THE APPLICATION OF CLOSE-RANGE PHOTOGRAMMETRY TO ARCHAEOLOGY: CHICHEN ITZA AND UXMAL, YUCATAN, MEXICO, 1989

by

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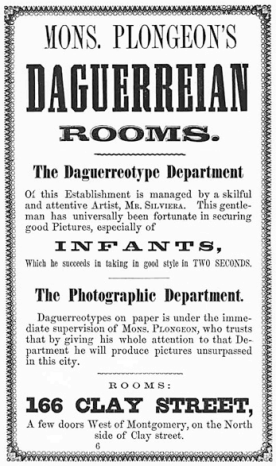
ABSTRACT

This paper will discuss the results of a close-range photogrammetric field study that was carried out in March 1989 at the archaeological sites of Chichen Itza and Uxmal in Yucatan, Mexico. The study was initiated to test the ability of archaeologists, only minimally trained in close-range photogrammetry, to successfully document La Iglesia at Chichen Itza and the Adivino Pyramid at Uxmal. Our results indicate accurate documentation of those buildings, and we encourage archaeologists to apply it to projects where precise measurements and drawings are required in order to increase the accuracy and speed of recording.

HISTORICAL BACKGROUND

Documentation of the Maya archaeological sites of Uxmal and Chichen Itza had its beginnings in the seventeenth-century with descriptions by the historian Diego Lopez de Cogolludo, and then early in the nineteenth-century with the drawings of the artist-adventurer Count Frederic Waldeck in the 1830s, and illustrations by Frederick Catherwood for travel books by John Lloyd Stephens in the 1840s. In the 1860s the French explorer Desire Charnay successfully made a number of photographic views at both Uxmal and Chichen Itza. But it was not until 1875 that detailed and systematic photographic recording was accomplished at Uxmal and Chichen Itza by Augustus and Alice Le Plongeon. Their documentation included several hundred photos of each site in both stereo 3-D and flat images. (Desmond and Messenger 1988)


MONS. PLONGEON'S

DAGUERREIAN

ROOMS.

The Daguerreotype Department

Of this Establishment is managed by a skilful and attentive Artist, Mr. Silviera. This gentleman has universally been fortunate in securing good Pictures, especially of

INFANTS,

Which he succeeds in taking in good style in TWO SECONDS.

The Photographic Department.

Daguerreotypes on paper is under the immediate supervision of Mons. Plongeon, who trusts that by giving his whole attention to that Department he will produce pictures unsurpassed in this city.

ROOMS:

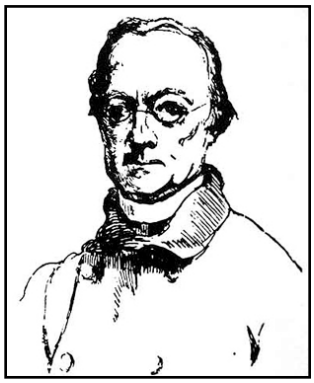
166 CLAY STREET,

A few doors West of Montgomery, on the North side of Clay street.

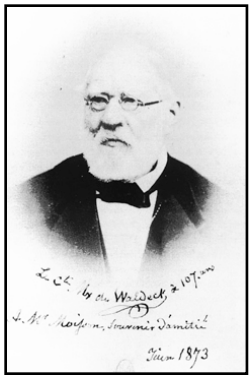
6

Augustus' photographic expertise extended back to the 1850s in San Francisco when he rented space on Clay Street for a studio. He was noted for his successful Daguerreotypes of squirming children taken "in good style in 2 seconds." Seeing new opportunities for a photographer in Peru, he opened a studio in Lima in 1862, and traveled widely in the Andean area photographing archaeological sites.

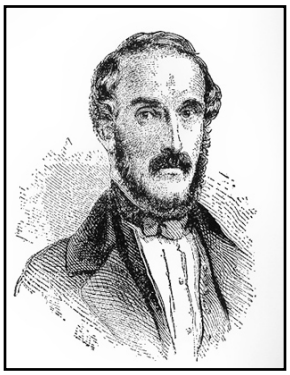
While in Peru he read the works of Brasseur de Bourbourg, Waldeck, and Stephens and Catherwood about the Maya, and decided on an expedition to Yucatan. To prepare himself for his work he traveled to London in 1870 where he met Alice Dixon who was working as a photographer at the British Museum. Alice had learned photography from her father Henry Dixon who was a well known photographer of London architecture and one of the inventors of panchromatic emulsion for negatives. The new emulsion allowed for a much broader range of grey tones by representing all colors in black-and-white photographs.



Brasseur

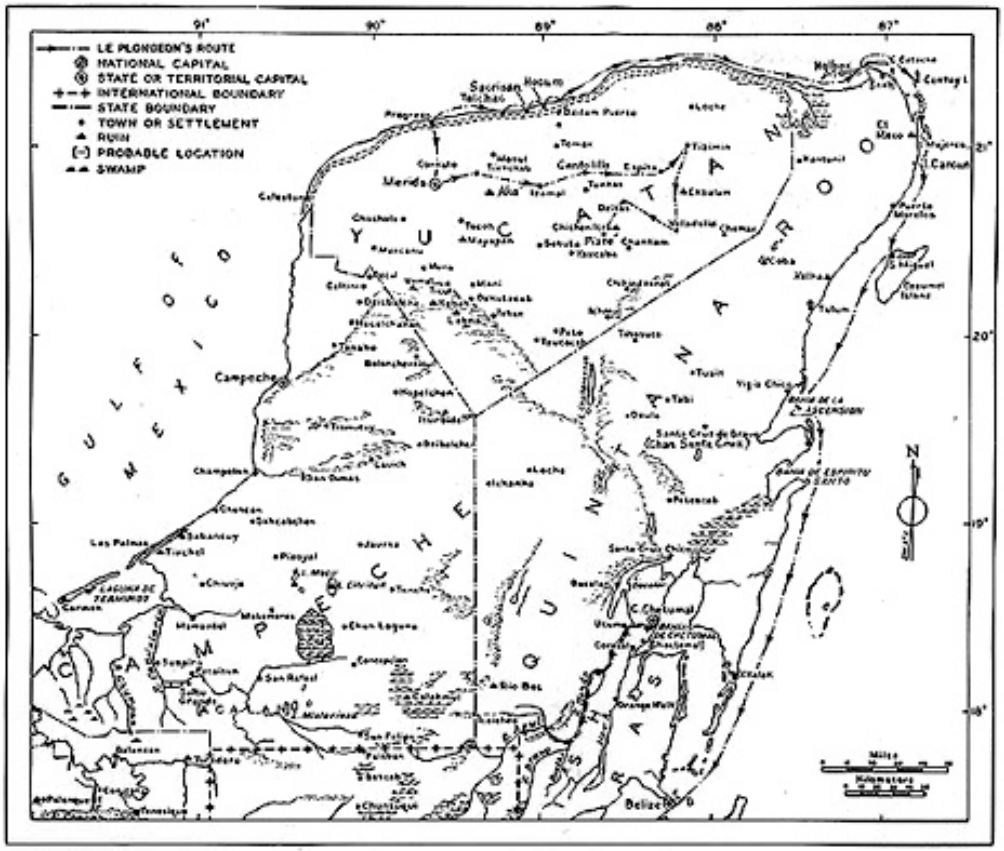


Waldeck



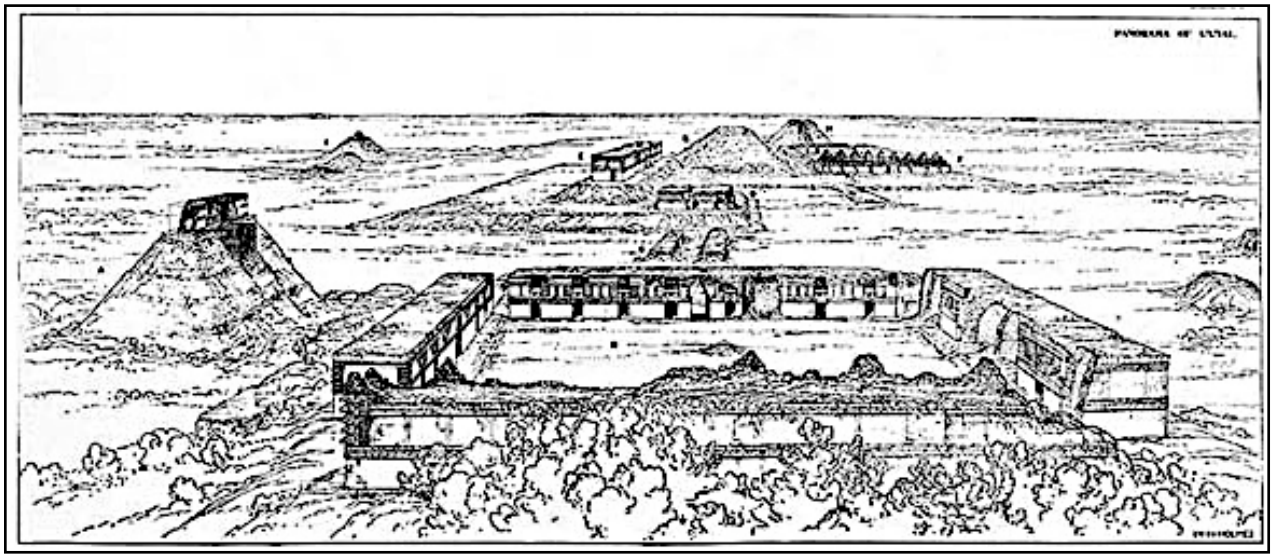
Stephens

Catherwood

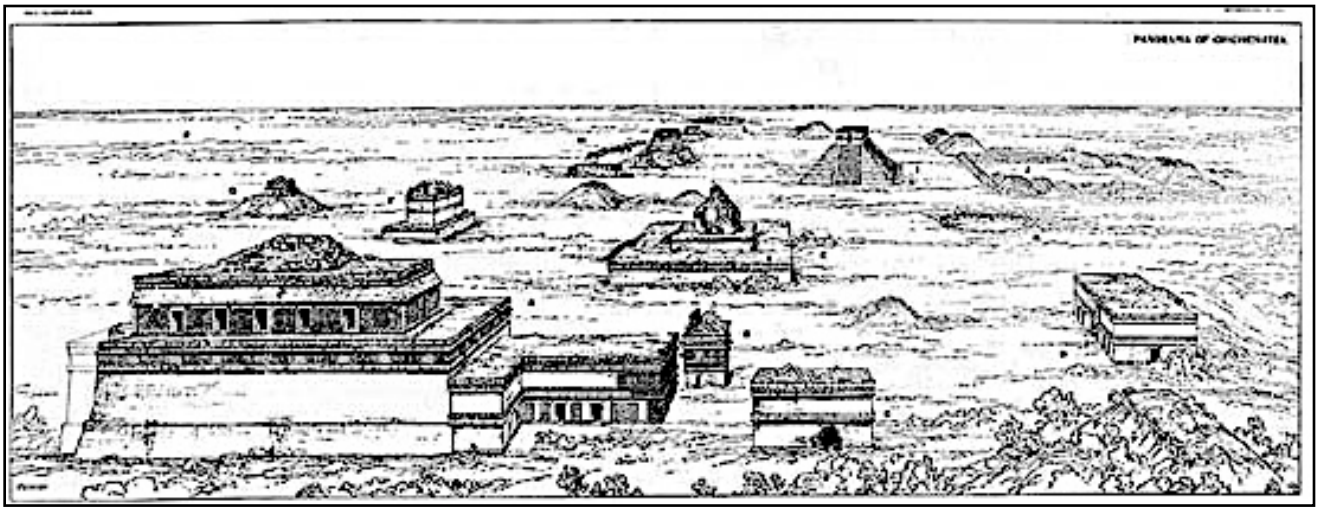


The Map of the states of Yucatan, Campeche, and Quintana Roo, Mexico with archaeological sites.

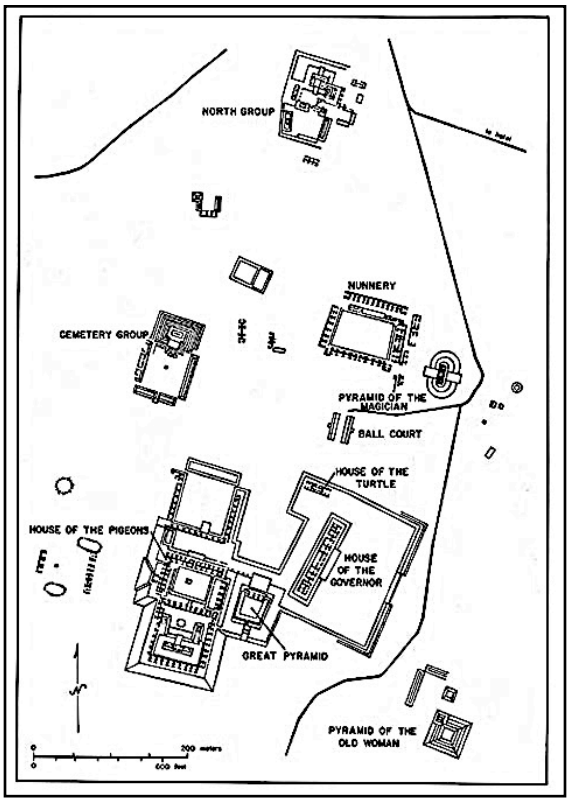
Le Plongeons spent from 1873 to 1884 in Yucatan and Belize, worked at Uxmal for five months, and at Chichen Itza for eight months, and approximately five hundred of their photographs of those sites survive (Maps1 and 2). They broke with 19th century photographic tradition where large format photographic glass negatives (some up to 16x20 inches!) were the rule of the day. Since they knew their work would require hundreds of glass-plate negatives to record an archaeological site they decided to use a smaller and more convenient format negative (4x8 inches), and make their photos in 3-D stereo where each image of the stereo pair would be 4x4 inches.



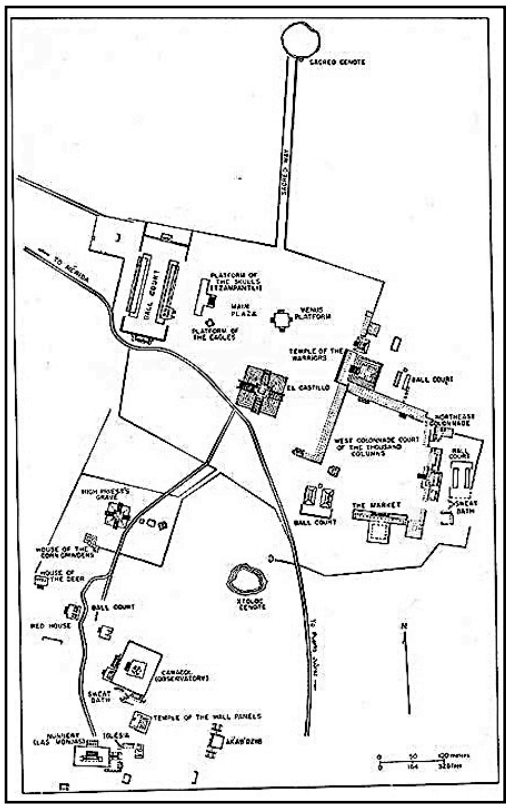
Aerial perspective drawing of Uxmal by William Holmes, 1895. Adivino Pyramid is on the left, Nunnery Quadrangle is in foreground, and Governors Palace is center rear "E"



Aerial perspective drawing of Chichen Itza by William Holmes, 1895. The Monjas on the left foreground, Monjas Annex extends to the right, and the next building is La Iglesia with the Observatory to the north in the direction of the Castillo Pyramid.



Map 1. Uxmal site plan.



Map 2. Chichen Itza site plan.

Stereo photography was not new in the 1870s when it was first used for archaeological documentation in Yucatan by the Le Plongeons. As early as 1856 the English scientist Sir David Brewster noted in his book, *The stereoscope: its history, theory and construction*, how the stereo effect is enhanced or reduced by changes in the distance between the lenses in a two lens stereo camera. The stereo technique was seen by the Le Plongeon to improve the quality of the photographic image used by archaeologists for documentation and analysis, but it took until the 20th century before

photogrammetrists were able to quantify the additional data contained in the stereo image and confirm Le Plongeon's intuitive conclusion. In a letter to Charles Bowditch of the Peabody Museum at Harvard University in 1902, Augustus Le Plongeon explained why he chose to use stereo over single negative flat photography for archaeological documentation:

> I took stereopticon pictures of Yucatan in preference to single ones because they are more realistic when looked at with the proper instrument and they enable me to study the monuments as well, and sometimes better, than if I stood before them [Augustus Le Plongeon 1902].

CLOSE-RANGE PHOTOGRAMMETRY AND ARCHAEOLOGY

Background

Photogrammetric instrumentation provides precise three dimensional measurements from photographs, and drawings can be made from those measurements. In Europe, close-range photogrammetry is often part of the process of historic preservation where monuments in need of consolidation or structural repair are recorded and working drawings are made for archaeologists, architects and civil engineers from 3-D stereo photographs and survey control data. In some cases damaged structures are regularly monitored using very precise close-range photogrammetric techniques to detect and track changes to the integrity of the building. In nationwide programs close-range photogrammetry has been used to make drawings of important monuments in England by English Heritage, in France by the National Center for the General Inventory of Monuments, and in most other European countries on a case-by-case basis. In third world countries such as Turkey, India, and Cambodia there have been quite a number of site specific programs. Organizations such as the International Committee for Architectural Photogrammetry (CIPA), which is part of the International Council on Monuments and Sites (ICOMOS) and funded by UNESCO, have encouraged and sponsored a number of international projects where monuments are in need of precision recording. Where funding is short, the stereo photographs and survey control data are archived until funding becomes available to make drawings.

Transit accurate to 30 sec. of arc was used to determine 3-D coordinates of targets on La Iglesia, and the Adivino Pyramid for the 1989 photogrammetry project. Pic: Lawrence G. Desmond, 1989.

The process of close-range photogrammetric recording is quite straight forward. First, survey targets or selected locations on the facade of a building are measured using a surveying instrument called a transit, and then it is photographed so that each photograph overlaps the other creating a three dimensional image. Documentation work can cease at this stage with the photographs and survey information stored to form a permanent archival record. Or, the photographs and survey data can be used to make accurate and detailed line drawings of the facade.

Photogrammetrist John Garcia with American Measuring Instruments 35/70 Stereoplotter at AMI offices in San Antonio, Texas. Pic Lawrence G. Desmond,1990.

To make a drawing of a facade, an optical-mechanical instrument called a stereoplotter is used. The operator places photographs of the facade in the instrument and views them as a three dimensional image. Then an elevation drawing is made of the facade by carefully tracing the detail of the stonework, cracks, doors, arches, architecture, etc. The stereoplotter is linked to a personal computer running a computer assisted drafting software program which captures the digitized data on a computer file. From the computer file the drawing can then be printed on paper or the file can be modified with the addition of layers of field information from architects, engineers and archaeologists and then printed at some future time to include their additional specifications.

Fieldwork at Uxmal and Chichen Itza

In order to test the application of close-range photogrammetry for use by archaeologists we documented one structure at the archaeological site of Chichen Itza and one at Uxmal with a metric (calibrated for photogrammetric photography) Bronica 70MM camera lent to us by American Measuring Instruments of San Antonio, Texas. Control point measurements on the buildings were made with a transit accurate to 30 seconds of arc.

Bronica 70mm camera remanufactured as a calibrated photogrammetric camera by American Measuring Instruments of San Antonio, Texas. Pic: Lawrence G. Desmond, 1989.

Adivino Pyramid from the northwest. Note vertical cracks in west facade filled with concrete.
Pic: Lawrence G. Desmond, 1990.

We had been offered the use of AMI's Twin Bar camera system which eliminates the need for target surveying in some situations or could have rented a total station theodolite, but we felt we would learn more by using a single camera and less technologically sophisticated equipment which is usually available to most archaeologists.

American Measuring Instruments twin bar photogrammetric units for photographing architecture without the use of survey targets. Pic: Lawrence G. Desmond, 1989.

Dell Foster, president of AMI, had seen a few of the Le Plongeon stereo photos of buildings at Chichen Itza and suggested that we photograph and survey La Iglesia when I told him that part of the roof comb, shown complete in a Le Plongeon photo, had AMI Twin Bar collapsed. He offered to calibrate the non-photogrammetric Le Plongeon stereo photo and draw to scale the complete roof comb as it looked in the 1875 photo. Recent advances in photogrammetric computer software made such a procedure possible and have made old stereo photos in archival collections potentially more useful for research and historic preservation.

At Uxmal we decided to record the west facade of the Adivino Pyramid because, as a very large structure, it presents a number of technical problems for photogrammetric documentation. And in terms of field work we wanted to test the ability of the 70mm Bronica camera with a 40mm wide angle lens to record the building so that drawings with a scale of 1:50 could be made.

The first step in recording La Iglesia was to stick survey targets on the west facade with masking tape, and then place the transit over a location called Station "A" about eight meters in front of the building. Then the angles and elevations of the targets were measured from that station. Once measurement was complete the transit was then used to measure from "A" the location of a second station called "B" which was a few meters south and about the same distance from the facade as Station "A." A tape was used to measure the distance between the two transit stations. The transit was then moved to Station "B" and the elevations and angles of the targets again measured from that station. This completed the survey portion of the project.

Photographing La Iglesia in stereo with the 70mm metric Bronica camera was a simple procedure and took ten minutes. The modified Bronica single lens reflex used a fixed focus Zenzanon 40mm wide angle F4 lens, automatic aperture control, and motorized film advance. The camera with batteries weighed about five and a half pounds. Since we planned architectural photography the focus was preset at five meters to infinity, but other lenses are available for close-up photography. Our procedure was to center the focusing circle on the door of the building for each exposure, and with the camera, hand-held, take photographs eight meters from the west facade with about two meters between them. Eight photographs were taken using Kodak Ektachrome 64, 220 roll film. While a tripod is advisable it was not used. Oblique photographic angles or perspective correction were of no concern since the stereoplotter computer program would make the required corrections. Later we were told that in standard close-range photogrammetric practice the whole building does not have to be included in each photo and the photos are taken parallel to each other with about a 75% overlap rather than pointing the camera at one central location. Even though only part of a building is in each photo this presents no problem since the drawing of the building is made section-by-section from stereo photos, and sections are then linked together by the software to produce a complete drawing.

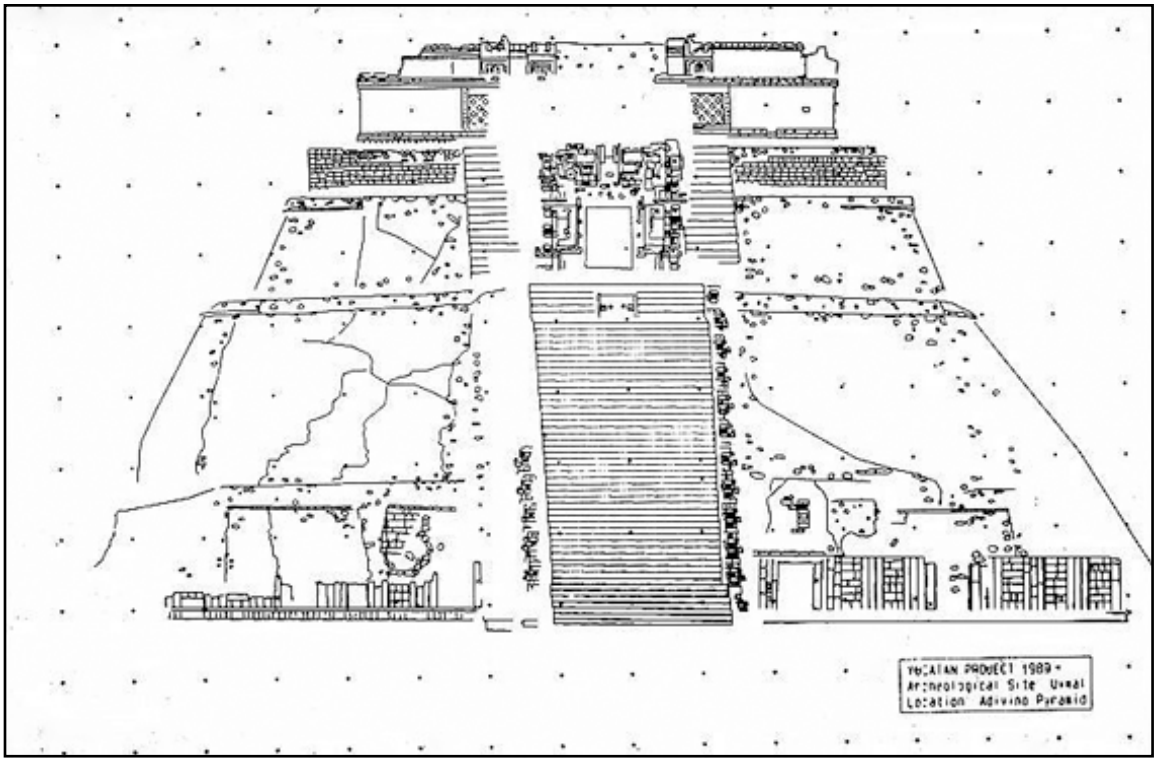
The day following our documentation of La Iglesia we traveled to Uxmal to record the west facade of the Adivino Pyramid. We placed twelve targets on the facade, and began transit work with stations "A" and "B" located on the mound to the northwest of the west facade, and with darkness overtaking us, finished after about three hours of surveying. Since all the targets were not in a line of sight from stations "A" and "B," the following day we set-up another pair of stations in the plaza area fifteen meters west of

the pyramid, and from those stations we were able to complete the work of surveying.

About one hour was required to take seventy-two Ektachrome 64 photographs of the west facade with the 70mm metric Bronica camera. Our procedures were essentially the same as used on La Iglesia with the whole pyramid included in each photo. Two sets of photos were taken by Desmond, one at about twenty meters and the other fifteen meters from the pyramid. This completed the field work.

Desmond photographing the west facade of the Adivino Pyramid at Uxmal with the Bronica 70mm camera.

West facade of the Adivino Pyramid at Uxmal. Photo taken with AMI Bronica photogrammetric camera.
Pic: Lawrence G. Desmond. 1989.



Measured drawing of the west facade of the Adivino Pyramid made by John Garcia with an AMI 35/70 Stereoplotter from photographs and project survey data. Cracks in west facade are drawn to the left and right of the main stairway. 1989.

Post fieldwork and analysis

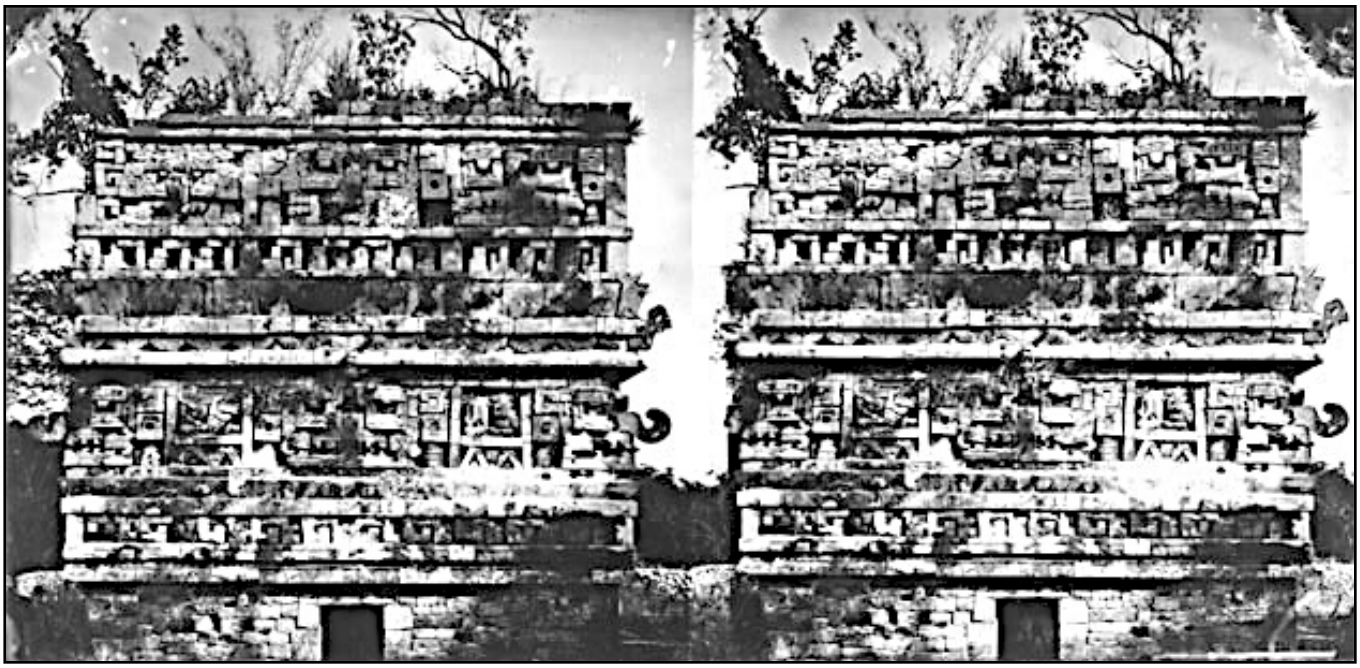
On return to San Francisco the Kodak 220 Ektachrome 64 film was professionally processed. The color stereo transparencies of the Adivino Pyramid and La Iglesia, along with the survey control data, were then sent to Dell Foster at AMI in San Antonio where they were used to make drawings using an AMI 35/70 analytical stereoplotter.

Once the color transparencies were placed in the stereoplotter and the control data entered into the software program, John Garcia, a stereoplotter operator with AMI, drew the west facade of the Adivino Pyramid in about fifteen hours. It is interesting that Garcia was able to see and draw the narrow fissures in the facade that were produced by hurricane Gilbert in 1988 and later repaired by archaeologists.

Using a stereoplotter, color transparencies and the same setup procedures, La Iglesia was drawn by Garcia in about ten hours.

Next, the roof comb of La Iglesia was drawn using the Le Plongeon stereo photo made in 1875, but it was first calibrated using our current stereo photos and survey control data. The two Le Plongeon black-and-white glass negatives of La Iglesia (together they make one stereo image of the building) were copied and sent to scientific photographer Larry Harwood of the University of Colorado's Biovisuals photographic laboratory. He processed each negative into a positive black-and-white transparency and reduced the original 4x4 inch format of each negative to 70x70mm so that they could be used in the AMI 35/70 stereoplotter.

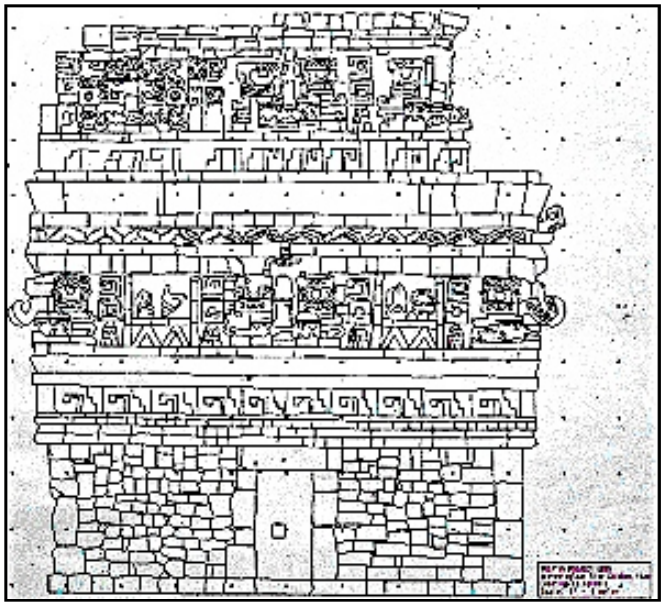
Curtis Yarbrough, a photogrammetrist with AMI, worked out the mathematics for the



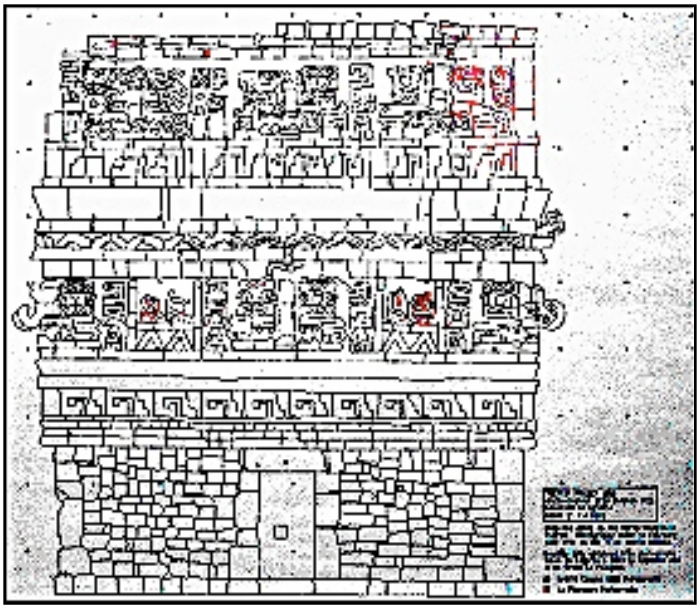
Stereopticon 3-D photograph of La Iglesia made by Augustus and Alice Le Plongeon in 1875. Note the upper right corner of the roof comb is complete. Courtesy of the Peabody Museum at Harvard University.

control parameters based on our photographs and field measurements, and calibrated the 100 year old Le Plongeon stereo image for use in the stereoplotter. Garcia then drew the missing portion of the roof comb to correct scale using the newly calibrated Le Plongeon stereo photo. The whole building could have been drawn from the 1875 photo, but rather than take additional time from pressing AMI commercial projects to make two whole drawings, he chose to draw the building as it is today from our photos and survey data, and then add on the missing part of the roof comb by merging the two computer plotted drawing files and them as one (closeup of roof drawing).

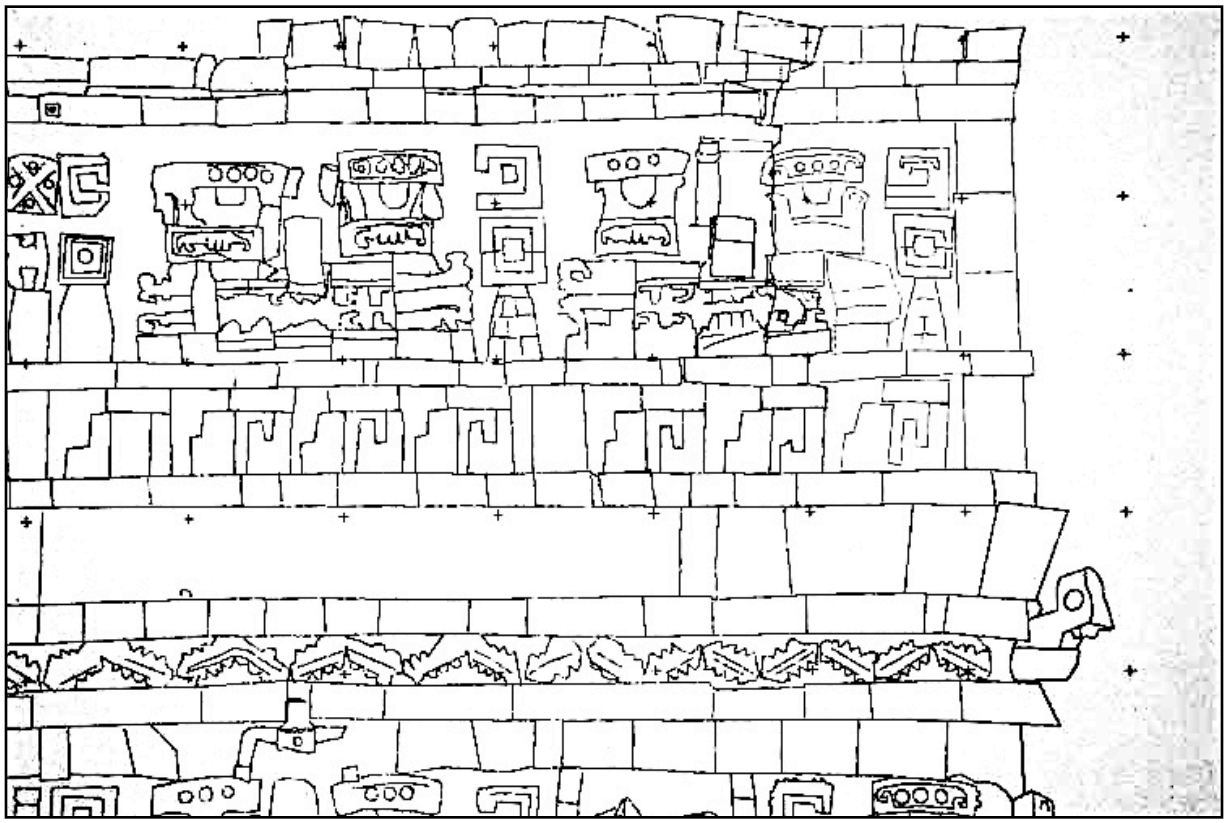
La Iglesia, Chichen Itza. Photogrammetric photo.
Pic: Lawrence G. Desmond. 1989.



Measured drawing of La Iglesia at Chichen Itza by John Garcia made using an AMI 35/70 Stereoplotter from photographs and survey data by Lawrence G. Desmond. This is a drawing of the structure as it stood in 1989. Note the upper right corner of the roof comb is missing. 1989.



Measured drawing of La Iglesia by John Garcia using an AMI 35/70 Stereoplotter based on 1875 & 1989 3D photographs and survey control data. Note Garcia has drawn the missing part of the roof comb (red- upper right) based on calibration of Le Plongeon photographs from 1875. 1989.

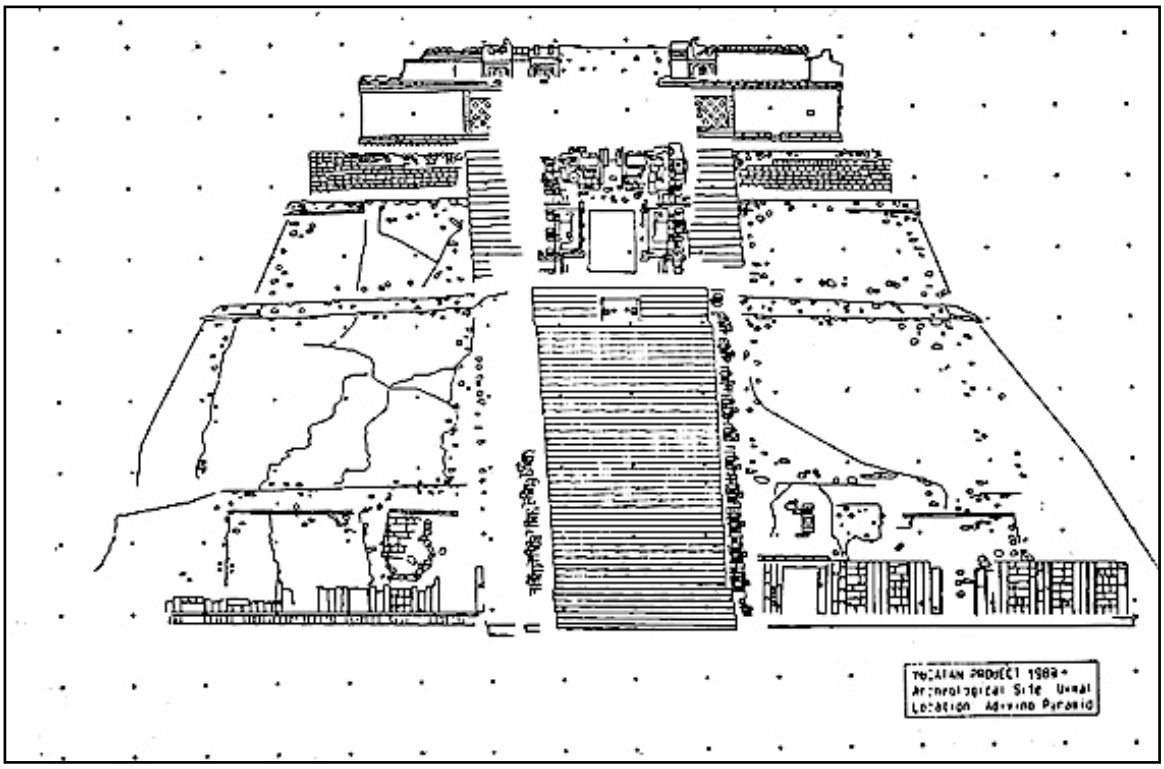


Detail of upper right corner of La Iglesia roof comb made from the 1875 Le Plongeon 3D stereo photo, and calibrated using the 3D stereo photos and data made in 1989 by this project. Drawing by John Garcia of

CONCLUSIONS

The use of the single 70mm metric camera for documentation of La Iglesia resulted in accurate and measurable photographs for our pilot study, and therefore we would recommend a medium format camera (70mm) for use in recording buildings with roughly the same dimensions as La Iglesia or smaller. The camera was quick and simple to use, and the quality of image was excellent in resolution. An inexperienced operator should be able to learn how to use the camera in a day.

The Adivino Pyramid is a very large structure, and when the building as a whole is photographed on one 70mm transparency, details beyond 15 meters from the camera begin to be lost in the grain of the film. Bas-reliefs in the upper temples were especially difficult to draw even when the very fine grain Ektachrome 64 film was magnified with the fine lenses of the stereoplotter. And the center portion of the upper temple could not be drawn where it was blocked from view by the lower temple. Also, the small size of the subject matter on the film prevented us from making a drawing larger than 1:125, and while the drawing made by Garcia is excellent for illustration, a scale of 1:50 or larger is necessary as a historic preservation working drawing. Drawings, including all necessary architectural details, and with a scale of 1:50 or larger can be drawn in future projects by using a larger format camera such as the Wild P-31 4x5 inch and 100mm lens, taking the photos about eight meters from the subject, and lifting the camera to a position level with and nearer to the upper temple facades.



Measured drawing of the west facade of the Adivino Pyramid made by John Garcia with an AMI 35/70 Stereoplotter from photographs and survey data by Lawrence G. Desmond. Cracks in west facade are drawn to the left and right of the main stairway. 1989.

A total station theodolite with an accuracy of five seconds of arc or better, and a computerized data recorder is recommended when a project such as the Adivino Pyramid is undertaken. Standard practice in close-range photogrammetry is to use a minimum of three survey control targets in each photo so surveying can become time consuming with larger structures and field time can thus be reduced with an automated theodolite system.

This project clearly demonstrates that with some training archaeologists can apply close-range photogrammetry to their work. While the technique has been used primarily in connection with historic preservation projects, with some development it can be adapted to documentation of excavations. Ideally, a calibrated camera should be used, but a high quality non-calibrated camera can be used in some cases if additional targets are surveyed. If a calibrated camera and surveying instrument is not available, and the project is important, systematic stereo photos should be taken with any camera in the hope that they can be calibrated at a later date.

As was mentioned previously, close-range photogrammetry is used internationally, and is currently the most accurate technique used to document cultural heritage monuments. Recent development of high speed personal computers, new photogrammetric software programs and computer assisted drafting programs have simplified the technique and increased both the accuracy and sophistication of the final drawings. Most archaeologists, architects and other historic preservationists would agree that a good portion of the world's cultural resources are at risk from human and natural causes. Therefore it is imperative that we train persons concerned with archaeology and historic preservation in the use of close-range photogrammetry and organize a long term program using this technology to create a permanent, and scientific record for use by conservation architects and archaeologists to monitor the condition of the buildings and take corrective action when needed.

ACKNOWLEDGEMENTS

Fieldwork for this project was greatly facilitated by Director Ruben Maldonado of INAH-Centro Regional Yucatan, who, early on, saw the value of close-range photogrammetry to archaeology. At Chichen Itza Administrator Feliciano Salazar L., and at Uxmal Administrator Pedro Casanova welcomed us and expedited our fieldwork. Dell Foster, president of American Measuring Instruments in San Antonio, Texas deserves an enormous amount of credit for lending the project the AMI 70mm metric camera and for supporting the application of close-range photogrammetry in archaeology. And, credit is also due to Curtis Yarbrough of AMI for his elegant mathematical solution which was used to compile the stereo models of La Iglesia and the Adivino Pyramid, and to John Garcia of AMI for spending many hours making drawings on AMI's analytical stereoplotter. Our thanks go out to Professor Edward Kurjack of Western Illinois University for his counsel in the field and assistance with transportation, and to Charles and Elena Lincoln, and Patricia Anderson for use of the surveying instrument. To Larry Harwood, scientific photographer at the University of Colorado and to his photographic assistant Andrea Olsheskie-Gray, our great appreciation for exceptional images and all the long hours in the darkroom. Finally, to

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REFERENCES

Brewster, David Sir
1856 *The stereoscope: its history, theory and construction*. New York: Hastings on Hudson.

Desmond, Lawrence G. and Phyllis M. Messenger
1988 *A Dream of Maya: Augustus and Alice Le Plongeon in 19th Century Yucatan*. Albuquerque: University of New Mexico Press.

Le Plongeon, Augustus
1902 Letter to Charles Bowditch of the Peabody Museum at Harvard University, December 13. Letter in the archives of the museum.