DIGITAL-3D-MODELLING AND VISUALIZATION OF ANCIENT MAYA ARCHITECTURE

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International Committee for Architectural Photogrammetry CIPA

ABSTRACT

This paper will describe **a combined surveying method** and the **three dimensional computer-modelling** of this **partly collapsed structure**, just as the application of animation software for its **presentation and reconstruction**.
In the recording and in the digital presentation of the site, this outstanding object had to be dealt with the utmost exactitude in order to provide reliable data for archaeological interpretation. This task proved exceedingly difficult, because the complex shape of the palace, which in several, almoust crumbled, parts did not allow exact geometric definition.
The work in situ were controlled by **check-lists** and the "digital field book".
For the 3D-presentation a conventional CAD-system adjusted by self-written programs were used.
Finally the application of an animation programs on the **solid 3D-model** allow the scientist (architect, archaeologist) to single out and thoroughly study any interesting parts of the structure.

1. INTRODUCTION

It is due to environmental pollution and to the influences of tropical vegetation (rain forest) that the specimen of pre-Columbian Maya-architecture still existing are in great danger. The cutting down of vast parts of the jungle and its colonization as well as large-scale projects, e.g., hydro-electric power plants or road building, also have their share in endangering the survival of Maya-architecture.
It is, therefore, important to geodetically record and document the architectural stock in order to supply the best possible basis for further studies by researchers today and in future times.

Methods of presentation that have up to now been used in the field of Maya-research are confined to sectional drawings, sectional views or axonometric or perspective views in analogue, two-dimensional form. The potentiality of modern computer-aided design and the call for plans for the Maya-site of Santa Rosa Xtampak led to the first phase of geodetic stock taking in the summer of 1989.

A second phase took place in autumn 1992, when complete and detailed plans of the more than 4O interior rooms and smaller architectural elements were extracted from the recordings

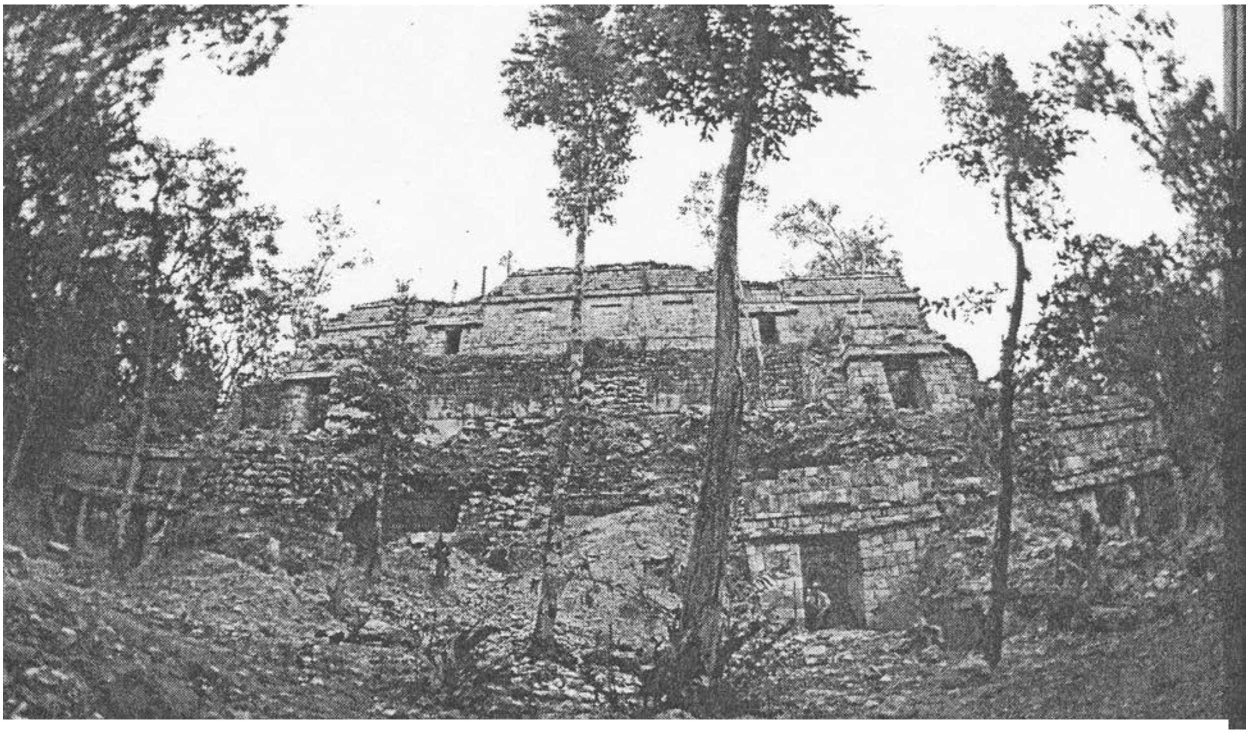


Fig. 1: Fisheye-photograph of the west-facade of the palace of Sanat Rosa Xtampak

with the aim of producing - for the first time in the history of Maya-resarch - a three-dimensional digital "architecture model" of a Maya-building. The extensive site of Santa Rosa Xtampak in Campeche (Mexico) belongs to the late classical period of Maya-culture (7OO to 8OO A.D.). It contains a number of buildings which are in comparatively good condition. In the centre of this Maya city there is a three-storey palace consisting of 44 interior rooms and two almost symmetrical staircases. Influences of the weather have considerably damaged the facade of this palace, so that it is difficult to distinguish any clear lines or structures.

2. GEODETIC AND PHOTOGRAMMETRIC DATA-RECORDING

Since 1841, when Catherwood and Stephens visited Santa Rosa Xtampak for the first time, there has been a number of research-camps, but never before has a scientifically precise recording of the structures been attempted. Not until 1989 were there exact recordings and presentations by means of CAD. Based on the experience of 1989 checklists were worked out in cooperation with the "Inter-disziplinäre Arbeitsgruppe Mayaforschung" in the summer of 1992 to guarantee completeness and accuracy of the recordings. The demand for completeness is to be made, on the one hand, respecting characteristic style-elements of architectural structures and, on the other hand, concerning the geometry of the whole object. Whoever takes these recordings needs a good capacity of understanding geometric abstractions as well as considerable knowledge about constructions by means of 3D-CAD-systems.

2.1. Geodetic recording of individual points by means of automatic data-registration

Checklists used in this process are composed in accordance with the recordings and consist of the following items:

- name, resp. number, of the building;
- name of the architectural structure to be recorded, together with its
  * thematic code and
  * the point numbers given.

This additional information allows for a clear definition of the points and architectural elements registered as well as for an individual storage of the various structures and elements in individual thematic layers.

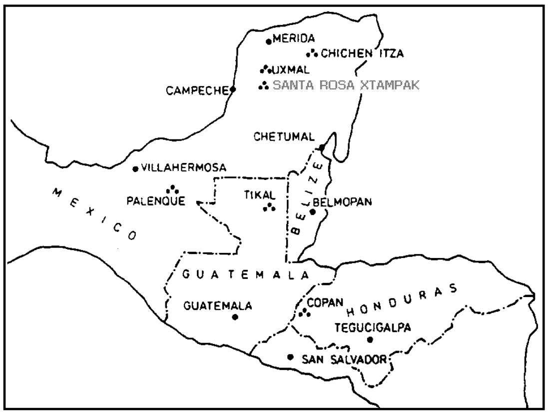
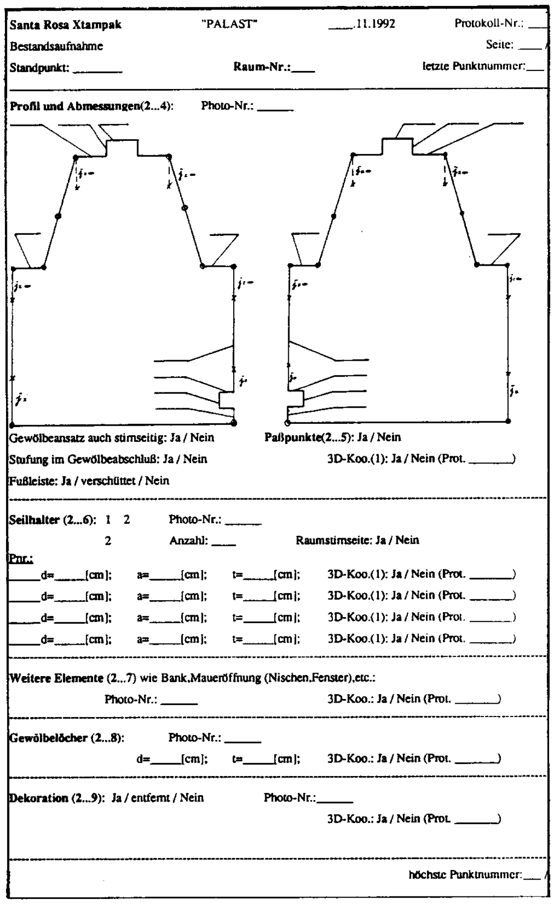


Fig.2: Living space of the Maya

According to this method every interior room of the palace was registered by means of 3D-point clusters and stored in digital form. Because of the complex data-material, the efficient use of total stations with automatic data-registration absolutely requires a profoundly experienced worker.



Santa Rosa Xtampak "PALAST" ____.11.1992 Protokoll-Nr.: ___
Bestandsaufnahme Seite: ___
Standpunkt: _______ Raum-Nr.:___ letzte Punktnummer:___

Profil und Abmessungen(2...4): Photo-Nr.: _____

Gewölbeansatz auch stirnseitig: Ja / Nein Paßpunkte(2...5): Ja / Nein
Stufung im Gewölbeabschluß: Ja / Nein 3D-Koo.(1): Ja / Nein (Prot. _______)
Fußleiste: Ja / verschüttet / Nein

Seilhalter (2...6): 1 2 Photo-Nr.: _____
2 Anzahl: ___ Raumstirnseite: Ja / Nein
Pnr.:
_____d=_____[cm]; a=_____[cm]; t=_____[cm]; 3D-Koo.(1): Ja / Nein (Prot. _______)
_____d=_____[cm]; a=_____[cm]; t=_____[cm]; 3D-Koo.(1): Ja / Nein (Prot. _______)
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Weitere Elemente (2...7) wie Bank,Maueröffnung (Nischen,Fenster),etc.:
Photo-Nr.: _____ 3D-Koo.: Ja / Nein (Prot. _______)

Gewölbelöcher (2...8): Photo-Nr.: _____
d=_____[cm]; t=_____[cm]; 3D-Koo.: Ja / Nein (Prot. _______)

Dekoration (2...9): Ja / entfernt / Nein Photo-Nr.:_____
3D-Koo.: Ja / Nein (Prot. _______)

höchste Punktnummer:___

Fig. 3: Checklist used in the field-work

2.2. Photogrammetric computing of data-material

In general, the design of facades and decorations of Maya buildings is markedly sectionalized, which makes them valuable sources of information for architectural analysis. In order to achieve efficient and complete registration of all available information, the elements were recorded photo-grammetrically. The pictures were taken with a medium-size camera, a Rolleiflex 6OO6 with 5Omm lens. This camera is both light in weight and convenient in use; under the difficult, rather uncomfortable circumstances in the jungle this certainly was the best choice of instrument.

Because of the foreground being strongly overgrown with trees and bushes, all interesting parts and decorations of the facade were recorded by means of individual models with accordingly individual control point clusters. Additional work in control point registration, though, was well made up for in the following process of photogrammetric analysis by the time-saving and uncomplicated orientation of the individual models.
All in all, thirty-three stereo-models were orientated and registered with an accuracy of plus/minus 1.5 cm per control point. Analysis by means of a Zeiß P3 photogrammetric workstation and the graphic package PHOCUS was divided into two parts. At first, all well defined elements were analysed as to their exact edges, profiles and bounds, and afterwards, the amorphous parts of the building were defined by contour lines. In this case of a highly complex geometric facade design it is essential, that photogrammetric analysis and digital 3D-models be worked out by the same person, who must command the technique of digital three-dimensional model-processing.This condition is imperative for the efficient selection and analysis of relevant data from the photogrammetric model.

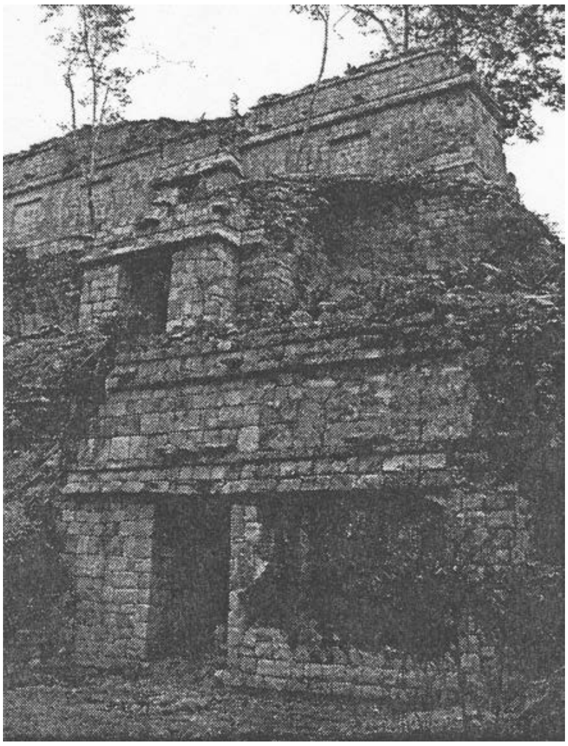


Fig.4: Markedly sectionalized design of facade

3. DIGITAL PROCESSING OF 3D-MODELS

Hard- and Software
The output of this research work was to be accessible to interests of various fields. A PC-based CAD-system was, therefore, an essential criterion of the project. The system also was to be open to the programming of macros in order to allow for a large - if possible, unlimited - number of thematic layers. This is an important condition for the fading out of information that lies before or after the topical working layer. So, the processing was executed on a commercial 486-PC, with the internationally current CAD-system AutoCAD installed.

Interfaces
Data-material of tachymetrically recorded individual points and photogrammetric vectors was transferred by means of self-made transformation programmes. These programmes define the respective architectural elements by their layers and descriptive items. Moreover, they transfer point-and vector information into the AutoCAD-compatible data exchange format DXF.

Wire frame model
Constructions including surface elements are, in general, possible with the help of AutoCAD. But once surface elements are defined, there is no way of altering the data; deletion and renewed construction of the whole element are consequential. In the topical case, numerous alterations of the model had to be carried out with the available CAD-tools, for instance "Extend" or "Trim". Accordingly, the first step was the construction of a wire frame model.
Its construction was supported and carried out by special macro-programmes. Written in the computer-language LISP.

They executed recurring routine work, e.g., the automatic turning of the object into the layer of construction relevant for the following working stage, the automatic switching from one thematic layer to the other or the coordination of the construction process itself.

Contrary to the construction of the interior rooms the modelling of the facade with its strongly sectionalized design was rather difficult and lenghty. The great number of details leads to manifold spatial intersections, which are not supported by CAD. Consequently, the construction of intersections requires a large number of single steps, which is extremely time-consuming.

The construction of such three-dimensional wire frame models requires a high capacity of spatial imagination and profound knowledge of descriptive geometry. In all cases it is of great advantage that the operator should thoroughly know the site - in several cases, like the reconstruction of walls and ceilings, this is imperative. Architectural details, like joist holes in the vaults, were not represented in the wire frame model, because it is difficult to construct intersections of cylinders with planes arranged in slanting steps.

When the reconstruction of the upright walls was completed, contour lines resulting from photogrammetric processing and describing the amorphous parts of the palace were fed in.

Solid model

In order to produce horizontal or vertical sections as well as axonometric or perspective views, the wire frame model had to be transformed into a solid model. This was achieved by inserting planes (in AutoCAD, these are called "3D-faces") into the wire frame model. The wire frame model was completely covered with these triangular planes. Individual space-constructing elements like front walls, ceilings, floors, etc., were, once again, registered in individual thematic layers.

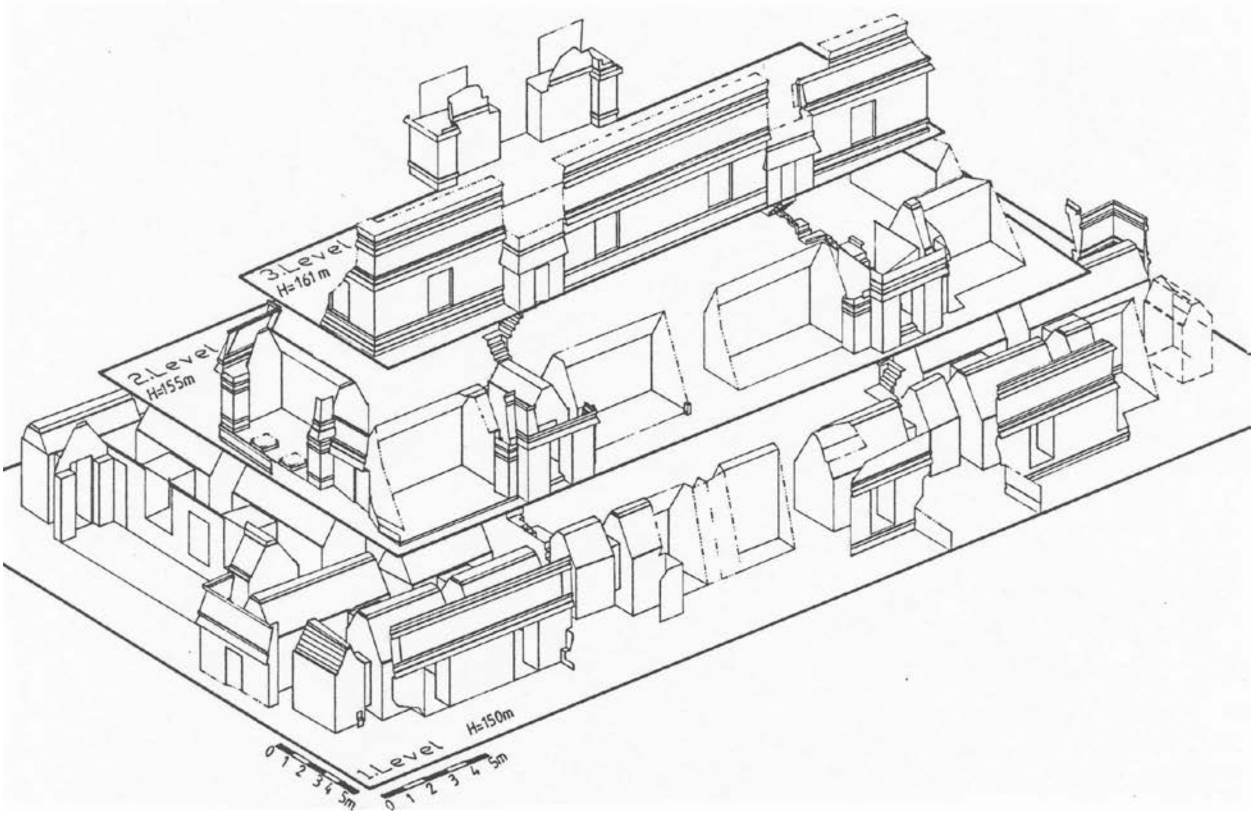


Fig. 5: Axonometric view from north-west, showing rooms, stairwais and facades of the different leves

4. GRAPHIC PRESENTATION

The complete solid model is, thus, a graphic data bank, and all required presentations can be derived from it. Subdivision into different thematic layers allows for the convenient selection of architectural elements. Apart from any kind of sectional drawings it is also possible to gain axonometric and perspective presentations. The use of "hidden-line"-algorithm adds to the clearness and lucidity of the presentations.

For the processing of section drawings the 3D-modelling and animation programm "3D-studio" by Autodesk was used. Among other things, it allows for further processing of solid objects computed in AutoCAD. The package contains a number of possibilities, from which two tools were selected for use in this project:

1) Combination, intersection and difference of two solid objects:

This opened the possibility to produce intersections and combinations of wall surfaces and architectural details, like joist holes in vaults, etc.

Moreover, sectional drawings of any kind can be produced quite easily.

2) Photo-realistic presentations of the building by selection of appropriate plane material, arrangement of sources of light, etc.

Fig. 6: Axonometric view from south-east: Contourlines showing the amorphous parts of the structure

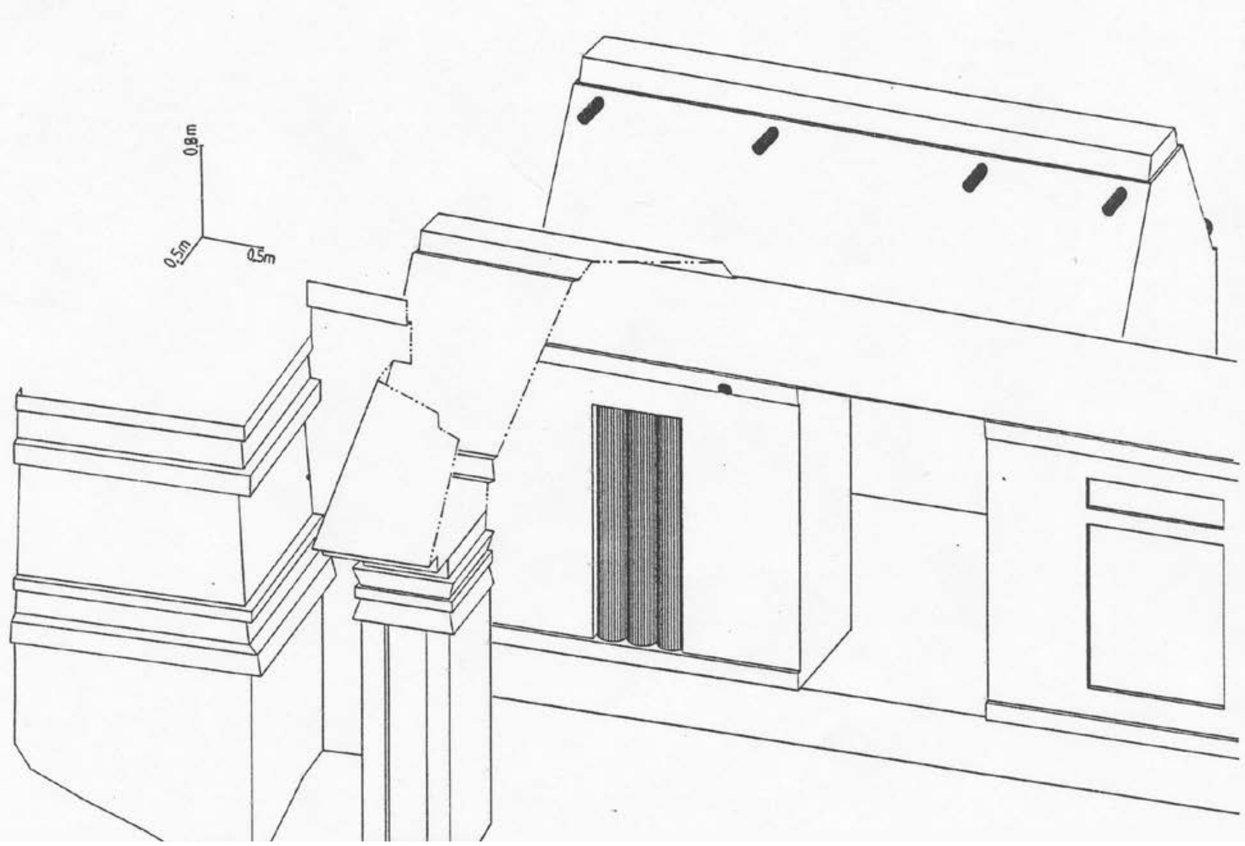


Fig.7: Example for the high accuracy and the vastness of small elements of which the model is made

5. SUMMARY

The project completed, it became evident how important it is to work on the basis of good quality geodetic-photogrammetric recordings, especially for an efficient computing of a digital three-dimensional "architecture model". A solid model can only be promptly and easily constructed if the results of the data recording are complete and clearly defined.

The advantages of the digital model are numerous:

- plans for any possible field of research can be computed at invariant scales, homogeneously and completely, in adequate form;
- axonometric and perspective presentations, which make it easier to understand complex spatial and structural relations, are directly accessible;
- data material can easily be supplemented and reconstructed because of its digital storage;
- animation- and simulation programmes produce highly realistic presentations of the objects;
- the graphic three-dimensional "architecture model" is, at the same time, a multi-functional data bank and a basis for stock presentations serving further archaeological and cultural-historical research.

From this point of view the Santa Rosa Xtampak project also functions as a successfully completed
exemplary study.

ACKNOWLEDGEMENT

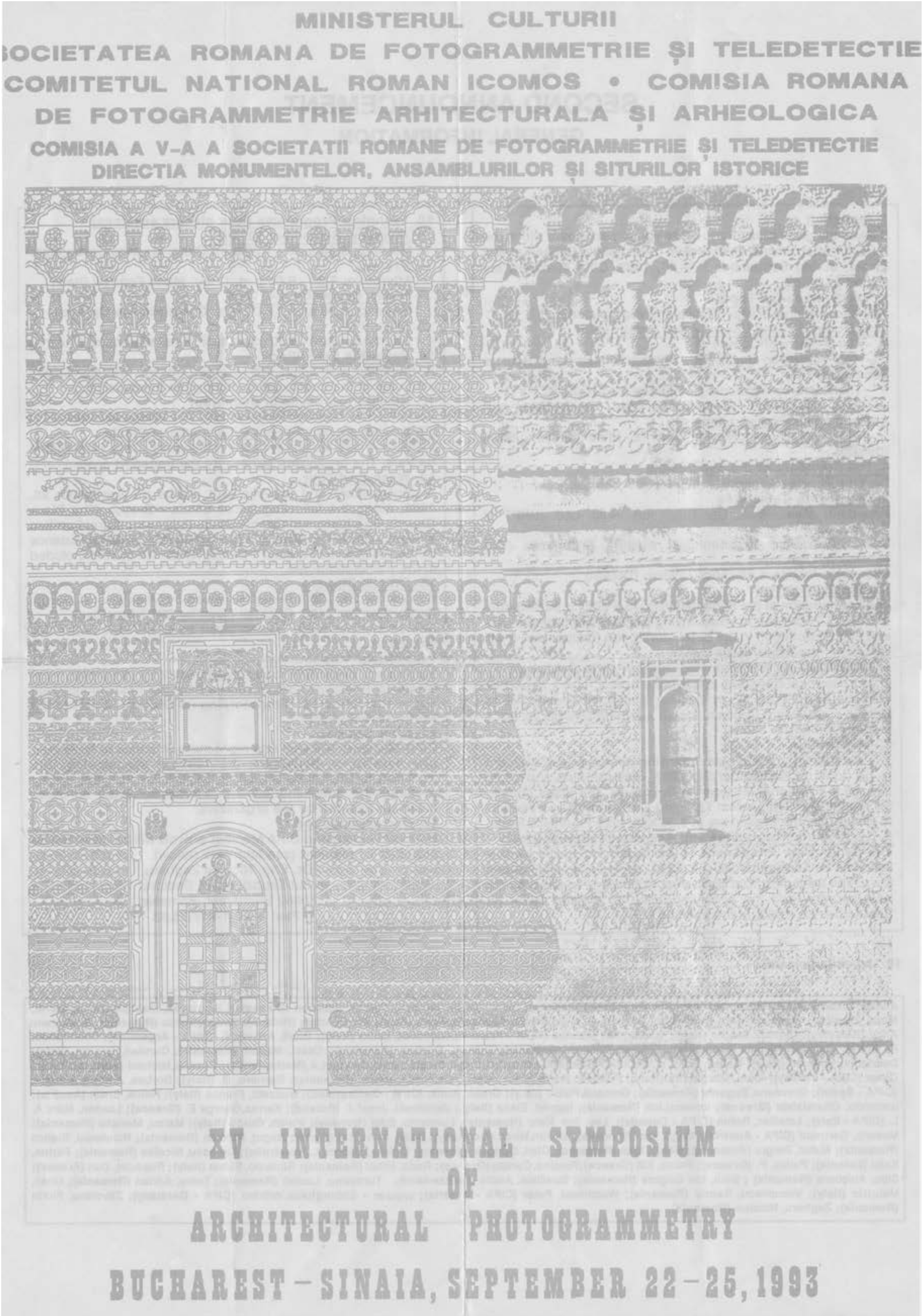
This project was made possible by financial means provided by the "Fonds zur Förderung der wissenschaftlichen Forschung" in Vienna.

Invaluable support has been provided by following institutions:

- Dr. Dipl.Ing. Hasso Hohmann, Interdisziplinäre Arbeitsgruppe Mayaforschung Graz, Austria
- Mexico´s Instituto Nacional de Antropología e Historia (I.N.H.A.)
- Dr. W. Folan, Universidad Autónoma del Sudeste, Campeche, Mexico
- Institute for Applied Geodesy and Photogrammetry, Technical University Graz, Austria.

Sion, I.G. (Editor)
Architectural and Archaeological Photogrammetry. Proceedings of the International Committee for Architectural Photogrammetry, Vol. XV, 314 p. IGFCOT Bucharest.

XV International Symposium of Architectural Photogrammetry, Sept. 22-25 1993, Bucharest.



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