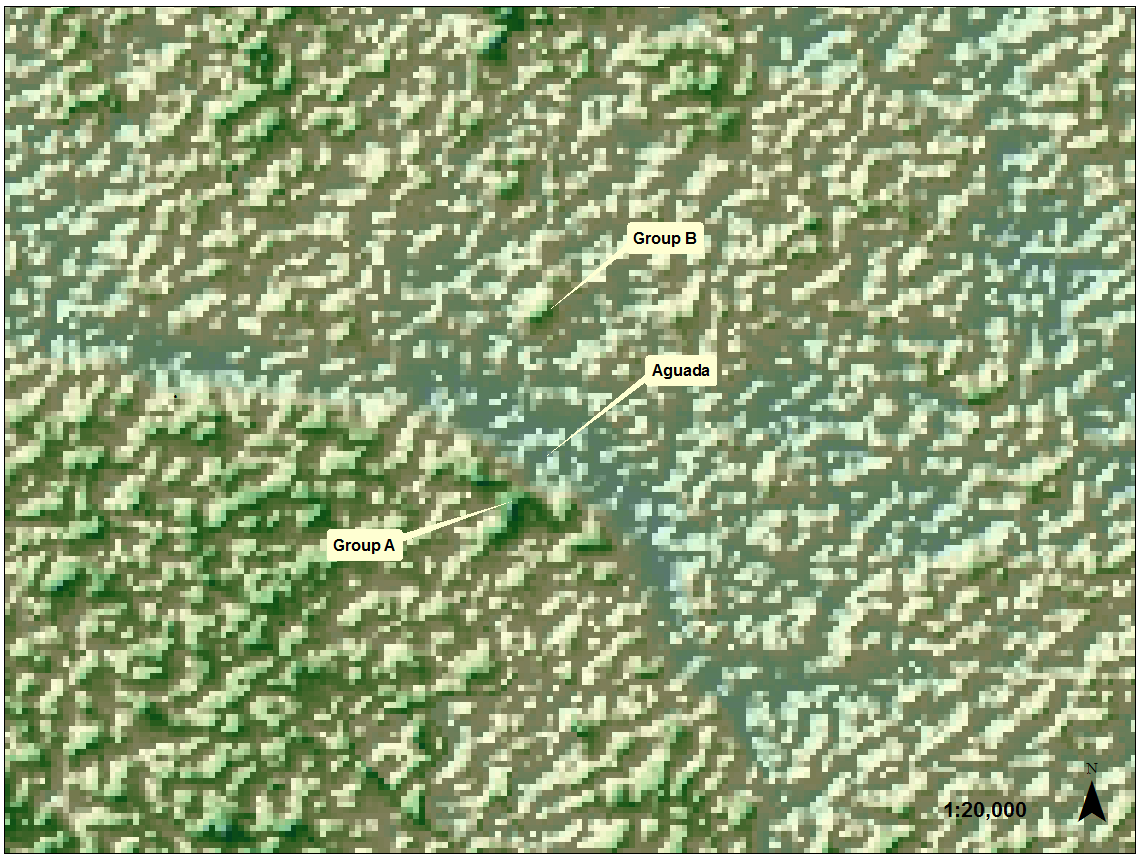


Figure 23 ASTER DEM of the landscape surrounding the likely location of Yo'okop. Slight variations cane be seen where Group A, Group B, and the Aguada are located. Refer to the site map in Figure 19.

Figure 24 Google Earth image of the landscape surrounding the likely location of Yo'okop. Most significant are the larger, darker trees where Group A and B are located; the aguada; and the linear feature in the forest where the sacbe runs north. Refer to Figure 19.

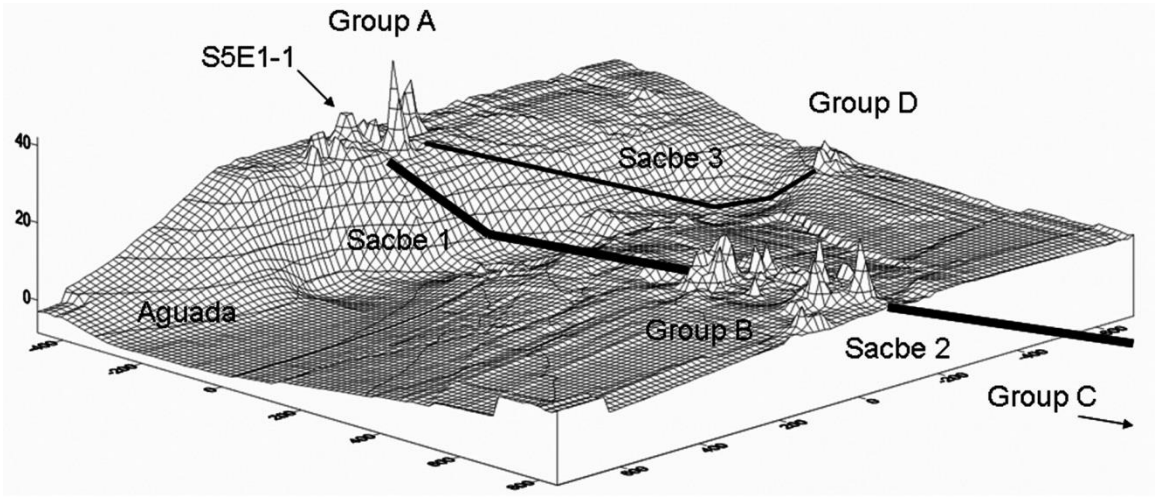


Figure 25 Intensity map of Yo'okop that illustrates the finer features of the landscape not visible in the ASTER DEM (Normark and Göteborgs universitet 2006).

5. DISCUSSION AND CONCLUSIONS

5.1 Discussion

Based on the results from the two methods implemented in this thesis, a clear distinction can be made as to their effectiveness. While site identifications cannot be made with absolute certainty, the landscape method offered a much more likely set of results than the distance method.

The distance method relied too heavily on the measurements from the 1929 article and the EAAMS, both of which contain errors and inconstancies. Even if the literature search for the candidates of the distance method had provided more information, the likelihood that the sites they had observed were located within the search buffers is slim due to the location error in the EAAMS. Even small errors in the EAAMS could place the site they observed outside of the selection zone. It should be noted that when using an electronic dataset like EAAMS, it is important to understand the extent and causes of location errors and adjust the methodology to account for them.

The landscape method, on the other hand, proved much more reliable because it was based on the characteristics of the sites and environments themselves rather than distances alone. For example, the location for Yo'okop based on the imagery is approximately 20 miles east of Lake Chichancanab while the article describes it at 30 miles east of the lake. In addition, the EAAMS places the point for Yo'okop approximately 6 miles to the southwest of its position in the imagery. Therefore, if a

simple distance search had been implemented for this site it would not have been identified. The landscape method allows for a broader search that made it possible to identify the site.

It should also be noted that the methods presented here are not direct comparisons but analyze two different sets of points. The reason for this is the limited information available in the Ricketson and Kidder article. The three sites investigated with the Distance Analysis did not include landscape information necessary to apply the Landscape Analysis. Likewise, the three sites investigated in the Landscape Analysis did not include distances traveled along the flight path that would be necessary to apply the Distance Analysis. Therefore, when using historic records, one has to apply the methodology that fits the available information.

5.2 Further Research

Many factors stood in the way of positively identifying these sites including missing aerial photographs, limited site information and DEMs too coarse to adequately represent the finer features of the landscape. Different data sources and search methods could be pursued to clarify the results.

First, the Artstor database could be searched again for more photographs taken during the 1929 flight. So far the search resulted in photographs primarily of known archaeological sites such as Chichen Itza and Tikal as well as a few of unidentified landscapes and towns but there may be some yet unidentified photographs that include the ruins investigated in this thesis. The primary reason for the limited search results is incomplete metadata. So far, 64 photographs from the flight have been identified but few

of them include any indication that they were a part of the Lindbergh flight at all. Instead many were collected based on a similar style and quality to that of the photographs included in the article. It may be possible to find more photographs through further searches of the database or with one-on-one assistance from Artstor librarians.

Second, as discussed in the results for the distance method, one reason why a search of the may have literature offered little information about the site candidates could be due to misspellings or variations in spellings unknown to me. Further research of sites throughout the region could offer insight into the spelling variations that could offer better results for a literature search.

The lack of results for the distance method does not necessarily mean that the distances are incorrect. It could simply mean that the sites they observed during their flight have not been recorded since or simply were not yet added to the electronic database. Other methods could be employed to search for corresponding structures such as searching the imagery for vegetation signatures similar to that of other ancient Mayan sites of the region (Garrison et al. 2008) or conducting Lidar surveys of the areas in question in order to visualize the surface and structures without being hindered by the vegetation (Chase et al. 2012).

Finally, DEMs with finer spatial resolution or Lidar surveys could also be used to positively identifying the sites from the landscape analysis. The ASTER DEMs acquired through EarthExplorer were the only freely available DEMs found at the time of this study. ASTER's spatial resolution is only as fine as 30 meters, which is too coarse for most archaeological remains to be visible. While they are capable of offering an overall

impression of the regional landscape and the general indication of the footprint of an entire Mayan complex, the subtler characteristics of the sites are missed. DEMs with finer resolutions could help to better understand the landscape and site structures. For example, Yo'okop was described as located on "an inconsiderable natural elevation". The variation in elevation seen in the ASTER DEM is very subtle. A more detailed DEM or Lidar survey could better accentuate the finer structures of the landscape if not the individual buildings themselves, which could lead to a positive identification.

5.3 Conclusion

Historic records are a unique source of clues that can help researchers understand past environments, study landscape change and identify archaeological sites. The results of these two methods indicate that if they were to be repeated for other past aerial surveys, the focus should be on the physical characteristics of the landscapes and structural descriptions rather than relying on the distance measurements alone. However, the comparison of these two methods shows that no single method offers definitive results. The error in distance measurements from the article could be due to the fact that they often veered off course to more closely observe features and then returning to their previous path, meaning that their actual flight path was not a straight line as illustrated in the map. This along with variations in flight speeds mean that the distance measurements and flight path are predisposed errors or miscalculations; however, the path offers a starting point for a landscape based search. No single data source or type can be relied on to identify historic observations; instead, a multi-media model that utilizes wide variety of overlapping data should be employed.

APPENDIX A

Table 4 Observations from the first day of the aerial survey on October 6, 1929

Flight 1: October 6, 1929 (Belize to Merida)

Flight	Date	Departure	Arrival	Direction	Flight Time (Minutes)	Speed (mph)	Altitude (Feet)	Distance (Miles)	From	Features	Discovered by	Discovered Date	Feature Type	Feature Class	Feature Direction	Visibility	Page #
1	6-Oct	9:18	10:05		47	85	500	66.7	Belize City	El Cayo			City/Town	Modern			180
1	6-Oct					85	1500		El Cayo	Followed E branch of the Belize River			River	Natural			181
1	6-Oct		10:15			85	500	7	El Cayo	Indian Shrine			Village	Modern			181
1	6-Oct		10:22			85	500	16?	El Cayo	Vaca Falls or Chaqui Bull?			Natural	Natural			181
1	6-Oct					85	500			Benque Viejo			City/Town	Modern			182
1	6-Oct				3	85	1500			Yaxha Lakes, El Cayo Flores road, Gabelan			Mayan Structure	Combination			182
1	6-Oct				10	85	500	14.2 (13)	Benque Viejo	Yaxha settlement			Mayan Structure	Archaeo		Not Visible	182
1	6-Oct	10:40				85	500		Yaxha	Tikal			Mayan Structure	Archaeo		Visible 20 miles away	182
1	6-Oct	10:54	11:00		6	85	500		Tikal	Uaxactun (Group E)			Mayan Structure	Archaeo			182
1	6-Oct	11:06	11:10	North	4	85	2000	5.7	Uaxactun	NW to SE Valley			Natural	Natural			183
1	6-Oct		11:22	North		85	500	22.7	Uaxactun	Flat country to W and low hills to E. Bajos			Ag & Natural	Combination			183
1	6-Oct			North		85	500	42.5	Uaxactun	Possible artificial conical hill			Unclear	Unclear	East	No masonry visible	183
1	6-Oct			North		85	500	56.8	Uaxactun	Yeso or Rio Bec? Two temples facing each other on artificially raised plaza.			Mayan Structure	Archaeo			183
1	6-Oct		11:55	North		85	500	69.6	Uaxactun	Milpa without house			Agriculture	Modern			186
1	6-Oct					85	500	4	Milpa	Change in jungle from vivid green to gray			Natural	Natural			186
1	6-Oct		12:04	North		85	500	82.4	Uaxactun	Bajo with better drainage			Agriculture	Modern			186
1	6-Oct		12:08	North		85	500	88	Uaxactun	Aguada Concepcion or Aguada Carolina			Lake	Natural			186
1	6-Oct					85	500	10	Aguadas	Chicle camp			Village	Modern			187
1	6-Oct			North		85	500	112	Uaxactun	Town with Spanish church. Xkanha?			Village	Modern			187
1	6-Oct			North		85	500	125	Uaxactun	Stream running NW to SE before sat a small Mayan pyramid			Mayan Structure	Archaeo		Visible	187
1	6-Oct	1:00		East		85	500	162	Uaxactun	Turned to ward Tekax, Peto and Saban. Escarpment.			City/Town	Modern			187
1	6-Oct		1:24			85	500	196	Uaxactun	Small Mayan temple in clearing. Walls and part of vaulted roof intact.			Mayan Structure	Archaeo		Visible	190
1	6-Oct		2:02			85	500	54	Small temple	Henequen field			Agriculture	Modern			190
1	6-Oct		2:10			85	500	11.4	Henequen field	Temax			City/Town	Modern			190
1	6-Oct				5	85	500		Temax	Gulf of Mexico			Ocean	Natural			190
1	6-Oct				5	85	500		Gulf of Mexico	Motul			City/Town	Modern			190
1	6-Oct	**END**	**2:39**		**5hrs 21min**	**85**	**500**	**454.8**	**Belize City**	**Landed in Merida**			**City/Town**	**Modern**			**190**

Table 5 Observations from the second day of the aerial survey on October 7, 1929

Flight 2: October 7, 1929 (Merida to Belize)

Flight	Date	Departure	Arrival	Direction	Flight Time (Minutes)	Speed (mph)	Altitude (Feet)	Distance (Miles)	From	Features	Discovered by	Discovered Date	Feature Type	Feature Class	Feature Direction	Visibility	Page #
2	7-Oct	9:35							Merida	Chichen Itza			Mayan Structure	Archaeo			190
2	7-Oct			South				10	Chichen Itza	Yaxuna			Mayan Structure	Archaeo		Not visible	190
2	7-Oct		11:05						Yaxuna	Lakes. Chichn Hanab?			Lake	Natural			190
2	7-Oct	1:24	1:42	150*					Lakes	Escarpment with bajos.			Natural	Natural			191
2	7-Oct		2:10	180*-225*				55	Escarpment	whaleback hill			Natural	Natural			191
2	7-Oct		2:39				1000	106	Lakes	Rio Hondo			Natural	Natural			192
2	7-Oct		3:50				2000			Chetumal Bay			Natural	Natural			192
2	7-Oct		3:00							Corozal			City/Town	Modern			192
2	7-Oct	**END**	**4:06**		**4hrs 23min**			**373**	**Merida**	**Belize City**			**City/Town**	**Modern**			**192**

Table 6 Observations from the third day of the aerial survey on October 8, 1929

Flight 3: October 8, 1929 (Belize to Flores and Return South of Cocksombs)																	
Flight	Date	Departure	Arrival	Direction	Flight Time (Minutes)	Speed (mph)	Altitude (Feet)	Distance (Miles)	From	Features	Discovered by	Discovered Date	Feature Type	Feature Class	Feature Direction	Visibility	Page #
3	8-Oct	9:25		210*					Belize City	El Cayo			City/Town	Modern			192
3	8-Oct		9:35					20.6	Belize City	Indian shrine			Village	Modern			192
3	8-Oct		9:47				1000			Pine Ridge of Cockscomb Mountains			Natural	Natural			192
3	8-Oct		9:55							Belize River			River	Natural			192
3	8-Oct		10:04				1300	55.4	Belize City	Rougher terrain			Natural	Natural			192
3	8-Oct		10:10					63.9	Belize City	El Cayo			City/Town	Modern			192
3	8-Oct		10:15							Benque Viejo passed, Yaxha lakes ahead.			City/Town	Modern			192
3	8-Oct		10:20-10:30	North						Naranjo ruins			Mayan Structure	Archaeo		Not visible	193
3	8-Oct		10:35							Landed on lake to view Yaxha			Mayan Structure	Archaeo		Difficult to view from the air.	193
3	8-Oct	10:38								Passed over Yaxha again			Mayan Structure	Archaeo			193
3	8-Oct		10:45							Nakum. Second growth with finer texture and lighter color			Mayan Structure	Archaeo			193
3	8-Oct		10:57							Tikal lesser mounds. Marked by heightening and bunching of bush and darker green foliage			Mayan Structure	Archaeo		Vegetaional footprint	193
3	8-Oct	11:02	11:15							Uaxactun lesser mounds. Marked by heightening and bunching of bush and darker green foliage			Mayan Structure	Archaeo		Vegetaional footprint	193
3	8-Oct			210*		85	1500			Passed between Uaxactun and Tikal							193
3	8-Oct		11:34			85				Swampy savana with 50-75' cliff in which a 15-18' cave could be seen. Suggest future investigation.			Mayan Structure	Archaeo			194
3	8-Oct		11:40			85				Lake Peten			Natural	Natural			194
3	8-Oct	12:30				85				Took off from the town of Flores on Lake Peten			City/Town	Modern			194
3	8-Oct		12:44			85		19-20	Flores	2 east to west lakes			Natural	Natural			194
3	8-Oct		12:59			85		41	Flores	Rough hills			Natural	Natural			194
3	8-Oct					85		6	Rough hills	Approaching steep range with limestone cliffs that looked like masonry			unsure	unsure			194
3	8-Oct	1:15	1:22	E		85	1500-1700			Limestone hills with steeply conical tops and sheer cliffs.			unsure	unsure			194 & 196
3	8-Oct		1:30			85	2000	85	Flores	Indian villages near the border of Guatemala and British Honduras. Skyline to the south has steeply conical silhouette.			City/Town	Modern			196
3	8-Oct		1:43			85	2000			Bay of Amatique, bush houses and milpas.			Town and natural	Combination			196
3	8-Oct		1:50			85				Rainstorm							196
3	8-Oct		1:55			85				Passed storm and arrived at coast 10-12 miles north of Punta Gorda and landed at Cary Cay (?)			Natural	Natural			196
3	8-Oct	**5:05**	**5:50**		**5hrs 14min**			**443**	**Belize City**	**Belize City**							**196**

Table 7 Observations from the first day of the aerial survey on October 6, 1929

Flight 4: October 9, 1929 (Belize to Cozumel)																	
Flight	Date	Departure	Arrival	Direction	Flight Time (Minutes)	Speed (mph)	Altitude (Feet)	Distance (Miles)	From	Features	Discovered by	Discovered Date	Feature Type	Feature Class	Feature Direction	Visibility	Page #
4	9-Oct	10:23	NNE						Belize City	Toward the Rio Hondo							196
4	9-Oct		10:43				500	28	Belize City	Long Narrow lake to SE and Ocean to E			Natural	Natural	SE & E		196
4	9-Oct		10:50					46.5	Belize City	Small lakes below and escarpment to the west			Natural	Natural	W		196
4	9-Oct		11:00							Orange Walk. Milpas. One with conical mound.			Both	Cobination			196
4	9-Oct		11:04							Rio Hondo			Natural	Natural			196
4	9-Oct			33*	17			24	Rio Hondo	Lake Bacalar							198
4	9-Oct			E					Lake Bacalar	Crossed Bajo with hills on northern edge that looked like mounds (Ruin I?)(Fig. 1)			Mayan Structure	Archaeo	E	No visible masonry	198
4	9-Oct			W	15			21	Lake Bacalar	Whaleback ridge about 5 miles long. (5mi W of bajo above)			Natural	Natural			198
4	9-Oct			N				3	Whaleback ridge	Group of 5 mounds. Tallest 50'. (Ruin II)			Mayan Structure	Archaeo		Masonry visible	198
4	9-Oct		11:30-11:40	S				3	Whaleback ridge	(Kidder sure this was Tzibanche !CHECK! Shown too far S on Blom-Ricketson map rather it lies W of Lake Bacalar and is confirmed by Dr. Gann) Group of 4 steep, high pyramids, (Ruin III), temple ruins on 2 of them, 1 with vertically slotted wall	Dr. Thomas Gann	1927	Mayan Structure	Archaeo		Masonry visible	198
4	9-Oct		11:50				2000			N-S escarpment 10 miles to the esy					W		
4	9-Oct			NE	12		Very Low	17	Ruins II & III	Sharp elevation in view to the N			Natural	Natural	N		198
4	9-Oct				14		Very Low	19.7	Ruins II & III	Passed over sharp elevation which proved to be a 75' pyramid (Ruin IV). Several lakes to the E and 1 to the W before arriving. 3 lower pyramids to the E surrounded by suspiciously lumpy landscape.	Site not previously identified!		Mayan Structure	Archaeo		No visible masonry	198-199
4	9-Oct		12:20	NE		85	500			Across milpas and villages near to ruins			Villages	Modern			199
4	9-Oct		12:29			85	500	12.7	Ruin IV	Indian town and milpas in which 15-20' mounds were visible. Flat-topped at 2-4' high. Modern Maya consider areas with ancient remains to be the best for agriculture.			Mixed	Archaeo			199
4	9-Oct		12:39			85	500	27	Milpa mounds	Ruin V. Large flat-topped mound 50' square and 10' high in the middle of a milpa. Surrounded by small conical mounds.			Mixed	Archaeo			199
4	9-Oct		12:49		4	85	500			Turned NW toward an eminence and left milpa country. Pyramid seen to the N and rounded hills to the S.							199
4	9-Oct		12:59		16	85	300	22.5	Sighting. 30 miles E of Lake ChiChan Hanab.	Ruin VI. Steep, high pyramid mound at northern end of low N-S ridge. 2-3 lesser mounds near the end of the ridge and a milpa	Site not previously identified!		Mayan Structure	Archaeo		Masonry visible	199-200
4	9-Oct		1:10			85	500			Ruin VII. Large mound flanked by smaller one. No milpas or villages present.			Mayan Structure	Archaeo		No visible masonry	200
4	9-Oct		1:25			85	500			Passed over low, rock-stren mounds. On the way to Ruin VI.			Mayan Structure	Archaeo		No visible masonry	200
4	9-Oct		1:27			85	500			Could see 4 ruins: 1) ahead 2&3) two smaller ones to the SE 4) Large group to the N			Mayan Structure	Archaeo		No visible masonry	200
4	9-Oct			NE		85	500			Ruin VIII. Smaller and less steep pyramid than VII. Standing on a slight ridge and dominating several smaller structures. S of Coba?			Mayan Structure	Archaeo		No visible masonry	201
4	9-Oct		1:30			85	500			Very tall, steep pyramid by a great squat mound surrounded by lower mounds.			Mayan Structure	Archaeo		Some rocky ground beneath veg.	201
4	9-Oct		1:45			85	500			Large ruin between the lakes of Coba. Castillo of Nahochmul. All major structures were easily recognizable. Many other mounds also visible from the view level to the tree tops.	1) Maler 2) Eric Thompson & Dr. Kidder 3) Lindbergh &	1) Date? 2)1926 3)Date?	Mayan Structure	Archaeo		Masonry visible	201
4	9-Oct		2:04	SE		85	900			Sea could be seen			Natural	Natural			202
4	9-Oct		2:15		19	90+	500	26.79+	Coba	Tulum (Landed, viewed ruins, spoke with locals who informed that Coba was only other large city in the area and it is 35-40 mi from Tulum.)			Mayan Structure	Archaeo		Masonry visible	202
4	9-Oct	4:35				85	500		Tulum	Headed for Cozumel			Natural	Natural			202
4	9-Oct		4:40			85	500		Tulum	Cozumel in sight.			Natural	Natural			202
4	9-Oct		4:55			85	500		Tulum	Cozumel reached and Ruin IX visible. Ruin IX was 60' square by 20-30' high and flanked by smaller mounds. Not on Blom-Ricketson map.			Mayan Structure	Archaeo		Masonry visible	202
4	9-Oct				**5hr**	**85**		**425**	**Belize City**	**Landed at San Miguel**			**City/town**	**Modern**			**202**

Table 8 Observations from the first day of the aerial survey on October 6, 1929

Flight 5: October 10, 1929 (Cozumel to Coba to Havana and Miami)																	
Flight	Date	Departure	Arrival	Direction	Flight Time (Minutes)	Speed (mph)	Altitude (Feet)	Distance (Miles)	From	Features	Discovered by	Discovered Date	Feature Type	Feature Class	Feature Direction	Visibility	Page #
5	10-Oct	9:24	9:32	W	8	85	500	11.28	San Miguel	Crossed mainland coast			Natural	Natural			202
5	10-Oct		9:42			85	500		San Miguel	Small cenote & Chemax Tancah road			Both	Combination			203
5	10-Oct		9:45		21	85	500	30	San Miguel	Coba seen to SW			Mayan Structure	Archaeo			203
5	10-Oct		9:47			85	500		San Miguel	Changed course toward Coba			-				203
5	10-Oct				12	85	500	17	San Miguel	Passed over Coba lakes. (Saw set od cenotes and mounds on the way). Coba is at least 15 mi S of maps from the time almost due W of S tip of Cozumel. Searched for causeways but were unable to identify them but suggest that morning or evening light would be better.			Mayan Structure	Archaeo			203
5	10-Oct	10:06		NE		85	600-1000		Coba	Headed back toward coast			-				203
5	10-Oct		10:15			85	500		Coba	Crossed Chemax Tancah road							203
5	10-Oct		10:26			85	500		Coba	Crossed shoreline at Puerto Morelos heading for Cuba							203
5	10-Oct		2:00			85	500		Coba	Reached Havana and refueled							203
5	10-Oct		Nightfall			85	500		Havana	Landed in Miami							203

APPENDIX B

Figure 26 Aerial photograph of Lake Chichancanab. Artstor library catalog # AHARVARD_10310424223.

Figure 27 Google Earth orientation of the Lake Chichancanab aerial photograph pictured in Figure 23.

Figure 28 Aerial photograph of the Rio Hondo. Artstor library catalog # AHARVARD_10310424225.

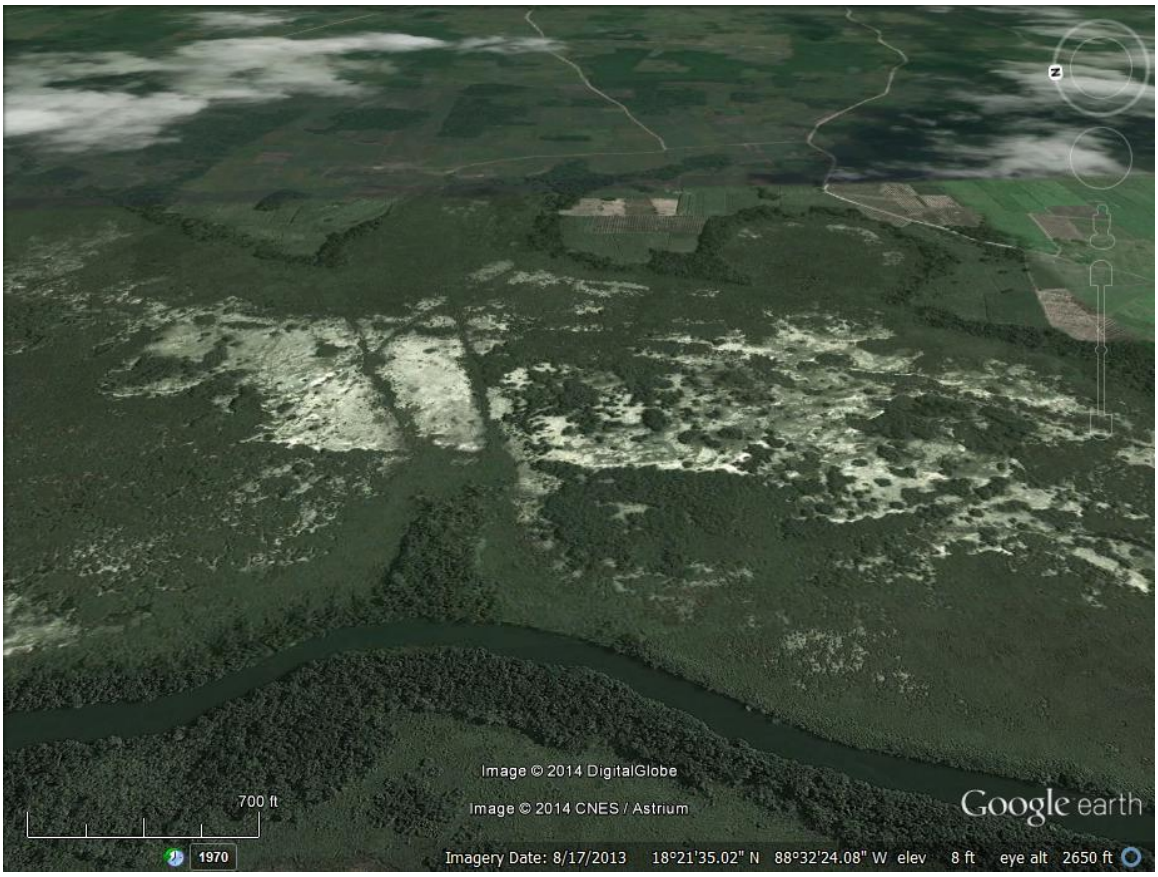


Figure 29 Google Earth orientation of the Rio Hondo aerial photograph pictured in Figure 25.

Figure 30 Aerial photograph of keys off the southeastern coast of Belize. Artstor library catalog # AHARVARD_10310435065.

Figure 31 Google Earth orientation of the keys aerial photograph pictured in Figure 27.

Figure 32 Aerial photograph of Yaxha. Artstor library catalog # AHARVARD_10310435086.

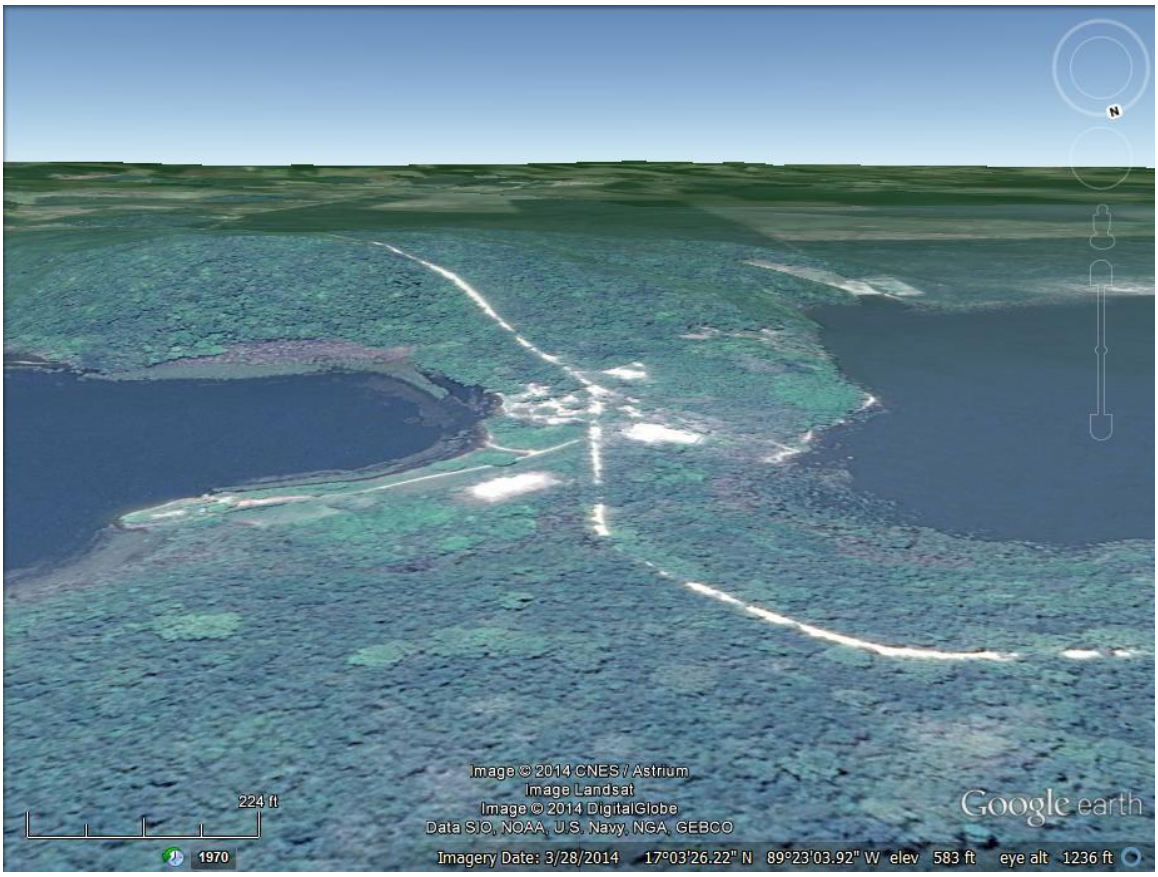


Figure 33 Google Earth orientation of the Yaxha aerial photograph pictured in Figure 29.

Figure 34 Aerial photograph of the town of Flores. Artstor library catalog # AHARVARD_10310424252.

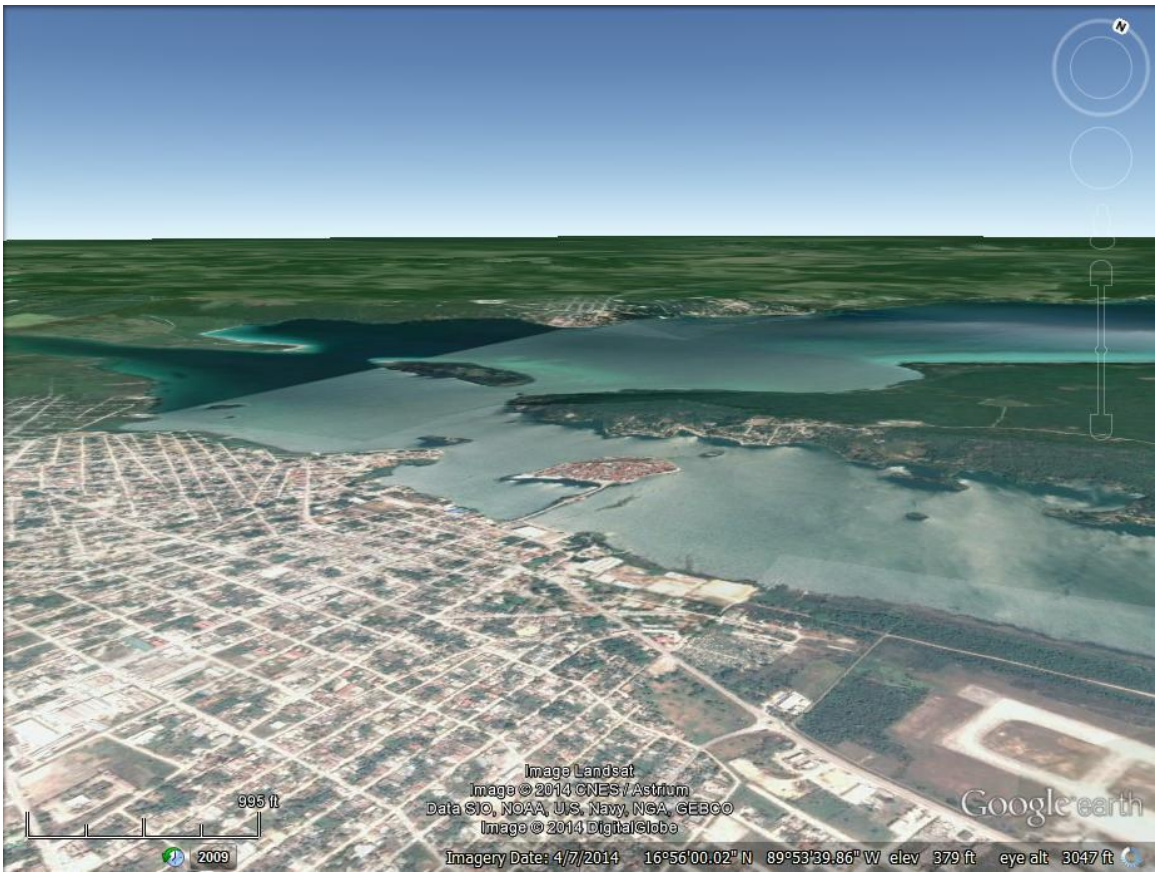


Figure 35 Google Earth orientation of the Flores aerial photograph pictured in Figure 31.

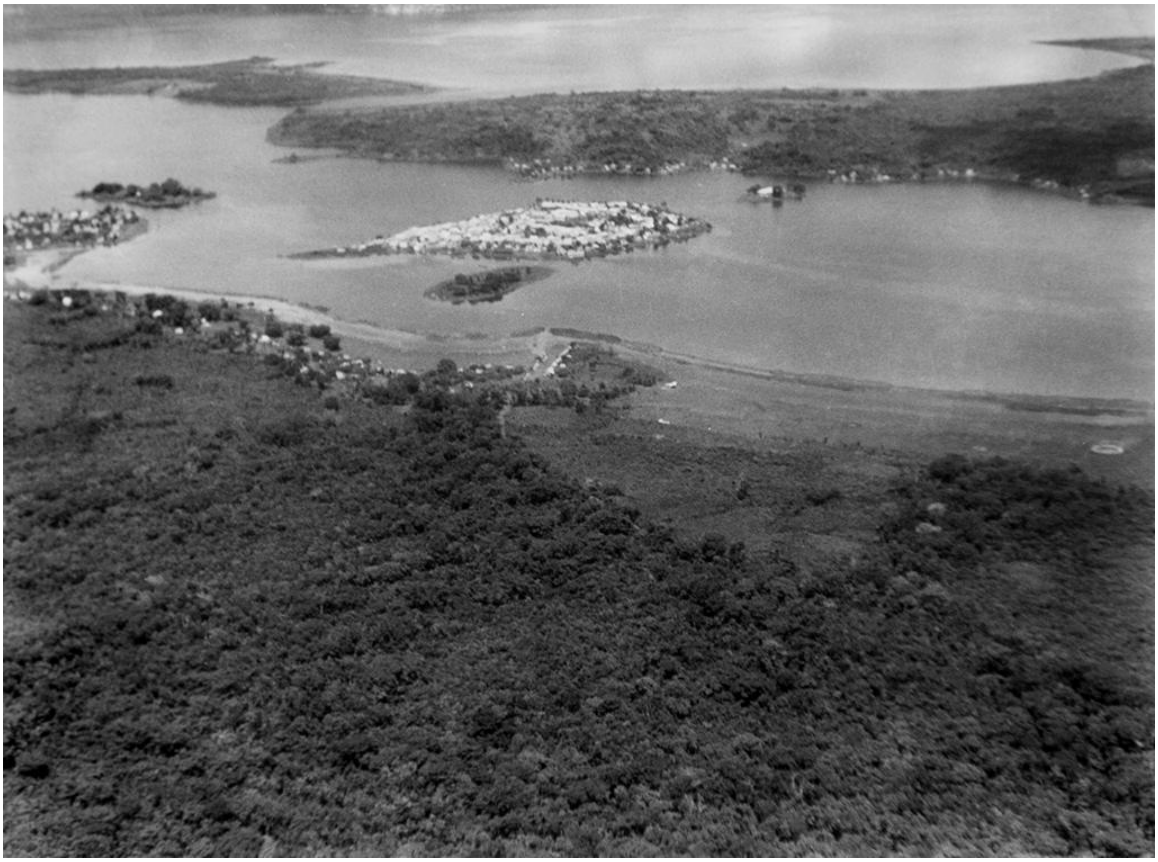


Figure 36 Aerial photograph of the town of Flores. Artstor library catalog # AHARVARD_10310438050.

Figure 37 Google Earth orientation of the Flores aerial photograph pictured in Figure 33.

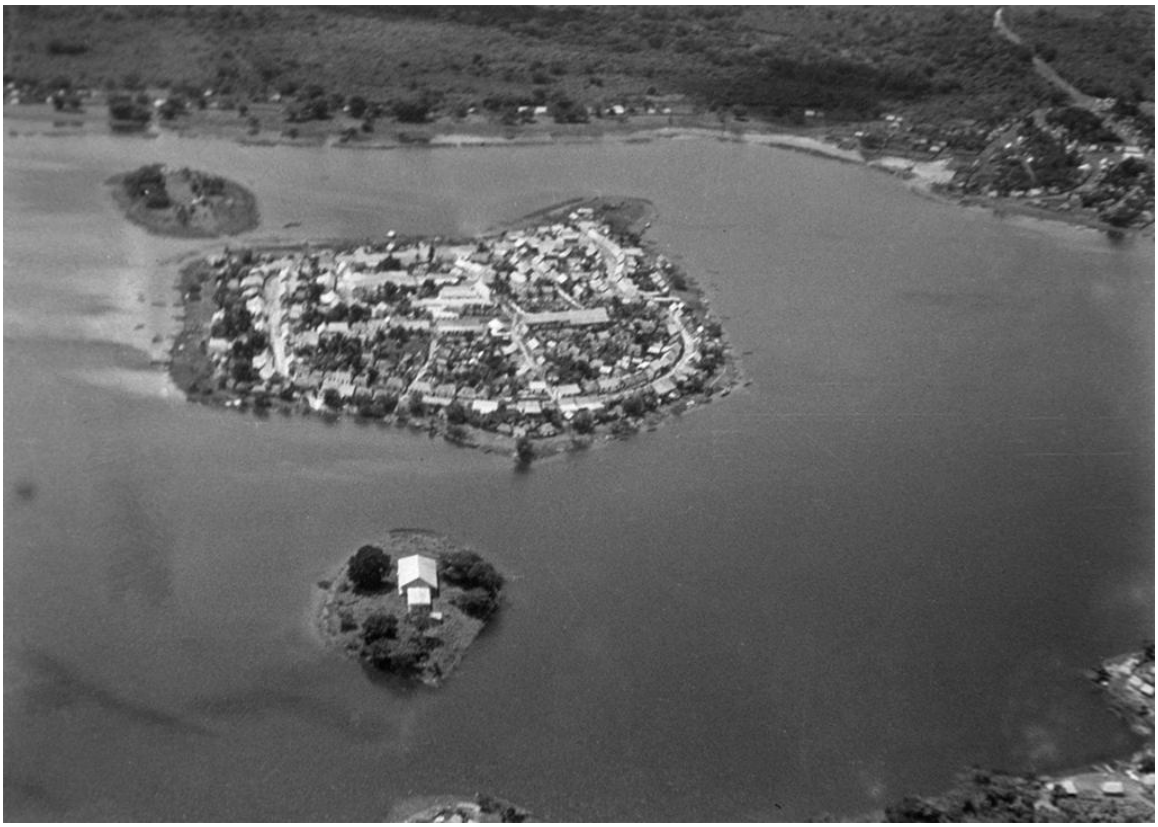


Figure 38 Aerial photograph of the town of Flores. Artstor library catalog # AHARVARD_10310438525.

Figure 39 Google Earth orientation of the Flores aerial photograph pictured in Figure 35.

Figure 40 Aerial photograph of Tayasal. Artstor library catalog # AHARVARD_10310435096.

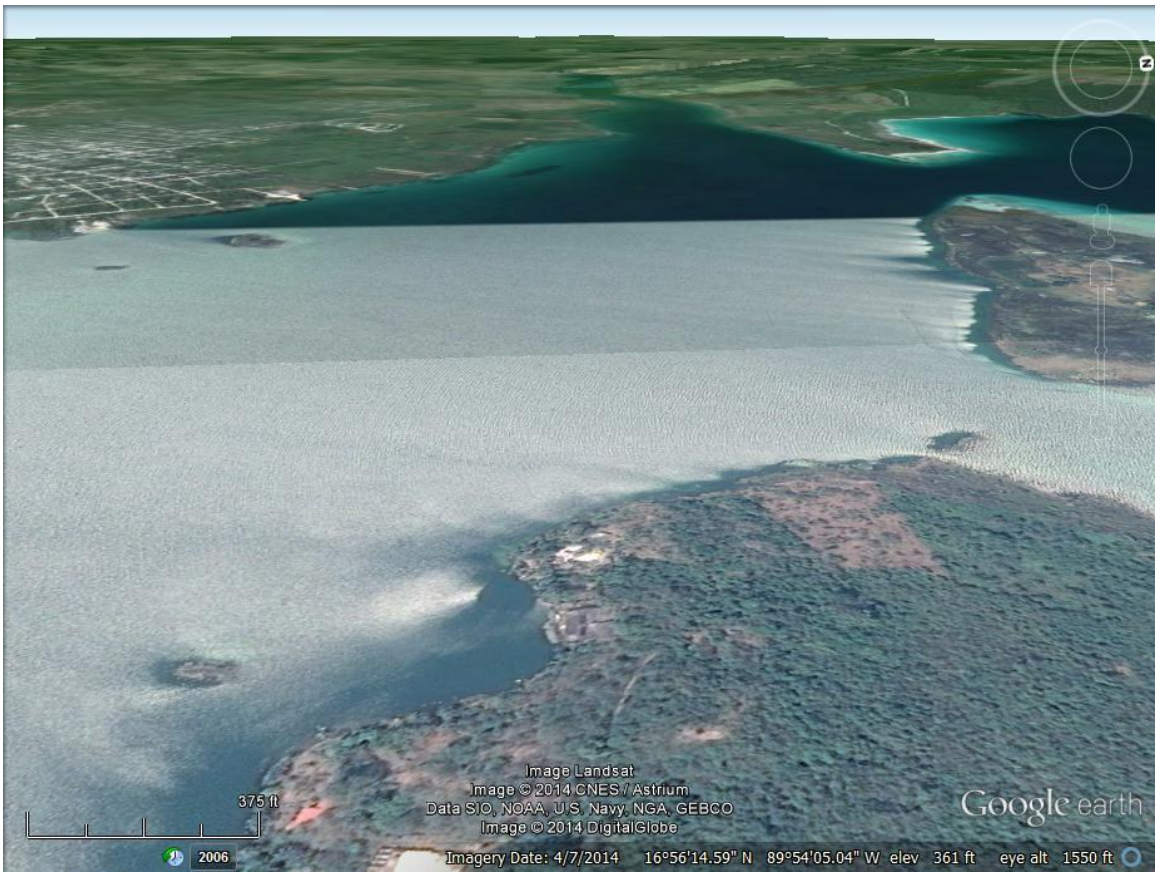


Figure 41 Google Earth orientation of the Tayasal aerial photograph pictured in Figure 37.

Figure 42 Aerial photograph of Tayasal. Artstor library catalog # AHARVARD_10310435097.

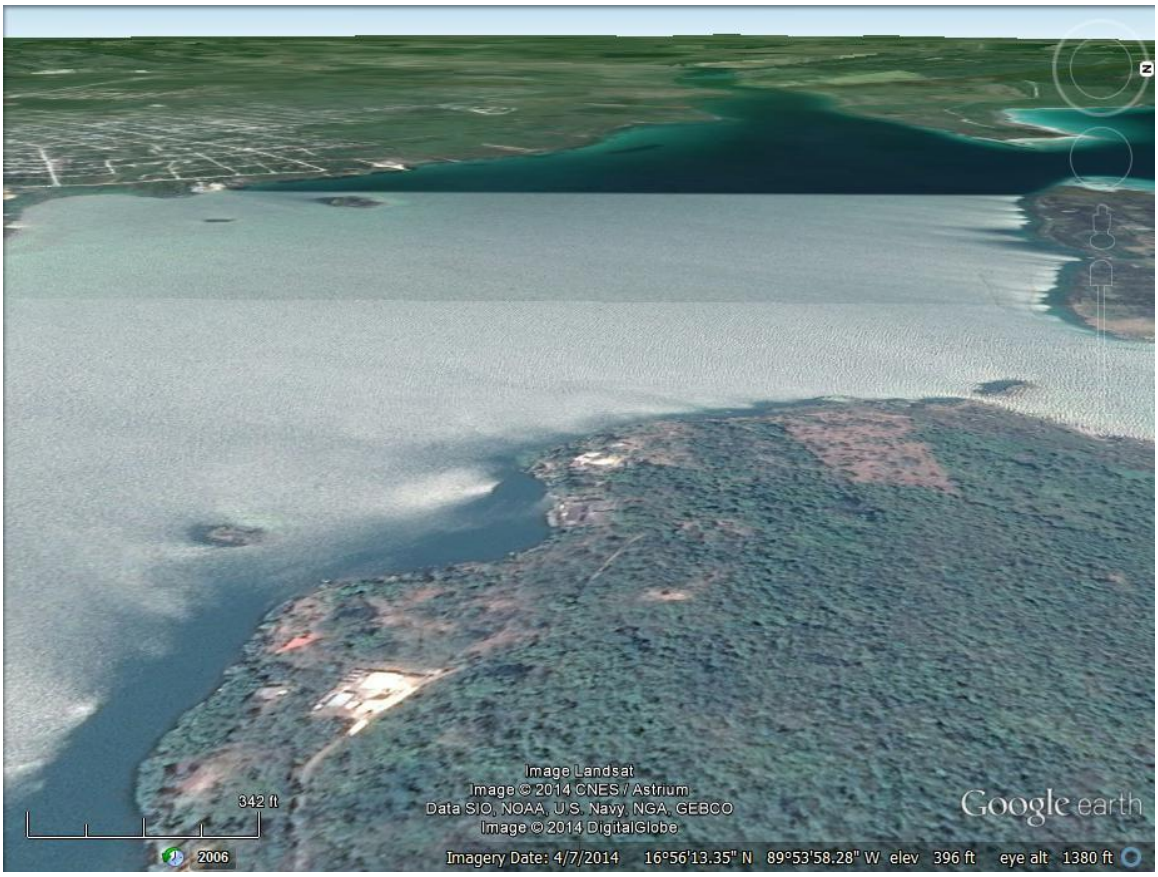


Figure 43 Google Earth orientation of the Tayasal aerial photograph pictured in Figure 39.

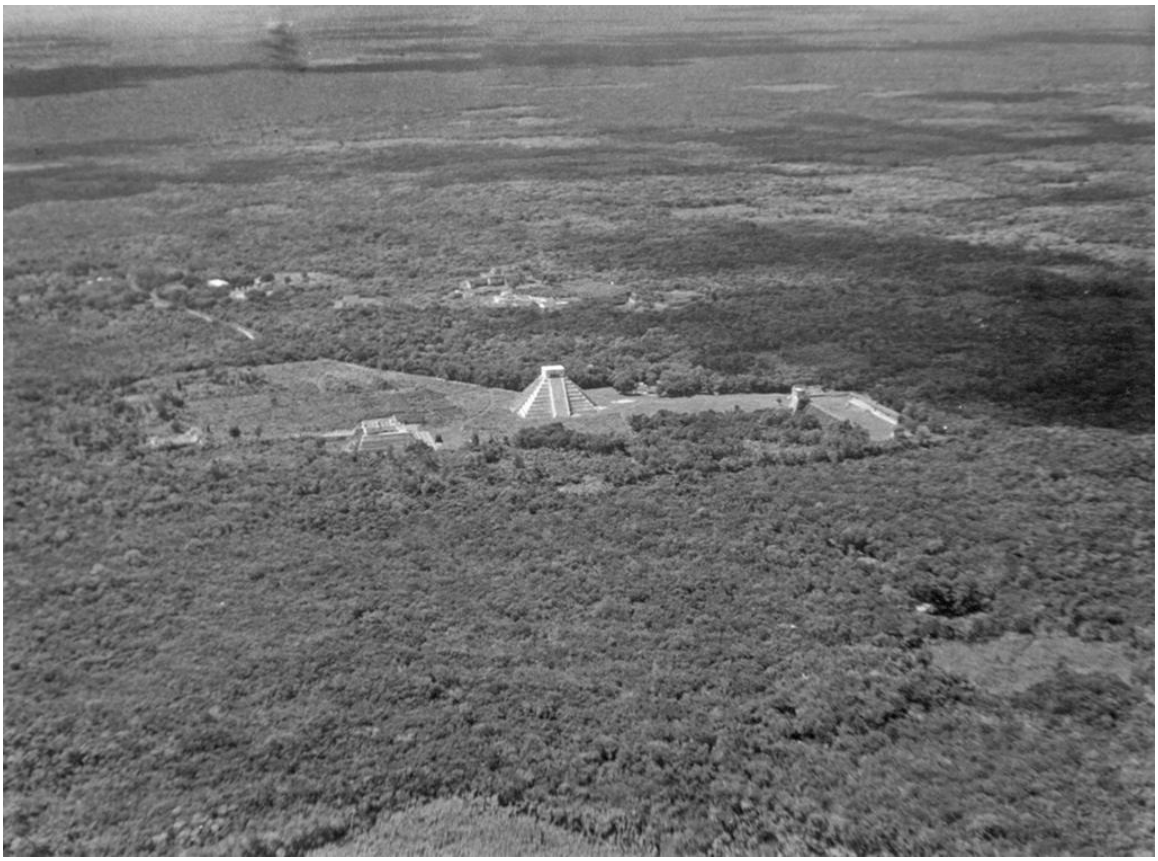


Figure 44 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310424257.

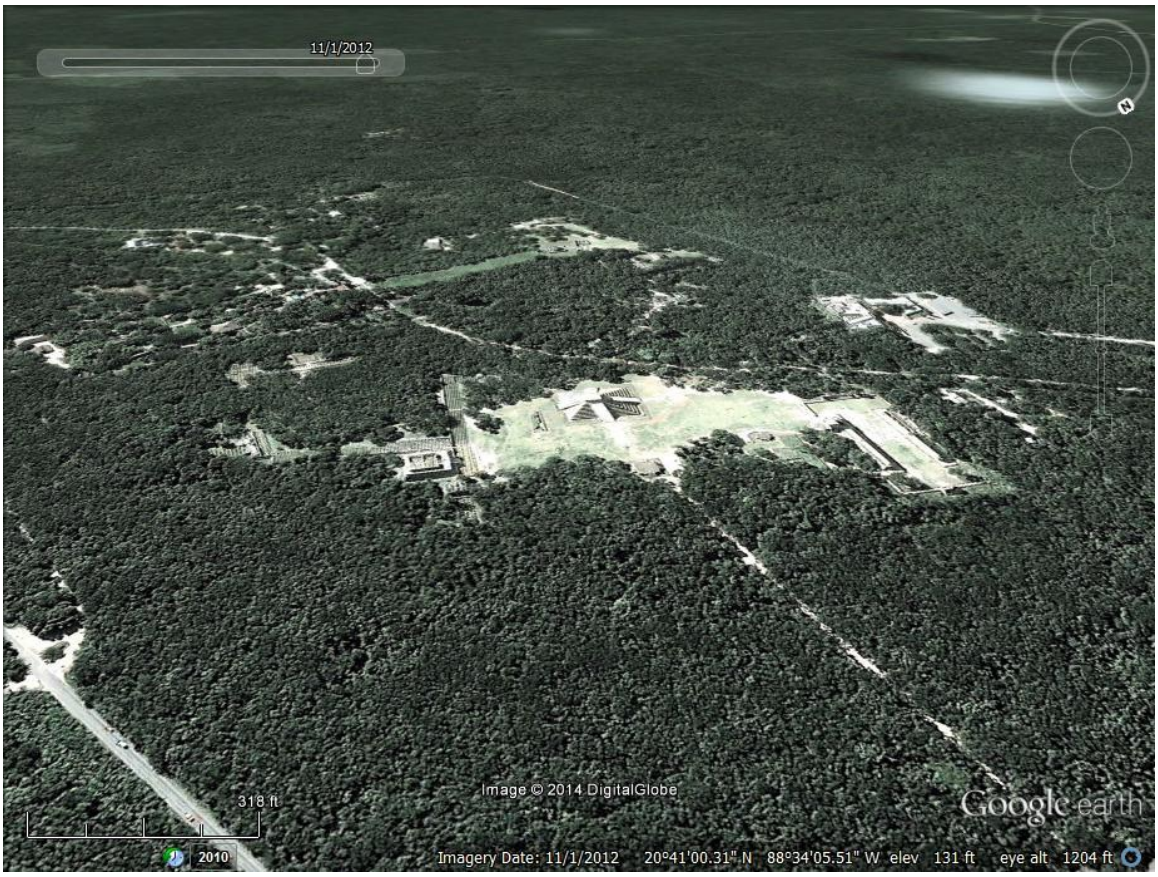


Figure 45 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 41.

Figure 46 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310424277.

Figure 47 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 43.

Figure 48 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310426768.

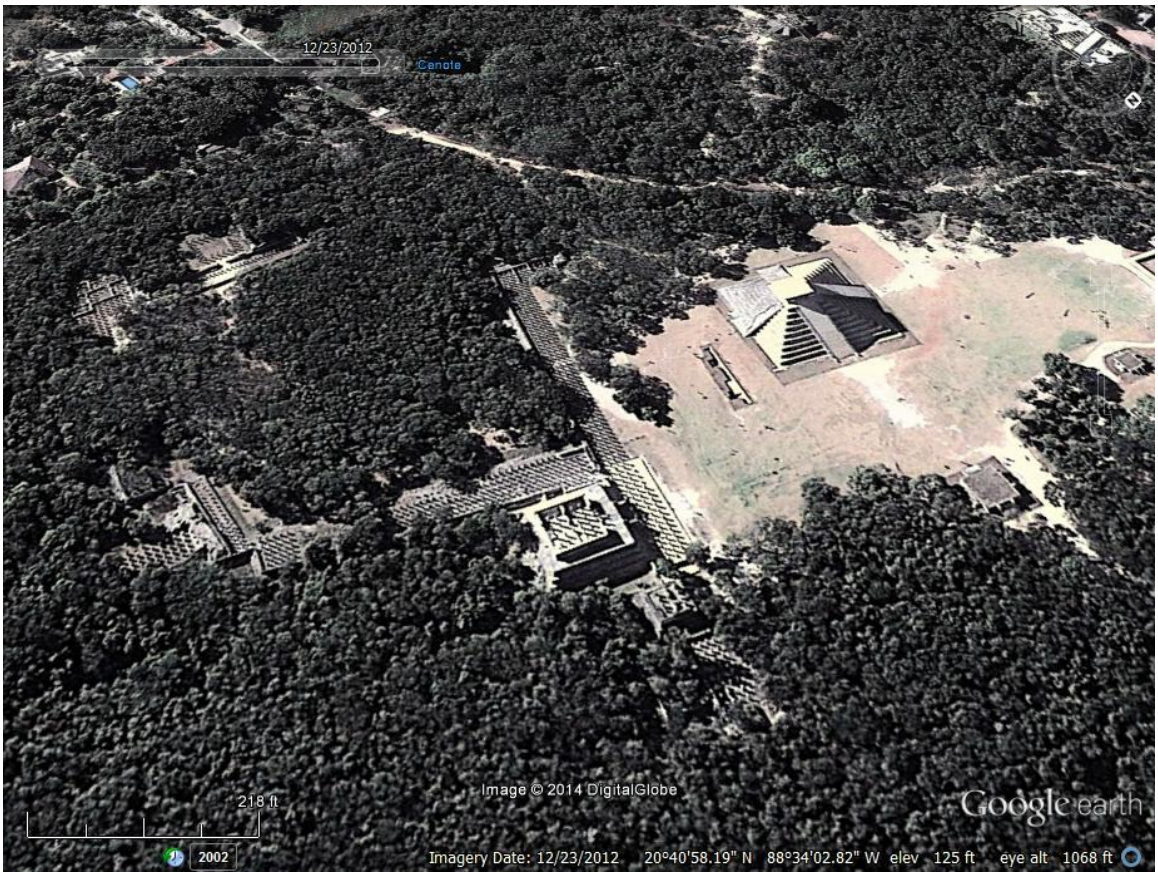


Figure 49 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 45.

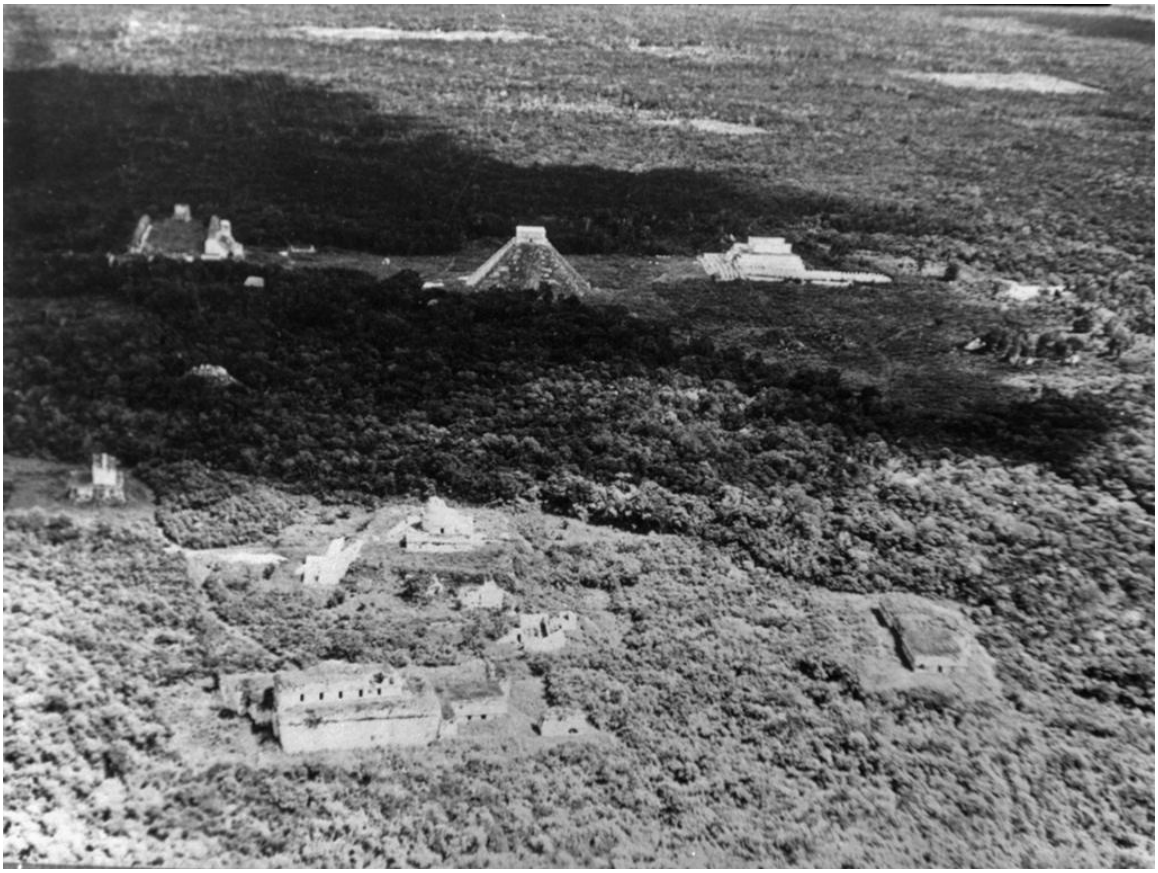


Figure 50 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310435103.

Figure 51 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 47.

Figure 52 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310435128.

Figure 53 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 49.

Figure 54 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10310435129.

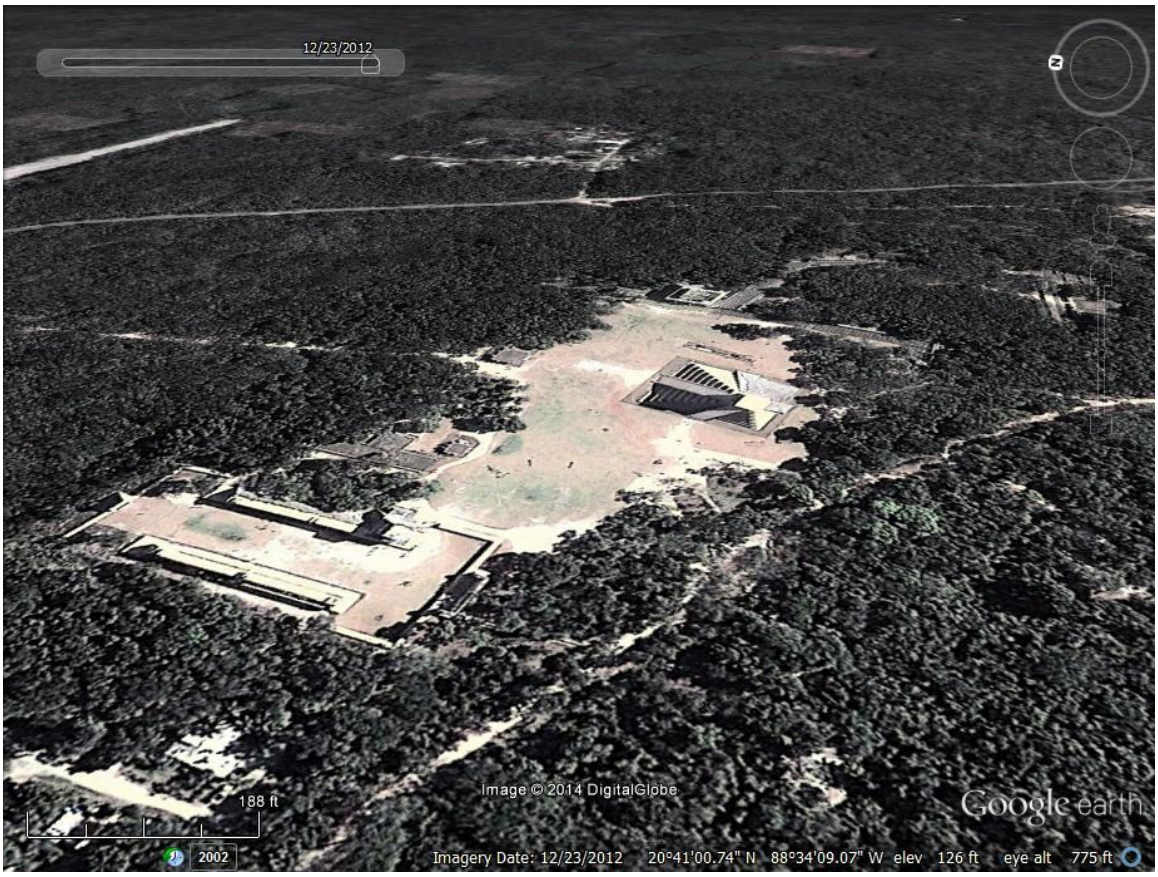


Figure 55 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 51.

Figure 56 Aerial photograph of Chichen Itza. Artstor library catalog # AHARVARD_10311717636.

Figure 57 Google Earth orientation of the Chichen Itza aerial photograph pictured in Figure 53.

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BIOGRAPHY

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