



CORPUS OF
MAYA
HIEROGLYPHIC
INSCRIPTIONS

3D IMAGING REPORT

2013

ALEXANDRE TOKOVININE

A PROJECT OF THE PEABODY MUSEUM
OF ARCHAEOLOGY AND ETHNOLOGY

INTRODUCTION

The Corpus of Maya Hieroglyphic Inscriptions (CMHI) leads the efforts to preserve and study the incredibly rich material heritage of the Maya civilization. The publications of the CMHI set the standard for the entire field of Maya studies.

Finding ways to document and publish sculptures and inscriptions has been one of the main challenges in this endeavor. Techniques such as photography and drawing have been limited in their ability to record three-dimensional data. Making paper or latex molds of monuments may damage the surfaces, which are often highly fragile because of erosion. As molds cannot be stored long term, casts have to be made. Such plaster casts are often heavy, bulky, and also fragile, so their storage and use present additional logistical and conservation difficulties.

This is why the CMHI has embraced the technology of three-dimensional (3D) digitization. The 3D models produced are an invaluable tool for controlling the lighting and studying minute details that are difficult to see with the naked eye. Furthermore, digital 3D scanning has several advantages over plaster casts: the recording process does not require direct contact with the object, therefore avoiding further damage; it is easier and cheaper to store, move, share, and study digital data; and it is still possible to make full physical replicas from the digital models.

After several trials, the CMHI staff felt that the available 3D digitization tools and software were accessible and efficient enough for use in the field. Once

the photogrammetric 3D-digitization system was acquired in the summer of 2008, the 3D-documentation project began.

From 2008 to 2012, the Project focused largely on the documentation of the huge Hieroglyphic Stairway at the UNESCO World Heritage archaeological site of Copan, Honduras. The on-going deterioration of this highly important monument made such documentation a top priority. Non-contact digitization was preferable because the surfaces of the stairway blocks and sculptures were too fragile for making conventional molds. Moreover, digitization would allow scholars to create a new virtual reconstruction of the stairway, which could then be reproduced in some physical media. The 3D project also recorded other monuments and artifacts at Copan with preference given to vulnerable objects which could not be documented by other means. In addition to the Stairway, the Project worked with collections of the National Museum of Archaeology and Ethnology of Guatemala, Metropolitan Museum of Art, Peabody Museum of Archaeology and Ethnology, Dumbarton Oaks, as well as at the archaeological sites of Quirigua, Holmul, La Sufricaya, and Yaxchilan.

This report was compiled to present the scope and principal results of the 3D scanning project of the CMHI. The work has been carried out by the author in collaboration with CMHI director, Barbara Fash, from July 2008 to present. If you are interested in obtaining 3D models or images from the project or have further questions, please contact us at:

cmhi@fas.harvard.edu

ACKNOWLEDGMENTS

The 3-D scanning project of the Corpus of Maya Hieroglyphic Inscriptions at the Peabody Museum of Archaeology and Ethnology at Harvard University would like to thank a number of institutions, projects, and individuals for their support and assistance that made the work presented here possible.

Banco Santander/Fundación Botín Fund for the Research and Conservation of Maya Sculpture

David Rockefeller Center for Latin American Studies, Harvard University

Dumbarton Oaks Research Library and Collection

Fundación Uno

Harvard Art Museums

Harvard Center Shanghai

Harvard China Fund

Instituto de Antropología e Historia de Guatemala

Instituto de Antropología e Historia de México

Instituto Hondureño de Antropología e Historia

Museo Nacional de Arqueología y Etnología, Guatemala

Peabody Museum of Archaeology and Ethnology, Harvard University

Proyecto Arqueológico Holmul and Iniciativa de Arqueología Maya

Proyecto Arqueológico El Zotz

Semitic Museum, Harvard University

Smithsonian Museum Conservation Institute

The Metropolitan Museum of Art

Universidad Nacional Autónoma de México/Coordinación de Difusión Cultural

University of Pennsylvania Museum of Archaeology and Anthropology

World Monuments Fund

The 3-D scanning team in Honduras:

Adelso Canan

César Martínez

Erasmus Ramírez

Harold Caballero

Assistants to the Honduran scanning team:

Juan Ramon Guerra

Rufino Membreño

The 3-D scanning team at Harvard University:

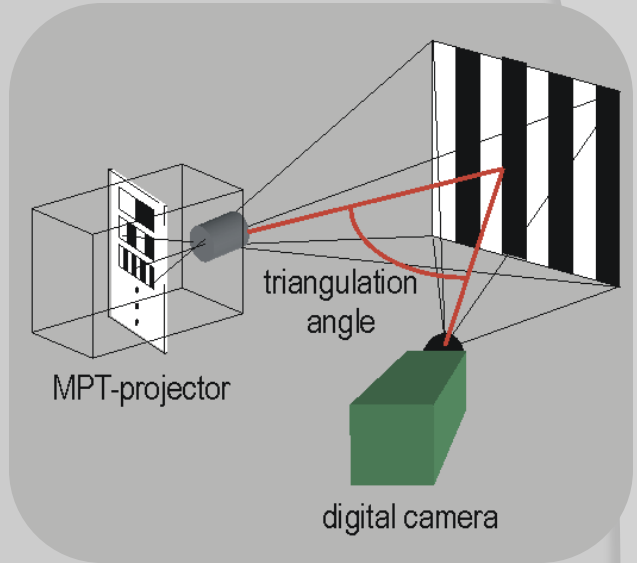
Lauren Santini

Steven Quinchia

DIGITIZING EQUIPMENT

A structured light scanner like *smartSCAN 3D* used by the CMHI project consists of a projector and two cameras mounted on a carbon fiber rod. The cameras and the projector are at an angle to each other and the operating distance from the scanned surface is fixed at 70cm. The system projects a sequence of patterns onto the object, while the cameras simultaneously record the surface. The distortion of the patterns caused by the surface is analyzed by the connected software that generates a 3D point cloud from the pixels of the digital images. Texture (color) value is assigned to each point from the same cameras. Each successive scan is semi-automatically aligned to the rest of the data in real time.

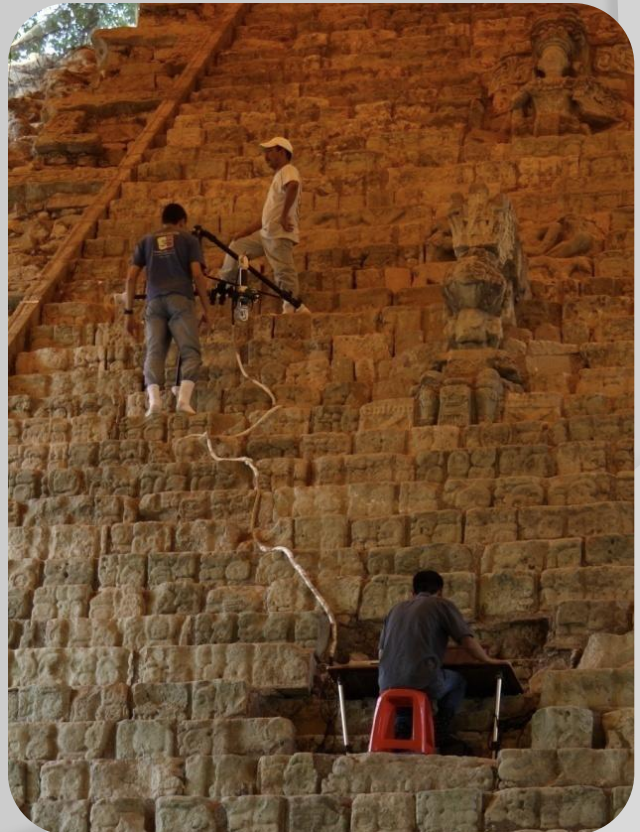
The CMHI chose this scanner model for its speed, resolution, accuracy, and portability. The light weight of the scanner (4kg) and its relatively faithful recording of color were also important. Another significant advantage was that the size of the scanned area or field of view (FOV) and the X.Y resolution (smallest distance between any two points in a single scan) could be altered by using different lens kits. The CMHI acquired three sets of lenses: 600mm FOV, X.Y resolution of 0.36mm for larger monuments; 300mm FOV, X.Y resolution of 0.18mm for most objects; 90mm FOV, X.Y resolution of 0.05mm for small and/or exceptionally detailed artifacts. Different resolutions may be combined during a single scanning project.



SCANNING TEAM

In the controlled conditions of an office or a museum storage setting, it is possible to operate the scanner and the software with just one person. Field conditions and use of bulky additional equipment, such as a camera crane pictured to the right, however, necessitate larger working crews. Usually, at least two persons are required to move the tripod or crane and to point the camera, and an additional person is needed to operate the software. The latter role implies some prior training because it involves monitoring capture settings (shutter speed, gain, number of captures and averaging) which may change depending on the angle of the shot, surface texture, and the amount of ambient light. The operator also needs to assist the software to align the scans by manually pointing to the approximate areas of the overlap between successive captures.

During fieldwork in Guatemala and Honduras, the project relied on the assistance from Harold Caballero, Adolfo Canan, Erasmo Ramírez, and César Martínez. Adolfo Canan's contribution as a software operator was particularly significant. 3D scanning on Harvard's campus has been assisted by Lauren Santini and Steven Quinchia who took turns at operating the scanner and the software. Museum curators at Dumbarton Oaks and the Guatemalan National Museum of Archaeology and Ethnology (MUNAE) also provided valuable help with access to the objects.



LIST OF SCANNED OBJECTS

COPAN

Hieroglyphic Stairway (HS)
Hieroglyphic Stairway MSC
Xukpi step
Yehnal stucco panel
Margarita stucco panel
Rosalila step
Structure 11-sub step
Ante step
Stela 63
Motmot marker
'Dazzler' vessel
 body (CPN C1523)
 lid (CPN C1530)
Rosalila 'eccentric flints'
(CPN P2706)
(CPN P2707)
(CPN P2759)
(CPN P2760)
(CPN P2761)
(CPN P2762)
(CPN P2763)
(CPN P2764)
(CPN P2765)

RASTROJON, COPAN

MSC stone block (CPN 29598)
Human head (CPN 30101)

PEABODY MUSEUM & HARVARD

Copan HS blocks
(93-27-20/C856)
(93-27-20/C857)
(93-27-20/C858)
(93-27-20/C859&859A)
(93-27-20/C861)
(93-27-20/C862)
(93-27-20/C865)
(93-27-20/C866)
(93-27-20/C867)
Warrior figure from Copan HS
 shield (92-49-20/C842)
 head (93-27-20/871.2)
 headdress (95-42-20/C753)
 body (93-27-20/C871.1)
Copan peccary skull (92-49-20/C201)

Copan MSC sculpture (92-49-20/C74)
Copan Altar F' (92-49-20/C88)

Piedras Negras Panel 2
La Corona HS blocks
(2003.32.1)
(2003.32.2)

Cast of Copan Altar Q (3093-27-20/C580)
Cast of Tenochtitlan 'Teocalli of the Sacred War' (30-48-20/C11033)
Harvard Tercentenary Stele
Cuneiform tablet (SM # 1911-08-004)

METROPOLITAN MUSEUM OF ART

Tortuguero Monument 6 fragment

DUMBARTON OAKS

Byzantine coins
(BZ.C.1948-17-2249)
(BZ.C.2005-24)
Byzantine bullae
(BZ.C.1956-23-2909)
(BZ.C.1961-20)

Maya bone bells (PC.B.192A-D)
Maya stone panel (PC.B.528)
Maya stone panel (PC.B.537)
Maya stone panel (PC.B.539)
Maya/Olmec pendant (PC.B.538)
Maya ceramic vessel (PC.B.554)

HOLMUL

Group 2 Building B-sub stucco frieze

LA SUFRICAYA

Stela 2 (carved area)
Stela 5 (2 fragments)
Stela 6 (carved area)

QUIRIGUA

Panel 1 (12 fragments)

YAXCHILAN

Stela 11 (front & sides)
Lintel 29
Structure 21 stucco frieze (part)
HS 2 Step 7
Stela 31 (part)

LIST OF SCANNED OBJECTS

NATIONAL MUSEUM OF ARCHAEOLOGY AND ETHNOLOGY, GUATEMALA (MUNAE)

El Zotz Lintel 1 (2 fragments)

Tikal 'Marker'

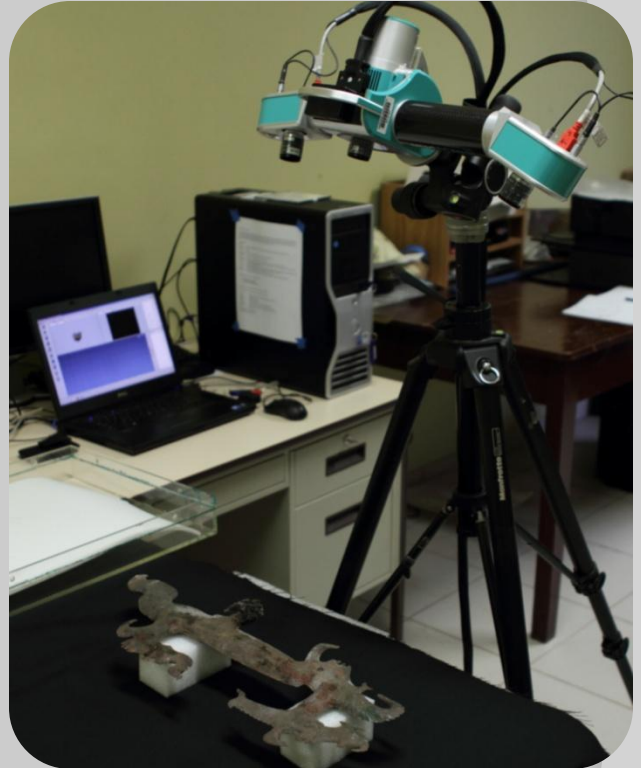
Piedras Negras Panel 3

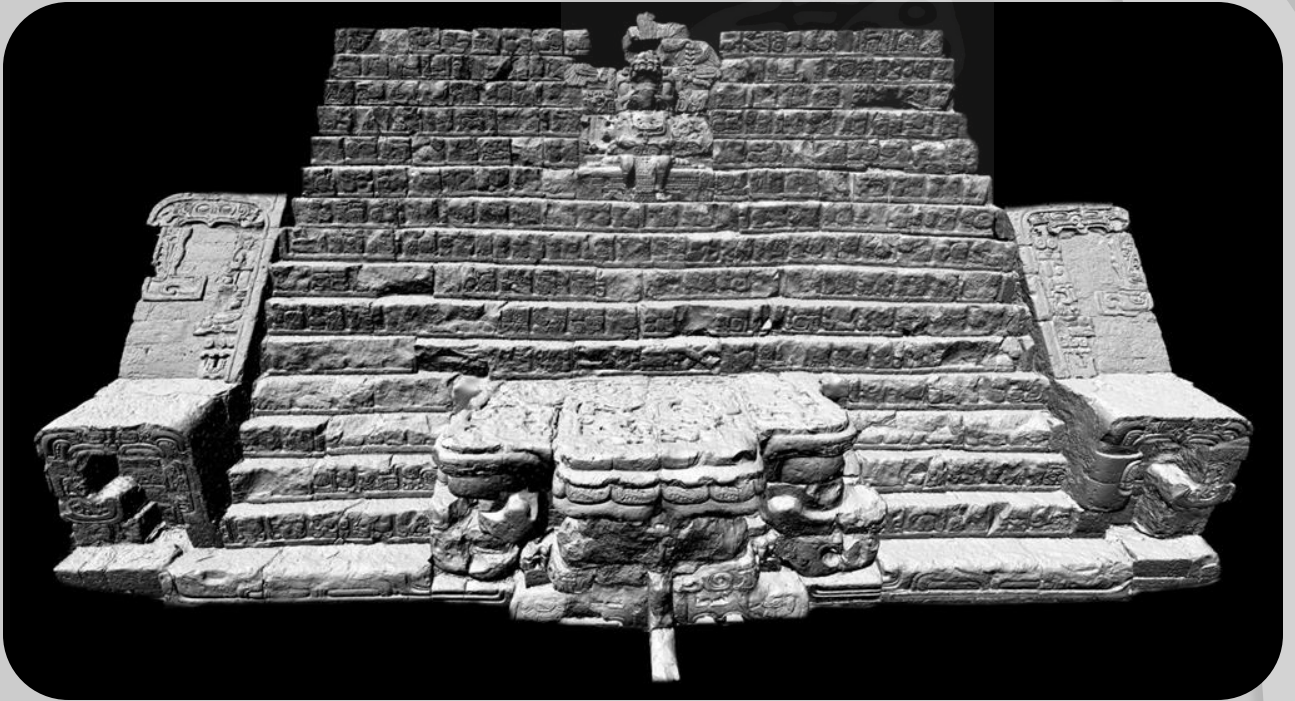
Piedras Negras Panel 4

Piedras Negras Panel 12

Piedras Negras Panel 15

Piedras Negras Stela 15





COPAN HIEROGLYPHIC STAIRWAY

A milestone for the Project was the completion of the scanning of the Hieroglyphic Stairway, the longest known Maya text. The process required focused CMHI field operations for four years and was part of a research and conservation initiative in collaboration with the Instituto Hondureño de Antropología e Historia. A high-resolution digital record of the stairway will preserve this monument for future generations, facilitate further research on the hieroglyphic inscription, and reduce the necessity of direct access to the original.

Only the first sixteen steps of the original 63 of the Hieroglyphic Stairway were discovered in their original order (their 3D reconstruction in low resolution is pictured above). All stairway elements were scanned separately with the goal of re-assembling them digitally in a new virtual

reconstruction of the Stairway with the other blocks in close to their original order. The virtual reconstruction could then be reproduced using a 3D printer or a milling machine.

The carved frontal surfaces of Stairway blocks were scanned at the 0.18mm X.Y resolution and their plain tops were documented at the 0.36mm X.Y. resolution. Larger Stairway features such as the altar at its base, lower sections of the balustrades, and the figures of warriors were also scanned at 0.36mm.

Each block and sculptural element constitutes a separate data set. Blocks are identified by their numbers. The warrior figures, the altar, and the balustrades have been assigned designations indicating their locations (Bottom Left/Right balustrades, altar, Figure 1 through 7 from the bottom up).



Each warrior figure decorating the Stairway has been scanned separately. There are six figures in total plus one at the Peabody Museum. Some of these figures which consist of multiple stone blocks may have been reconstructed incorrectly and would need a virtual 'deconstruction' when a new digital model of the Stairway is assembled.



COPAN HIEROGLYPHIC STAIRWAY MISCELLANEOUS SCULPTURES

Eighteen miscellaneous fragments of stairway blocks have been located in storage at the Regional Center of the Institute of Archaeology of Honduras (CIA) and scanned at 0.18mm resolution. In addition to the blocks of the steps, seven fragments of serpent heads were scanned in 2012 at 0.36mm resolution. Several more head fragments remained undocumented. The sculptures are currently located across the courtyard from the Hieroglyphic Stairway but were excavated in the 19th century from the stairway fall, and it is believed that they were originally associated with a terrace or platform on the upper section of the steps.





COPAN HIEROGLYPHIC STEPS

Pictured here (from top to bottom) are hieroglyphic steps discovered in tunnel excavations from the Ante, Rosalila, Temple 11-Sub, and Xukpi structures at Copan scanned at 0.18mm resolution. A detail of Temple 11-Sub step is shown to the right. This monument suffered further damage a year after its scanning highlighting the urgency of such documentation.





COPAN STUCCO PANELS

The stucco façade panels of buried Yehnal and Margarita structures were scanned at 0.36mm resolution in order to create a record of these unique and fragile monuments and to enable, if necessary, the production of 3D replicas. A full-size 3D replica of the Margarita panel (a detail of the replica is on the left) was recently made for the exhibition *Maya 2012: Lords of Time* at the University of Pennsylvania Museum of Archaeology and Anthropology.



MARGARITA PANEL

Full color view and a detail without texture.





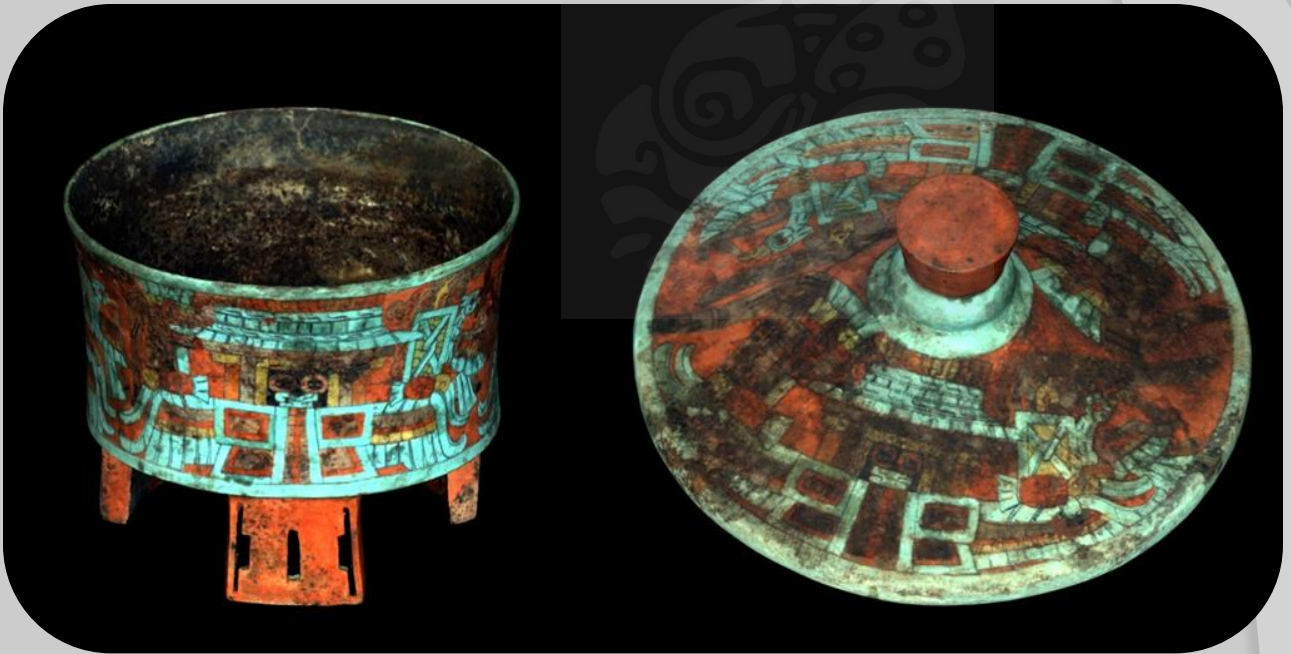
YEHNAL PANEL

Full color view and a detail without texture.



COPAN MOTMOT MARKER AND STELA 63

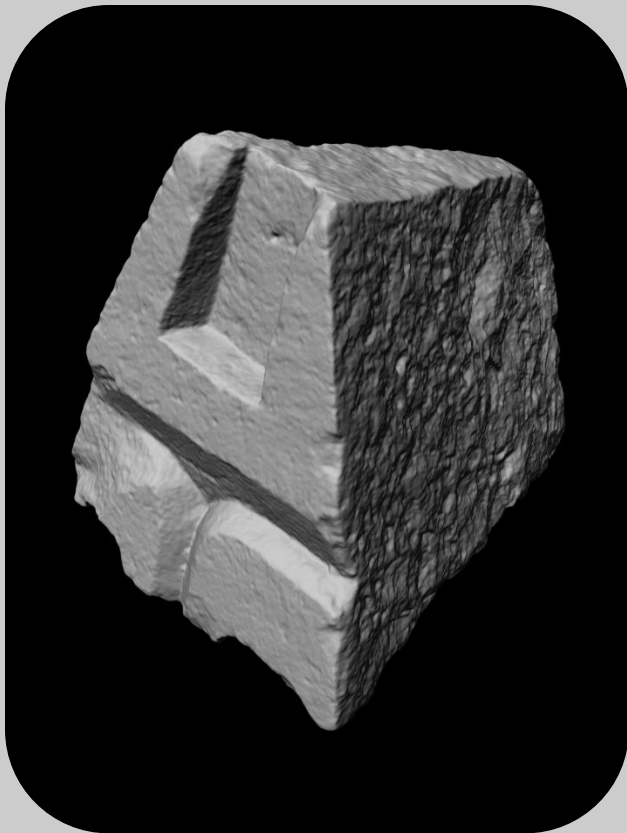
These Early Classic Copan monuments were scanned for the improvement of the current record and also for making physical replicas. The digital rendering and the 3D print of the Motmot marker are pictured above. The front and one side of Stela 63 are on the left. Carved sections of these monuments were recorded at 0.18mm and plain areas at 0.36mm resolution.



DAZZLER VESSEL AND ECCENTRIC FLINTS FROM COPAN

The goal of the 3D documentation (0.18mm resolution) of the Dazzler and its lid was to facilitate the production of a replica. The model was intended for helping the artist, but not for 3D printing. The slab feet and the bottom of the vessel were not fully recorded because that would be risky from a conservation standpoint (placing the vessel upside-down). For the same reason, the inner side of the lid was not scanned. Nine eccentric flints from Rosalila cache have been recorded at 0.18mm resolution to enable their measurement, drawing, and study without endangering textile fragments adhering to the surface. Only one flint (CPN P2707) was scanned from just one side because it was sent on exhibit loan to the Penn Museum prior to finding a way to scan the other side. A scanning protocol that would not require turning the objects upside-down was developed to document the other flints.





SCULPTURE FROM RASTROJON

A carved human head (CPN 30101) and a small carved stone block (CPN 29598) from Structure 6N-10 at the archaeological site of Rastrojon were recorded at 0.36mm resolution. The miscellaneous stone block was documented as a test of the equipment in 2008. The reason for recording the head was its exceptional preservation. These pieces represent two of over 2000 sculptures that have been excavated from Structure 10 by the Proyecto Arqueológico Rastrojon Copan.



PEABODY MUSEUM: COPAN STAIRWAY FRAGMENTS

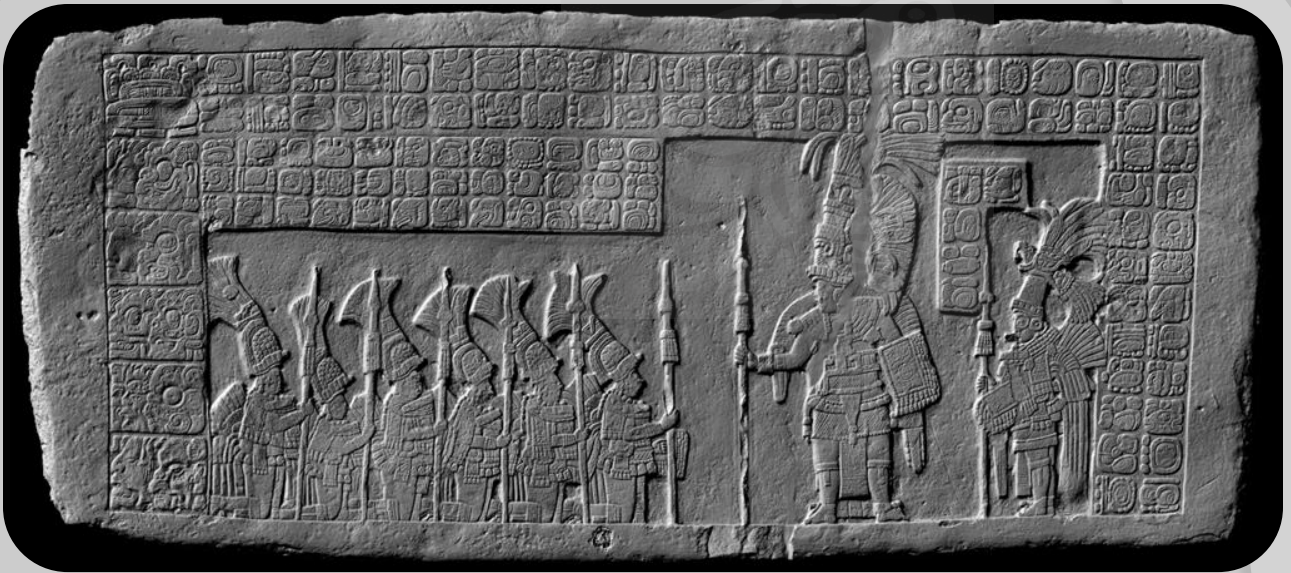
Nine blocks (three pictured above) from the Copan Hieroglyphic Stairway in the collection of the Peabody Museum since 1893, have been scanned at 0.18mm. Five sculptured pieces of the warrior figure from the stairway were scanned separately at 0.36mm resolution and then re-assembled digitally (right image).



**PEABODY MUSEUM:
COPAN MISCELLANEA**

The carved peccary skull from Copan in the Peabody Museum collection (pictured above) has been scanned at 0.05mm resolution. In addition to the peccary skull, an inscribed stone block (Altar F') and a

serpent head from Copan have been recorded at 0.36mm resolution. Some details of the Altar F' inscription may require additional documentation at 0.18mm. Interactive 3D views of the peccary skull are available online at:
<https://www.peabody.harvard.edu/node/822>



PEABODY AND SEMITIC MUSEUM COLLECTIONS

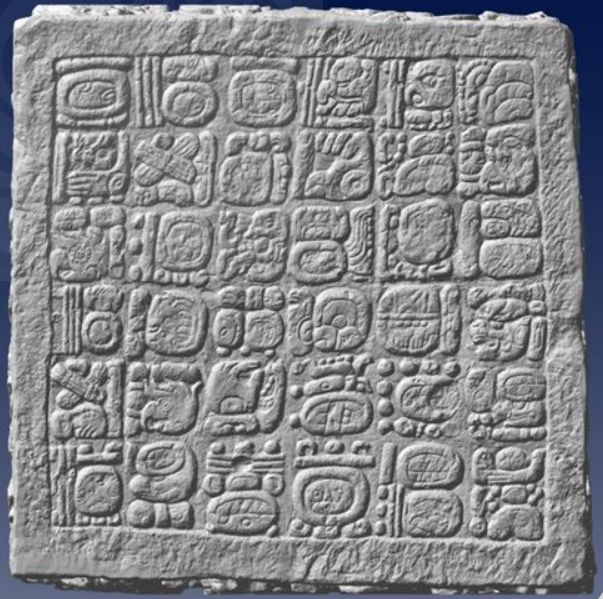
The CMHI 3D project also scanned three monuments from Guatemala: the carved side of Panel 2 from Piedras Negras (pictured above) and two stairway blocks, which likely originated from the site of La Corona. Plain areas were documented at 0.18mm resolution. Carved sections were scanned at 0.05mm resolution because of the small dimensions of the carved details. The carved fronts of La Corona blocks were sawn off by the looters, so the 3D models would allow to match the backs of the removed sections with the fronts of the blocks left at the site.

In addition to carved and incised objects, the CMHI tested its high resolution (0.05mm) scanner setup on a tiny (30x32x12mm) cuneiform tablet from the Semitic Museum collections (#1911-08-004).





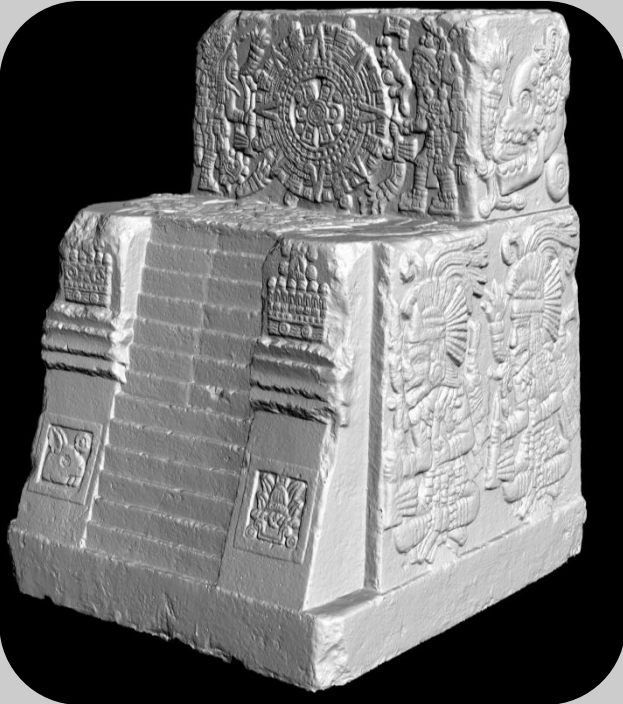
Piedras Negras Panel 2 color detail.



PEABODY MUSEUM PLASTER CASTS

The XIX century plaster cast of Copan Altar Q (pictured above) was scanned at the resolution of 0.36mm to produce a physical replica on the basis of 3D data. Replicas, which retain more detail than the original monuments, became part of the exhibitions *Maya 2012: Lords of Time* at the Penn Museum (pictured on the left), and *Maya: Hidden Worlds Revealed* premiering at the Science Museum of Minnesota in 2013.

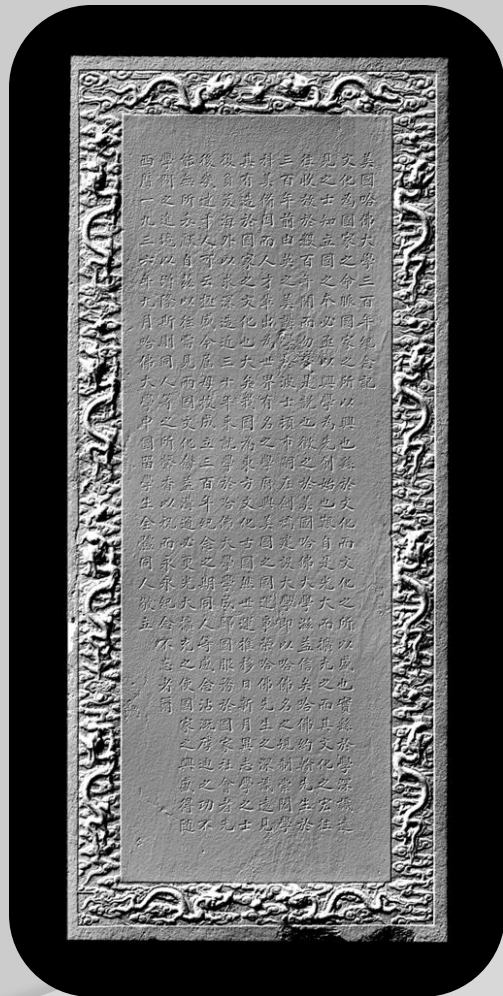
The cast of the “Teocalli of the Sacred War” from Tenochtitlan, Mexico, was scanned to test the 0.36mm resolution lens setup on a plaster cast and to explore the use of renderings (pictured to the left) and a 3D PDF of the object in the classroom.

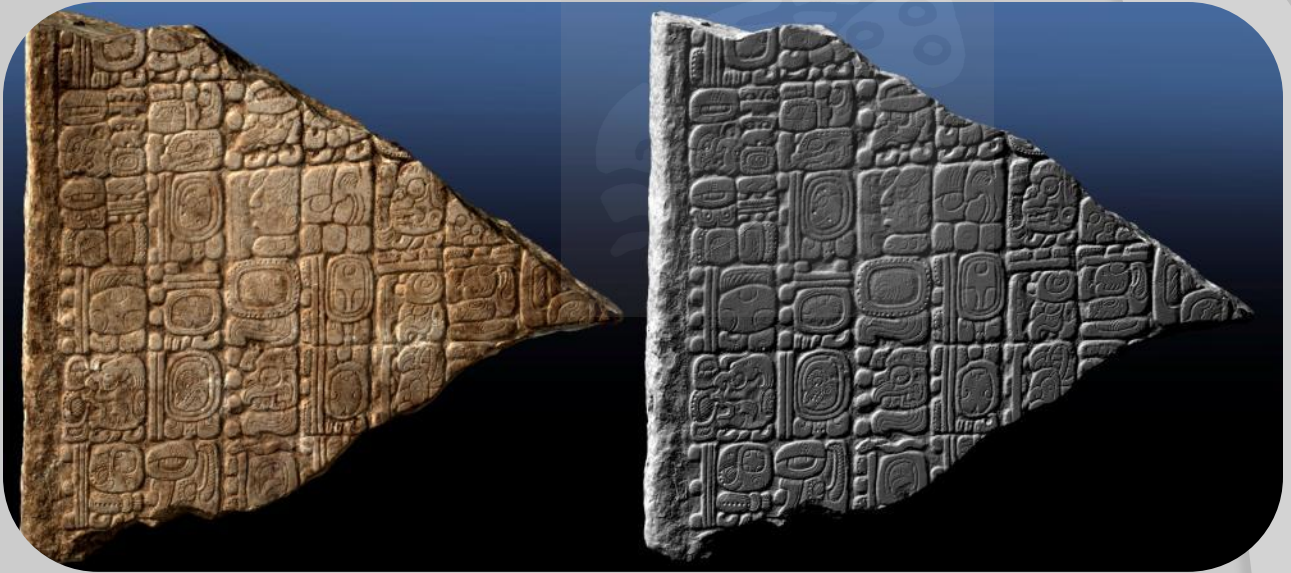




HARVARD TRICENTENARY STELE

This marble monument was donated to Harvard University by the members of the Harvard Clubs of Nanking and Shanghai to mark the Tercentennial Ceremony at the university in 1936. Located outside the Widener Library, the stele has been exposed to acid rain and temperature/humidity fluctuations, which caused substantial erosion. The goal of 3D scanning was to document the present state of the monument and to produce the data set that would allow a physical replica to be made. The original would then be relocated to a more protected setting. The stele was scanned at 0.36mm resolution. A higher resolution was not feasible because of the size of the monument. The project was carried out in collaboration with the Harvard Center Shanghai, the Harvard China Fund, and the Harvard Art Museums.





THE METROPOLITAN MUSEUM OF ART, NEW YORK

The fragment of Monument 6 from Tortuguero, Mexico, in the collection of the Metropolitan Museum was scanned to assist in the Mexican Instituto Nacional de Antropología e Historia's reconstruction of the original monument. The 3D data will be used to make a physical replica to be reunited with the rest of the stela in the museum in Tabasco, Mexico. The inscribed surface was scanned at 0.05mm resolution and the plain areas were recorded at 0.18mm.

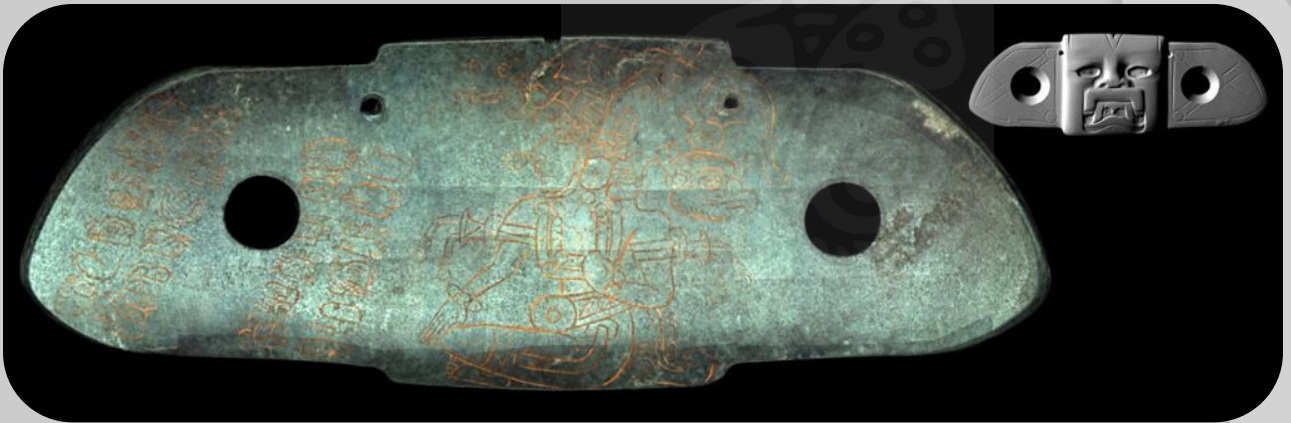




DUMBARTON OAKS BYZANTINE COINS AND SEALS

Two golden Byzantine coins and two golden seals have been recorded at 0.05mm resolution to test the feasibility of high-resolution scanning of these relatively shiny (but not highly polished) objects. Capturing the objects at oblique angles was successful where the surfaces proved to be too reflective for straight shots. Consequently, the color was not faithfully reproduced (as in the image above). Given that each object took one hour to scan and nearly an hour to process, scanning the whole collection was not feasible.



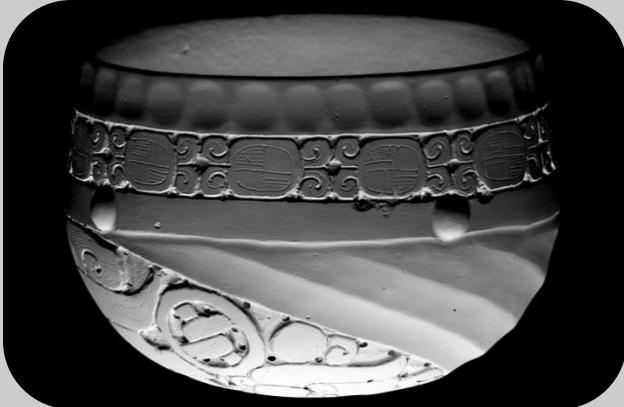


DUMBARTON OAKS BONE BELLS AND WING PENDANT

A set of four Classic Maya bone bells in the Dumbarton Oaks collection were scanned at 0.05mm resolution. Only part of the interior surface could be documented due to visibility issues. Multiple renderings of the 3D models of the bells were used for measurement and drawings in the catalog of the ancient Maya art at Dumbarton Oaks.

The Olmec Wing Pendant with incised Pre-Classic Maya image and text was also scanned at 0.05mm resolution for the same project. The reflective and partially translucent surface of the artifact caused too much noise in the data. A noise reduction algorithm could not be applied because it would also largely erase the incised lines on the back of the pendant. Consequently, the 3D model was not used as a source of the new line drawing of the pendant, although it is still of value for making measurements and cross-sections of the object.

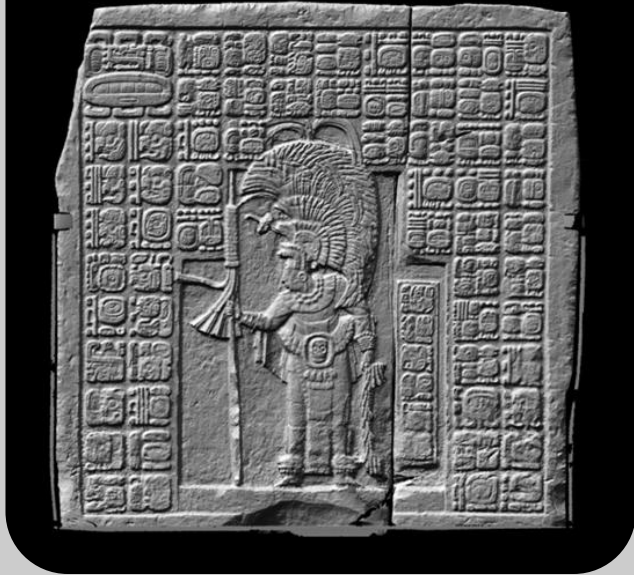




DUMBARTON OAKS MAYA INCISED VESSEL & PANEL

A unique double-walled Early Classic Maya vessel was recorded at Dumbarton Oaks. The exterior surface was scanned at 0.05mm and the plain interior at 0.18mm. The dark and polished surface, however, caused uneven color capture. The Late Classic panel from the site of Chancala in Mexico was recorded at 0.18mm resolution. The 3D model was used to make a drawing of the panel.





DUMBARTON OAKS CLASSIC MAYA PANELS

Two Late Classic Maya panels in the Dumbarton Oaks collection, one from the area of the site of Palenque in Mexico and the vicinity of Piedras Negras in Guatemala, were scanned at 0.18mm resolution. The 3D models were used to make new drawings of these monuments, which were published in the award-winning book, *Ancient Maya Art at Dumbarton Oaks*.





STUCCO MASK, FAÇADE OF BUILDING B-sub, GROUP 2, HOLMUL, GUATEMALA

The large stucco mask (4m x 3m x 1.4m) on the façade of Late Pre-Classic Structure B-sub at Holmul was a high-priority monument because of its fragile surface, insecure setting (archaeological tunnel), inaccessibility, and remote location. Given the size of the mask, 0.36mm was the only option in terms of the resolution. The constrained space and shape of the tunnel proved a serious challenge, particularly when using the camera crane (pictured to the right) to capture the top sections of the mask. Some features were obscured by the roof of the tunnel and could not be scanned.

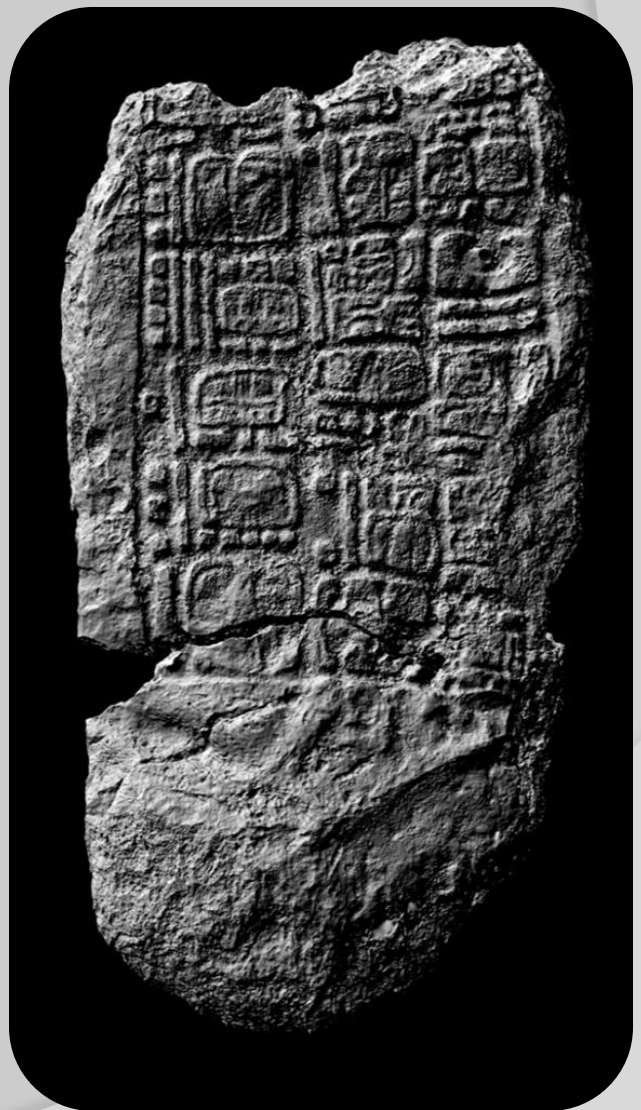
The resulting 3D model of the mask may be used for making a full-size replica. It can also facilitate making drawings and measurements of this monument.

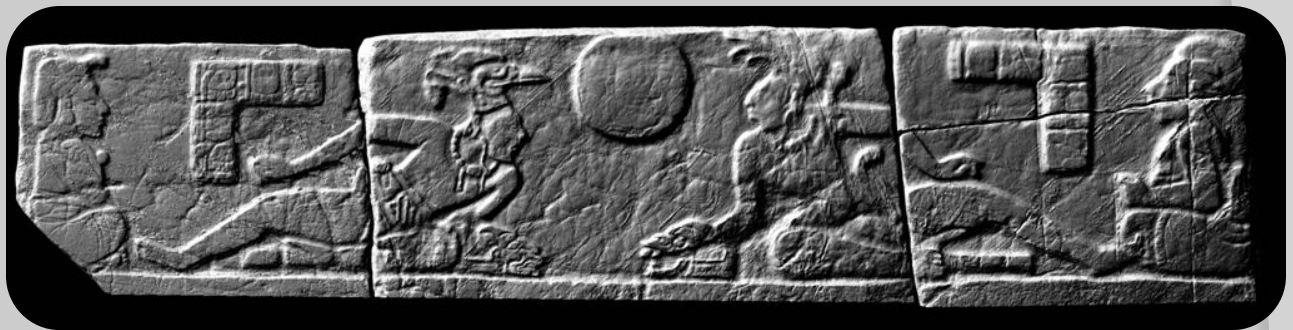
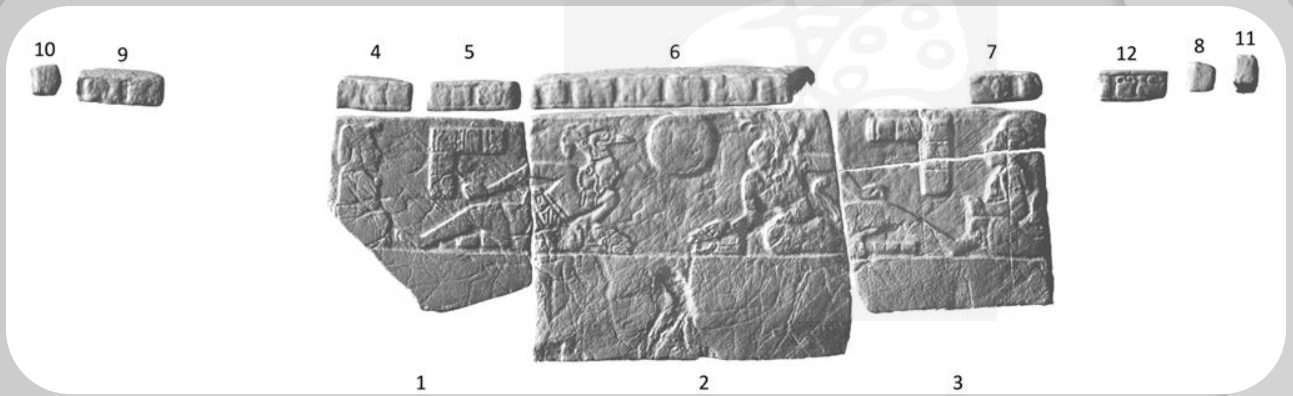




LA SUFRICAYA MONUMENTS

Stelae 2, 5 (2 fragments), and 6 from the site of La Sufricaya (Guatemala) were documented in the regional IDAEH office in Melchor de Mencos. The monuments were scanned at 0.18mm resolution. Only carved areas of Stela 2 (pictured below) and Stela 6 (pictured above) were recorded. Both fragments of Stela 5 were scanned in full.





PANEL/BENCH, QUIRIGUA

Twelve fragments of a C-shaped throne or bench from the site of Quirigua in Guatemala were scanned at 0.18mm resolution. Only accessible areas of the fragments 1, 2, 3, and 6 were recorded. Other fragments were scanned full-round.

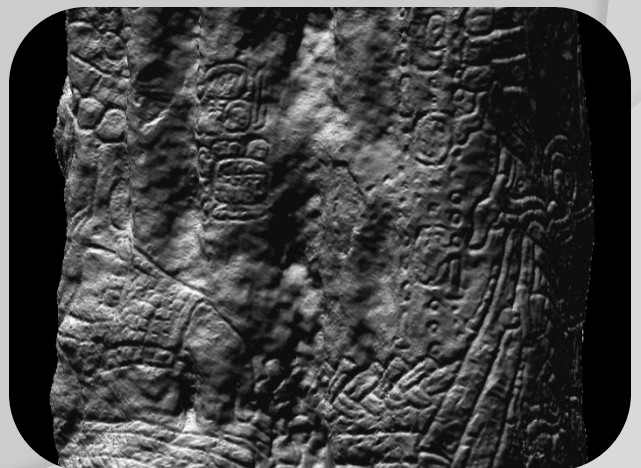
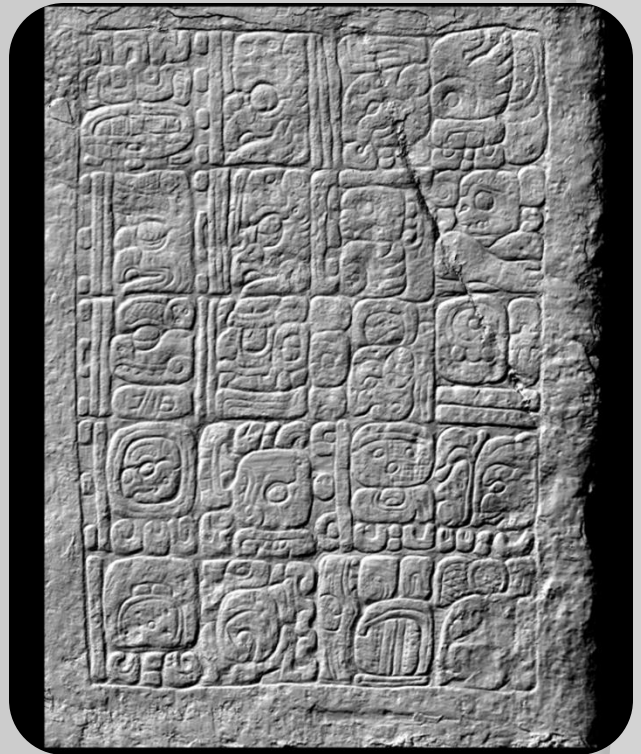
All fragments were re-articulated digitally to re-create their relative location on the bench: fragments 1-3 lined the front of the bench; fragments 4-7 were placed on top of the central bench section, and fragments 8-12 were located on the lateral sections of the bench.



YAXCHILAN MONUMENTS

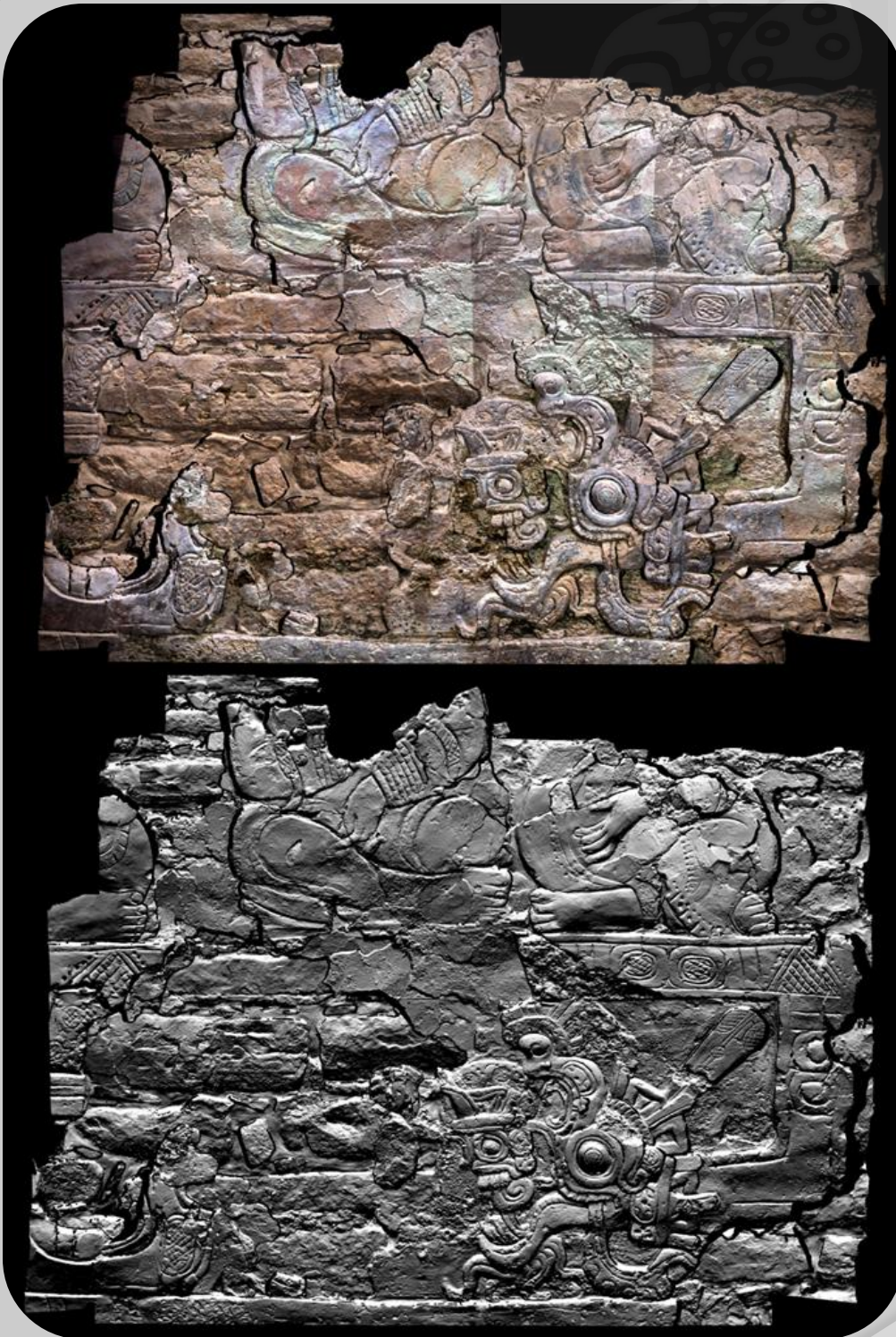
Several monuments at the site of Yaxchilan (Mexico) were scanned as part of the test of the digitizing equipment in 2007. An older model of the scanner (triTOS) was used. Step 7 of Hieroglyphic Stairway 2 (pictured above) was captured at 0.18mm resolution. Other monuments including Lintel 29 and Stela 31 (on the right) were recorded at 0.36mm resolution. A section of the stucco frieze of Structure 21 was also scanned at 0.36mm.

Technical problems with the scanner and an excess of ambient light made the quality of the 3D data less than satisfactory, and the 3D models are not sufficient to make full-size physical replicas. They may still be used, however, for measurement and as a valuable reference for drawing. Only a small section of Stela 31 (lower right) was captured. The accessible carved surfaces of Lintel 29 and Stela 11 were recorded, but the sides of Stela 11 (shown on the next page) were scanned at an oblique angle giving only partial coverage.



Stela 11, Yaxchilan, back and sides.





Structure 21 stucco frieze (the section that was scanned), Yaxchilan.



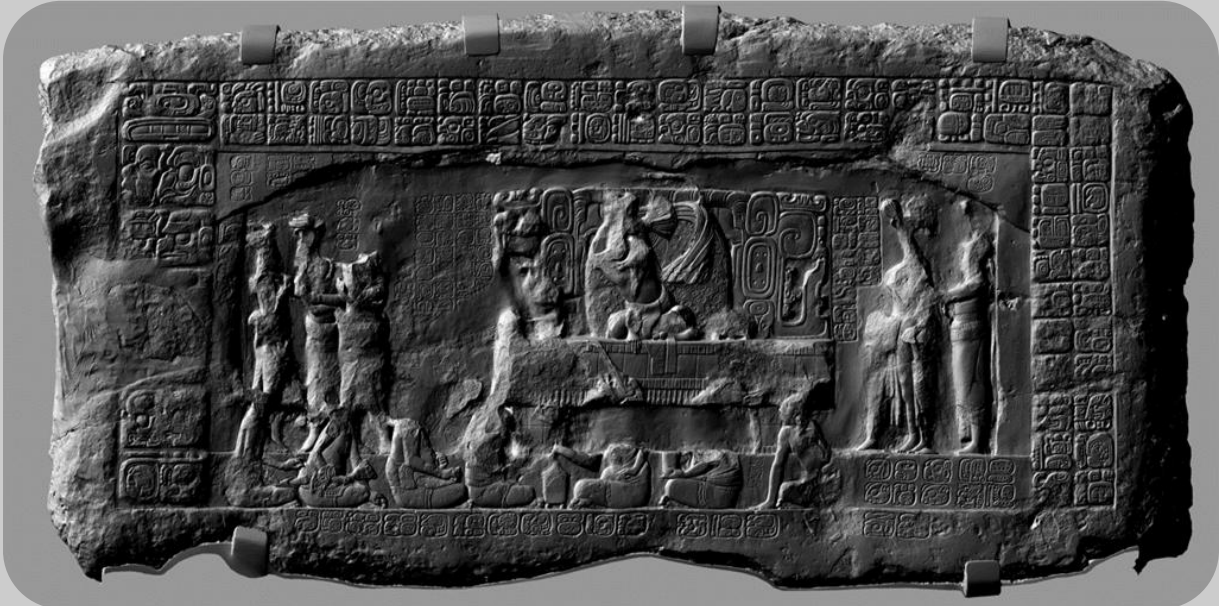
**NATIONAL MUSEUM OF
ARCHAEOLOGY AND ETHNOLOGY
(MUNAE), GUATEMALA**

EL ZOTZ LINTEL & TIKAL MARKER

Two fragments of Early Classic Lintel 1 from the site of El Zotz (pictured to the right) at the National Museum of Archaeology and Ethnology (MUNAE) were scanned at 0.18mm resolution. Only the front surface of the larger fragment could be accessed and scanned. The 3D model was requested to fabricate a replica for the site to replace the original.

The so-called Early Classic 'Marker' from Tikal was recorded at 0.18mm resolution. The text on the monument was then re-scanned at 0.05mm to capture finer details of the inscription. High resolution renderings of the 3D model of the 'Marker' (like the one pictured on the right) have already been used in the studies of the text.

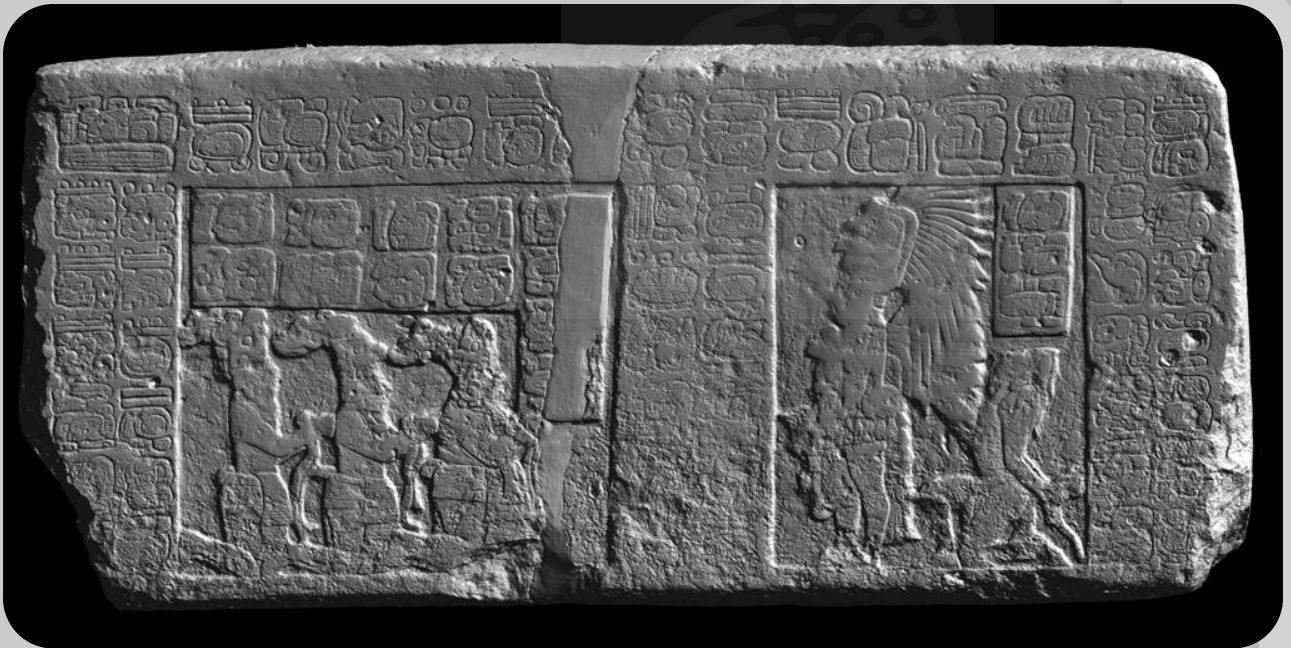




PANEL 3, PIEDRAS NEGRAS

This monument was scanned at 0.18mm resolution, but finer details of the inscriptions were again recorded at 0.05mm. It may be worthwhile re-scanning other carved areas at 0.05mm because the final 3D model showed that 0.18mm resolution was not enough to capture some carved and incised features.

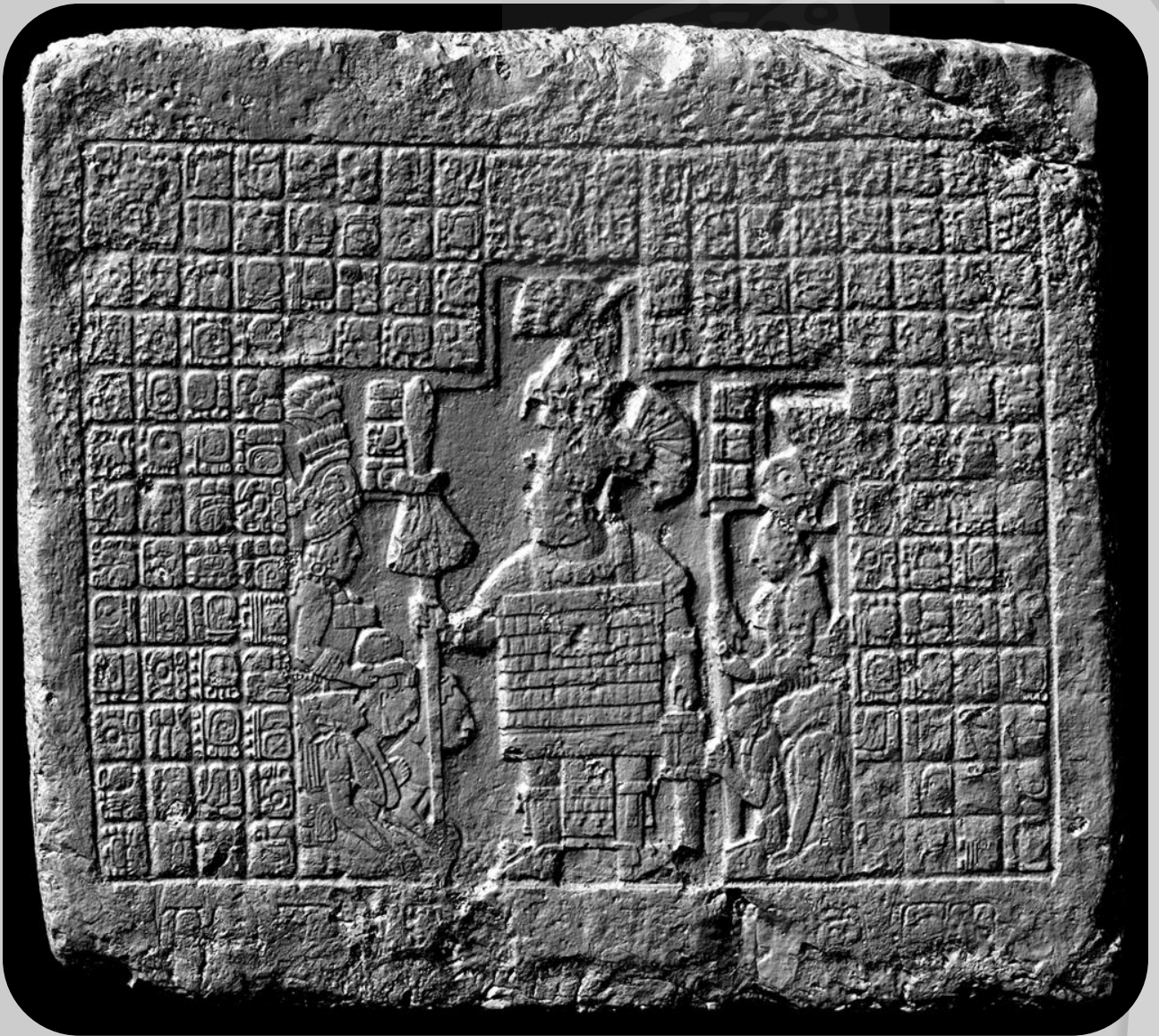




PANEL 4 & PANEL 12, PIEDRAS NEGRAS

Panels 4 (pictured on the left) and Panel 12 (above) in the collection of the Guatemalan National Museum of Archaeology and Ethnology (MUNAE) were scanned at 0.18 mm resolution that proved to be adequate for the carved and incised details on these monuments. Only the accessible surfaces were scanned. The back sides of the monuments were unrecorded. Although these Piedras Negras panels at MUNAE are not endangered, the monuments are difficult to photograph and have extremely fine details, which the 3D models help to reveal.

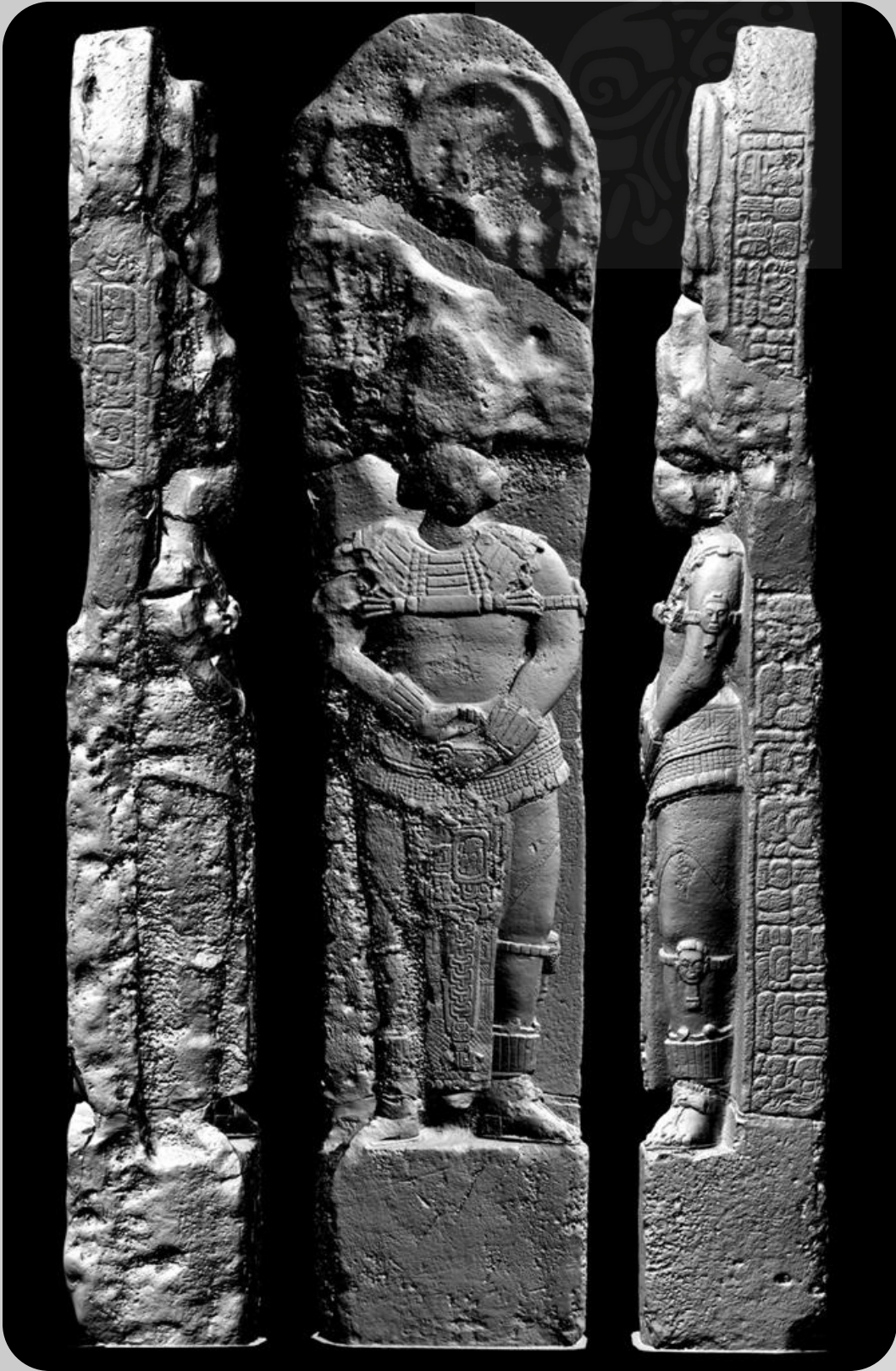




PANEL 15, PIEDRAS NEGRAS

Piedras Negras Panel 15 in the collection of the Guatemalan National Museum of Archaeology and Ethnology was recorded at 0.18mm resolution. The back and the bottom of the monument were not scanned.





Piedras Negras Stela 15,
MUNAE, Guatemala.