

Photogrammetric Survey of the Adivino Pyramid at the Maya Archaeological Site of Uxmal, Yucatán, Mexico

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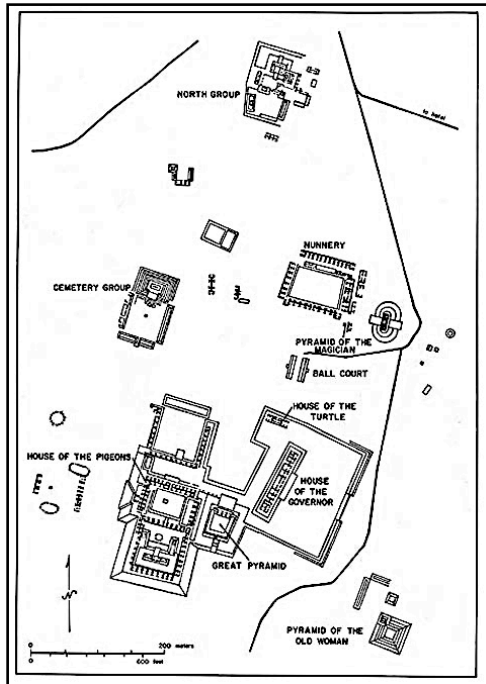
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Abstract

In 1999, the Adivino Pyramid, located at the Maya archaeological site of Uxmal in the state of Yucatan, Mexico was documented using close-range stereo photogrammetry. This paper summarizes the process of photogrammetric survey, the historical context that led to the use of close-range photogrammetry, and highlights the adoption of this technology by the Autonomous University of Yucatan (UADY) in Merida, Yucatan to support heritage preservation in Mexico and other Latin American countries.

Introduction

The Adivino Pyramid is located at the Maya archaeological site of Uxmal in the state of Yucatan, Mexico. Uxmal is registered as a UNESCO World Heritage Site, and the pyramid is considered by historians of architecture and archaeologists as one of the finest examples of Maya architecture. It is roughly 60 meters at base and 30 meters high, and was rebuilt a number of times until completed about 1000 years ago. It has grand stairways on the west and east sides leading to two temples.



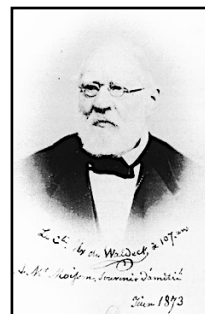
Uxmal, Yucatan. Site plan.



The Adivino Pyramid at Uxmal from the northwest. Note filled vertical cracks in the facade. Pic: L. G. Desmond. 1999.

In 1988, hurricane rains destabilized the west façade. Immediate measures were taken to stabilize the pyramid and succeeded in preventing a catastrophic collapse, but in 1997 archaeologists noted small new cracks had developed in the facade. The Adivino Pyramid Conservation Project was then initiated by the National Institute of Anthropology and History (INAH) and the University of Yucatan (UADY), and the entire pyramid was photogrammetrically surveyed to provide measurable 3-D visualization for engineering and archaeological analysis.

Documentation of Maya archaeological sites in Yucatan began in the 17th century with descriptions of Uxmal and Chichen Itza by the historian Diego Lopez de Cogolludo, and then early in the 19th century with the drawings by the artist-adventurer Count Frederic Waldeck in the 1830s, and the magnificent detailed illustrations of Frederick Catherwood in the 1840s.



Waldeck

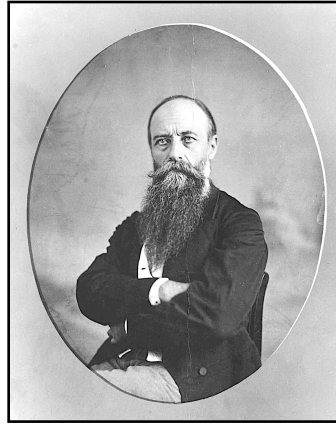


Catherwood

In the 1860s, the French explorer Désiré Charnay successfully made a number of photographic views of Uxmal, but it was not until 1875 that the first thorough and systematic photographic record, including stereo-photography, was accomplished at Uxmal by Augustus and Alice Dixon Le Plongeon [1].



Désiré Charnay, explorer and photographer. 1860.



Augustus Le Plongeon, and Alice Dixon Le Plongeon. Early Maya archaeologists, writers, and photographers. Courtesy of the Getty Open Content Program. 1870s.

Through the 1960s the pyramid was regularly repaired and maintained, and in the early 1970's a major conservation project was undertaken by INAH archaeologists to consolidate the sides and flat terraces, and to improve the structural integrity of the temples.

Periodic inspections of the pyramid after consolidation noted no structural problems, but late in 1988 Hurricane Gilbert swept across the Yucatan Peninsula with very high winds and great rain fall that caused extensive damage to crops and forests, and to both modern and ancient architecture.

A short time after the hurricane, archaeologists noted that cracks had developed in the walls of the south side, on both sides of the west stairway, and the stairway itself showed signs of instability. The vertical walls at the base of the pyramid on the west side were noted to be out of plumb--leaning in the direction of the plaza. Downward movement of the pyramid interior and facing stones caused the stone lintel of a doorway on the south side of the stairway to shear-off the top of the stone door jamb.



Inspecting cracks in the west stairway of the Adivino Pyramid, Uxmal. 1999



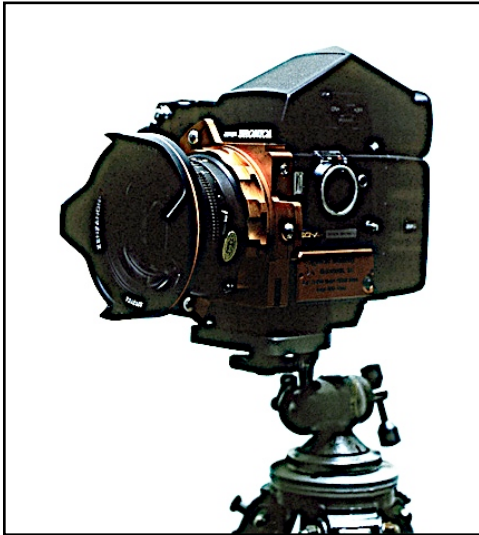
Shearing of stone due to downward thrust of pyramid onto wood lintel.
Pic: L. G. Desmond. 1989.

Archaeologists and conservators with INAH immediately began the process of developing a strategy for conservation and stabilization. The first step was to strengthen the west façade, monitor any structural changes, and institute emergency measures where needed. Plaster monitors then were placed at critical locations to detect any further movement. An open space under the west stairway dug by 19th century explorers and enlarged by looters was immediately shored-up with railroad ties, and then filled with stonework mortared with concrete.



Shoring under west stairway to prevent collapse. Note plaster patch upper right corner used to detect separation of stone.
Pic: L. G. Desmond. 1989.

Early in 1989, the director of INAH Centro Yucatan, archaeologist Ruben Maldonado requested that archaeologist Lawrence Desmond make a stereo close-range photogrammetric record of the west façade of the pyramid. The façade was documented at ground level using a calibrated photogrammetric camera, and surveyed with a transit theodolite [2][3].



Bronica camera remanufactured by American Measuring Instruments for close-range photogrammetric use.
Pic: L. G. Desmond. 1989.

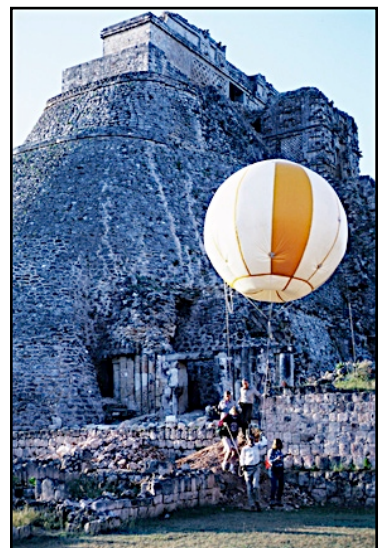


Survey transit accurate to 30 sec. of arc was used to determine 3-D coordinates of targets on La Iglesia and the Adivino Pyramid for the 1989 photogrammetry project.
Pic: L. G. Desmond. 1989.

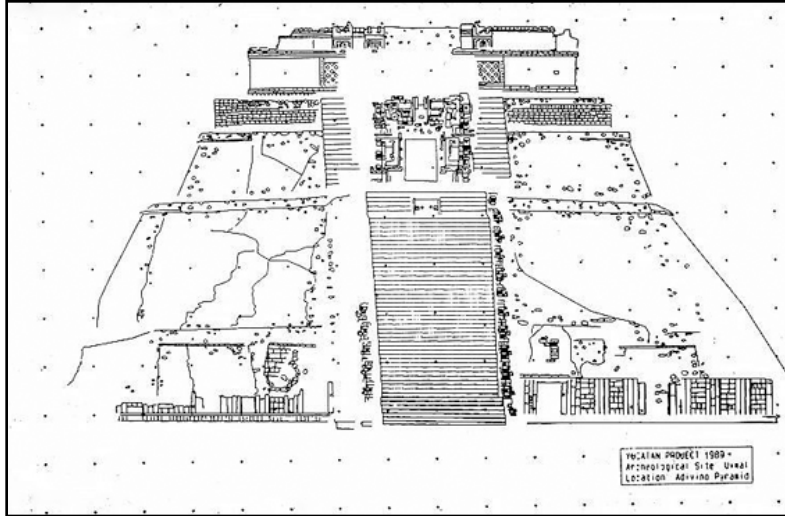
A second photogrammetric survey of the west façade was organized by Desmond in 1990. A total station was used to survey control targets, the entire west façade was photographed again from ground level, and a hydrogen balloon was used to lift a camera high enough to photograph the temples on the upper part of the pyramid [2][3].

The record of the pyramid generated by these two photogrammetric projects would have provided useful scaled drawings and measurable photographs for rebuilding should the west façade have collapsed. However the scale of drawings that can be produced from these data is insufficient for analytical purposes. (West façade drawing from 1989 photogrammetric survey)

The immediate measures taken to stabilize the pyramid had prevented a catastrophic collapse. But late in 1997 archaeologists noted additional small cracks had developed in the walls of the pyramid, and so further conservation action became necessary.



Hydrogen balloon used to photograph upper temples of the west facade of the pyramid.
Pic: L. G. Desmond. 1990.



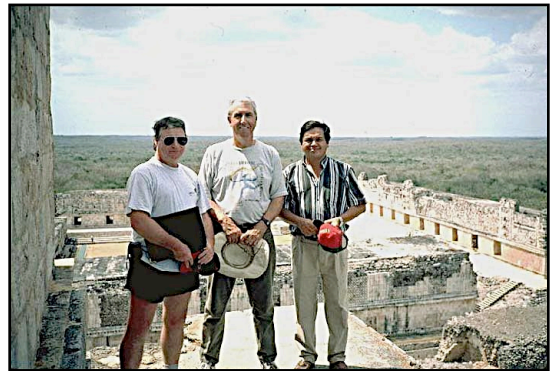
Scaled drawing of the west facade of the Adivino Pyramid from photogrammetric survey and photographic data. By John Garcia of AMI, 1989.

Therefore early in 1998, the UADY Adivino Pyramid Conservation Project was initiated and placed under the direction of UADY professor of engineering Roberto Centeno Lara in collaboration with archaeologist Alfredo Barrera Rubio, director of INAH Centro Yucatan, archaeologist José Huchím Herrera, director of the INAH Uxmal Archaeological Project, and UADY's University Center for the Preservation of the Cultural

Heritage of Yucatan (CUPPCY), directed by archaeologist James M. Callaghan.

Archaeologists and engineers concluded that the first step in analysis of the pyramid was to record the entire structure using stereo-photogrammetry. Desmond was asked to organize the photogrammetric documentation of the pyramid.

Because of the importance of the pyramid as a world heritage monument, the project director requested that personnel professionally trained in photogrammetric documentation carry-out the project. While there are highly trained photogrammetrists in Mexico who work on cartographic projects, there were none who were trained in the very specialized technique of close-range architectural photogrammetry, so assistance was sought outside of Mexico.



Michael Clowes, Lawrence Desmond, and Roberto Centeno Lara. Pic: Paul Bryan, 1999.

The director also requested that the photogrammetrists collaborate with INAH and UADY to organize a seminar on the use of photogrammetry for heritage preservation. The field project and seminar were scheduled for March 12 to 24, 1999.

Photogrammetric consultants

Photogrammetrists Paul Bryan and Michael Clowes from England were contacted to carry out the photogrammetric survey because of their international reputation as professional photogrammetrists and surveyors, and their dedication to architectural photogrammetry. They agreed to take time out from their work with English Heritage's Survey Team to volunteer during their vacation to carry out the documentation of the



Paul Bryan photographing details on the Chenes Temple of the Adivino Pyramid. (R) Mick Clowes.
Pic: L. G. Desmond. 1999



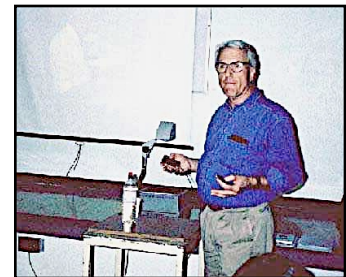
Mick Clowes pointing to a survey point as Paul Bryan takes measurements with the Nikon total station surveying instrument. Pic: L. G. Desmond. 1999.

pyramid, and to teach a portion of the seminar on photogrammetry for heritage preservation.

Seminar on photogrammetry for heritage preservation

The seminar on the use of photogrammetry for heritage preservation was held at the UADY Department of Engineering in Merida prior to the fieldwork. The purpose of the seminar was to provide archaeologists, architects, and architectural conservators with a basic knowledge of the application of close-range photogrammetry for documentation of architecture. While a number of archaeologists and architects in Yucatan knew the advantages of using photogrammetry because of earlier projects carried out by Desmond, this was the first time a seminar on the method was offered in this region of Mexico.

The seminar was led by Bryan and Clowes who made presentations on the use of photogrammetry for heritage conservation, and discussed field and laboratory procedures. An additional presentation was made by Desmond who provided a historical perspective on the use of photogrammetry for heritage preservation, including previous photogrammetric projects in Yucatan [2][3][4], and the important international work of UNESCO's International Committee for Architectural Photogrammetry (CIPA); by Callaghan who reported on the preservation projects of CUPPCY,



Lawrence Desmond



Paul Bryan



Mick Clowes



James Callaghan



Tomas Gallareta

and by archaeologist Tomás Gallareta N. who presented an overview of the archaeology of the Puuc region of Yucatan, and current site conservation projects.

The seminar was continued during the survey fieldwork. where classroom training was integrated with the actual process of photogrammetric recording of the pyramid. In this way participants gained a first hand experience in the taking of 3-D photographs, the placement of control targets on the pyramid, and in survey methods with a total station.

Equipment

A photogrammetric survey consists of two operations; the site based fieldwork, comprising stereo-photography and 3-D survey control, and office based processing using photogrammetric plotters or these days digital workstations. To acquire the necessary imagery, a Rollei 6006 (6x6 cm format) medium format calibrated photogrammetric camera, with a 50 mm, F4 lens was used for all photography. The films used were color Kodak Professional Ektachrome E100SW, ASA 100 – as the main image base for the survey - and black-and-white Kodak Verichome Pan (VP), ASA 125 – to act as the archival record.

The survey control was acquired using a Nikon total station theodolite Model DTM 310 (accurate to 5 seconds of arc in angle and +5mm in distance). This was loaned to the project by engineer Francisco Mendoza d'Argence, a professional land surveyor in Merida. Mendoza worked closely throughout the project with Bryan and Clowes to learn the technique of surveying control targets, placement of secondary survey monuments, and the setting of a primary survey grid around the pyramid – all elements to a successful photogrammetric survey.



Paul Bryan (L) and Michael Clowes with Rollei 6006 metric camera. Pic: L. G. Desmond, 1999.



Engineer Francisco Mendoza d'Argence and the Nikon total station Model DTM 310. Pic: L. G. Desmond. 1999.

Photogrammetry fieldwork

A team led by archaeologist José Huchím Herrera affixed targets on all sides of the pyramid using a removable clear silicon based adhesive. 245 targets were placed in total providing an abundance of control, with at least four targets for each stereo-pair obtained.



Survey target on Chenes Temple of the Adivino Pyramid. Pic: L. G. Desmond. 1999.



Paul Bryan photographing the Chenes Temple with a Rolleiflex 6006 metric camera as Desmond observes. Pic: Michael Clowes. 1999

To enable complete stereo-coverage of the pyramid, a number of levels of photography were required. The lower levels were all tackled from the ground, using imagery with a restricted upwards inclination of 15 degrees. However the upper levels, including the Chenes Temple at the top, required the camera to be raised substantially above the ground.



Adivino Pyramid east facade Hydraulic lift used to photograph the upper east, south and north facades of the pyramid. Bryan and Clowes are making stereo 3D photos from the lift bucket. Pic: L. G. Desmond. 1999.

Some detailed photos of the temple were taken from the platform in front of the temple because the lower part was blocked from view at 14 meter scaffold level. For the north, south and east sides, a rented hydraulic lift mounted on a truck was used to raise the camera and tripod, and a crew into position. As no lift controls were provided in the bucket itself, directions from

the crew members to the equipment operator were made by radio. The camera and crew could then be easily placed exactly where needed for stereo-photography.

However, because a hydraulic lift could not be driven into the plaza that fronts the west façade, and no other satisfactory access equipment could be utilized, a scaffold for



Scaffolding being erected for photographing the west facade of the Adivino Pyramid. Pic: L. G. Desmond. 1999.



Paul Bryan and Michael Clowes photographing the west facade from the 14 meter platform. Pic: L. G. Desmond. 1999.



A view from the top of the pyramid to the west of the scaffolding in the plaza for photographing the west facade of the pyramid. Pic: L. G. Desmond. 1999.

photography, the full length of the pyramid, and 14 meters in height was built in front of the west. The scaffold had two photo platforms from which photography was taken: the first platform was approximately 7 meters above ground, and the second 14 meters. In total 700 3-D stereo-photographs were taken in both black-and-white negative and color transparency film.

The Nikon total station was used to survey the 3-D locations of each target placed. These were tied into a network of permanently marked survey monuments, previously located around the base of the pyramid. This would enable subsequent survey observations to be tied into the same site coordinate system as well as enabling a longer term of comparison of data over time. While on site the survey data was downloaded onto a laptop daily for on-site analysis of accuracy, and blunder detection prior to post processing using the 'Landscape' software package – now part of the Terramodeler package.



Paul Bryan and Francisco Mendoza surveying the west facade of the pyramid. Laptop computer for storage of data from the total station. Pic: L. G. Desmond. 1999.

Current status of the project and future plans

After photographic processing, the color transparencies were scanned onto Kodak's Photo-CD-ROM to enable their potential use by all current digital photogrammetric systems, such as the Leica Helava. Files resulting from a 1200 dpi scan for each image were approximately 50 Mb in size. All of the original black-and-white negatives, prints and color transparencies are now stored at the UADY photographic archive in Merida along with a full listing of 3-D coordinates for survey control targets and permanent ground monuments.

As a first step in analysis, images of the west façade of the Chenes Temple on the pyramid were processed to create a measurable orthophotograph. Engineers and archaeologists with UADY and INAH are currently working with this and other analytical images and drawing.



Michael Clowes working in a 3-D environment to generate an orthophotograph of the Chenes Temple with the Leica Helava all digital photogrammetric work station. English Heritage, York, UK.
Pic: L. G. Desmond. 2000.



Orthophotograph (perspective corrected and scaled) of the west facade of the Chenes Temple by Michael Clowes. 2000.

However, with the complete survey, CAD drawings of any part of the pyramid can now be generated by photogrammetric processing, either digital or by the more traditional stereoplotter, when required to supplement the data already generated on the monument.

As a result of the successful outcome of this project, the engineering department of UADY is currently working to secure funding to purchase their own digital photogrammetric laboratory equipment in order to have a photogrammetric capability for heritage preservation at UADY in Merida. This will be the first close-range photogrammetric laboratory in Mesoamerica to work directly in support of the conservation of historic and pre-Columbian monuments.



Leica SD2000 stereoplotter. English Heritage, York, UK.: L. G. Desmond. 2000.

References

- [1] Desmond, Lawrence G. and Phyllis M. Messenger, *A Dream of Maya*, University of New Mexico Press, 1988.
- [2] Desmond, Lawrence G., "Registro fotogrametrico de la Piramide del Adivino, Uxmal, Yucatan, Mexico: Evaluation de campo, 1990", Consejo de Arqueologia Boletin, Instituto Nacional de Antropologia e Historia, 1991, pp. 75-78.
- [3] Desmond, Lawrence G., "The use of close-range photogrammetry for archaeological documentation: Chichen Itza and Uxmal 1989", Virginia M. Fields, ed., *Proceedings of the Seventh Palenque Roundtable Conference*, Vol. IX, San Francisco, Pre-Columbian Art Research Institute, 1994, pp. 43-48.
- [4] Desmond, Lawrence G., Patrick Collins, Tomás Gallareta Negrón, and James Callaghan, "Gateway into the past: Photogrammetric documentation of the Arch, Labna, Yucatan, Mexico", Luis Barba, ed., UNAM, *Antropología y Técnica*, 2002, Vol.II. In press.