THE USE OF CONTEMPORARY PHOTOGRAMMETRIC PROCEDURES FOR THE RECORDING AND DOCUMENTATION OF LARGE MONUMENTS AND THEIR GRAPHIC REPRESENTATION

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ABSTRACT

The continuous development of digital photogrammetric methods affects positively the application of photogrammetry in archaeology, providing improved methods for the recording, the documentation and the detailed restitution of monuments.
The modern image acquisition methods and systems, the field measurements, the data processing and editing, the production of fully digital detailed horizontal plans and facades of large monuments are examined, and cost and time improvements of the above procedures are investigated.
Special emphasis is given to the graphic representation of the digital information produced by the above methodology. Critical factors are the desired scale of the plans, the required degree of accuracy and the codified symbolisation of all characteristics of the monument which will provide the necessary information to the architects and archaeologists who will be the users of the photogrammetric products.
Specific examples of all the above steps and the results of our close co-operation with specialised architects are given for two comparatively large Byzantine castles and one monastery on the Greek islands of Kos and Chios.

1. INTRODUCTION

The task of recording an archaeological inheritance is of significant importance, especially for a country like Greece with a vast number of monuments dating from the prehistoric era up to the recent past. For this purpose, it is essential to use all the available means and methods of modern technology. It is widely accepted that digital photogrammetric methods provide a means for the rapid and satisfactory geometric documentation of monuments and one which provides a sound basis for a modern integrated recording through a GIS (Potsiou et al, 1991). Particularly for the survey of large monuments, or for the detailed surveying of part of a monument, the ever developing procedures of digital photogrammetry provide alternative solutions, which combine reliable surveys with positive savings in time and cost.

The theoretical knowledge and correct usage of photogrammetric methods, however, is not enough for the appropriate geometric recording of all the components of a monument. The large monuments are usually complex structures, whose contemporary outlines are derived in most cases from repeated interventions and demolitions, human or natural, through the course of time. Additional necessary factors for a successful recording are: a knowledge of the history of a specific monument, of the construction methods and the techniques of the various constructional phases etc.

The problem was faced in practicality when a team of members of the Laboratory of Photogrammetry in collaboration with members of the Laboratory of Surveying of N.T.U. of Athens, untertook the project of geometrically recording three large Greek Byzantine monuments (the project was commissioned by the Ministry of Culture of Greece):

a. The Castle of Nerajia, on the harbour of the Island of Kos. This Castle is one of the three (Rhodes, Kos, Alicarnassos) built by the Knights of St. John of Jerusalem. It consists in fact of two nested Castles. The newer, external one, built in the XVI century is in very good condition and has an area of 3 hectares and a perimeter of 845 m.
b. The seaward part of the Castle of the City of Chios, of the island of that name. This particular part of the castle is approximately 250 m length and includes a tower with a system of internal corridors.
c. The Monastery of the 'Nea Moni' inland on the Island of Chios, at an altitude of 450 m, with a yard area of 1.3 hectares and perimeter of 470 m. This monastery is of significant historical importance, with an extensive inhabitation during its period of high activity. An ancient Byzantine tower is still preserved, two blocks of monastic cells and three churches, the central one having exceptionally interesting golden mosaics in the cupola.

The geometric documentation included horizontal plans, facades and intersections on scales of 1:50 up to 1:200 and at various projection levels (at ground level, aerial view and at particular levels) according to the part of the monument concerned and the reasons for the restitution:

- reparation of a destroyed structure on the seaward aspect of the Castle of Chios
- restoration of the cells of the Nea Moni or
- surveys for developing planning studies at the Castle of Kos.

The definition of the necessary plans and the means and accuracy of the restitution of the components of these monuments, have clearly shown the need for a close interscientific co-operation by the research team (photogrammetrists and surveyor engineers) with members of other disciplines, such as architects and archaeologists. The result of this co-operation underlined the benefit of using modern digital methods of recording.

2. THE INTERSCIENTIFIC COOPERATION FOR THE GEOMETRIC DOCUMENTATION

The integrated documentation of a large monument and more specifically a Castle -as has been studied and applied (Potsiou et al, 1992)- requires the contribution of various disciplines, since it includes about 10 unites of

various aspects, including: general information, publications, images, measurements, archaeological, architectural and technical information, works of art etc.

The geometric recording area seems to be the concern of the Surveyor Engineer and to a great extent the Photogrammetrist. Yet, the approach to an object on large scales (1:100 and larger) is so complex as to demand the contributions of a specialised architect and archaeologist at all phases of its development. Reference to this has also been made briefly in the past, in the description of the surveying operations for monuments (i.e. Badekas, 1981) without a more detailed analysis of the problem. Besides, the modern means for the development of plans make the problem more extensive. For example, through the use of digital methods, the definition of the final scale of drawings is no longer a decisive factor for the accuracy of the plan, especially in the case of recording monuments where the future usages of the plans may be multiple.

Before the execution of any operation, particular critical questions have to be answered, which will to a considerable extent, define the method that should be followed and the strategy of its execution. Such questions are:

- What is the desired level of accuracy of the various components of the monument. The level of accuracy may vary even between components restituted on the same plan, i.e. in between the perigrammes of the apertures in the facade shown on Figure 1 and the detailed restitution of its masonry.
- What are the critical elements that must be restituted on a plan, i.e. in a semidestroyed area of the monument or in an area which has suffered serious interventions or alterations to the original structure, so that they can be distinguished in the final plan (see the arches on the facade of Figure 2 which indicate the existence of apertures at that location in the past).
- In what way all the various phases of construction will be demonstrated in the final plan, i.e. the condition today of the apertures of the castle (in Figure 3 are shown with various symbolisations of the apertures that have been filled-in or altered) or various building techniques (an example is a facade of the tower of Nea Moni on Figure 4).

The solution which proved practically to be the best for the prompt answering of questions such as those mentioned above, avoiding the unnecessary repetition of operations or a decreased quality in the results, was the creation of a 'working-group' consisting of Surveyor Engineers and Photogrammetrists, Architects and Archaeologists, which actively contributed at almost all stages of the project. More specifically they contributed to:

1. The preparation and the organisation of the whole work, of all four specialities.
2. The field work (measurements, photography), by all four specialities.
3. The calculations of the data (point coordinates, orientations of photos etc.), by the Surveyor or the Photogrammetrist according to each specific task.
4. The digital restitution of the plan on the screen, by the Surveyor or the Photogrammetrist and the Architect in close co-operation, for a significant percentage of the working time.

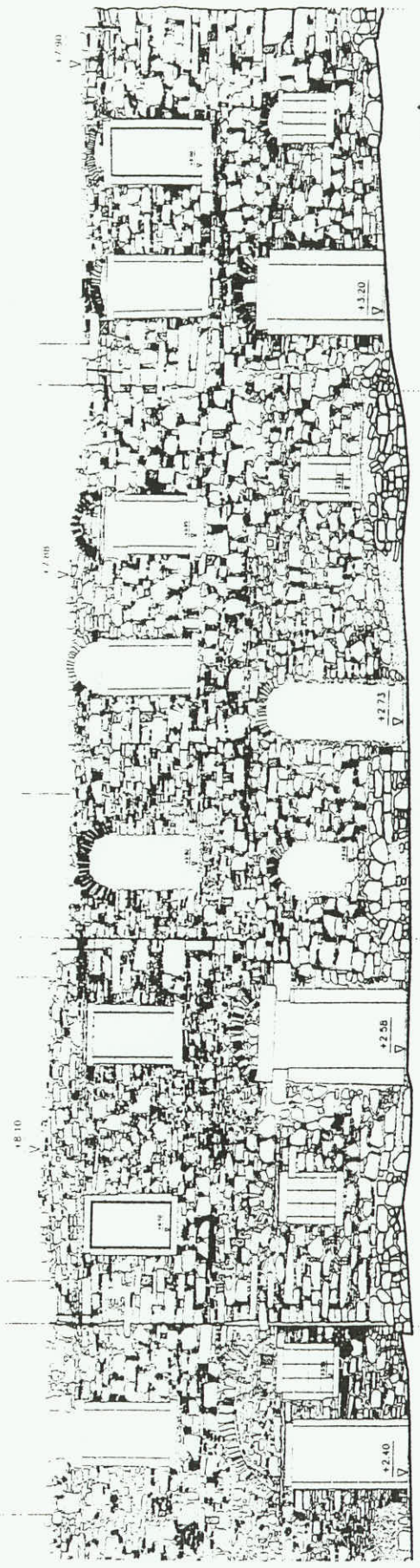

Figure 1. Detailed survey of the facade of the southern block of monastic cells of Nea Moni (decreased to a scale of 1:100)

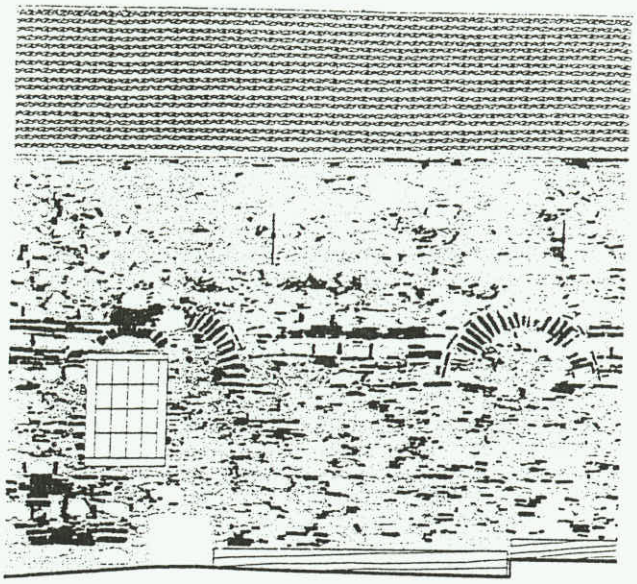

Figure 2. Part of the facade of a building of Nea Moni with interventions in the initial structure

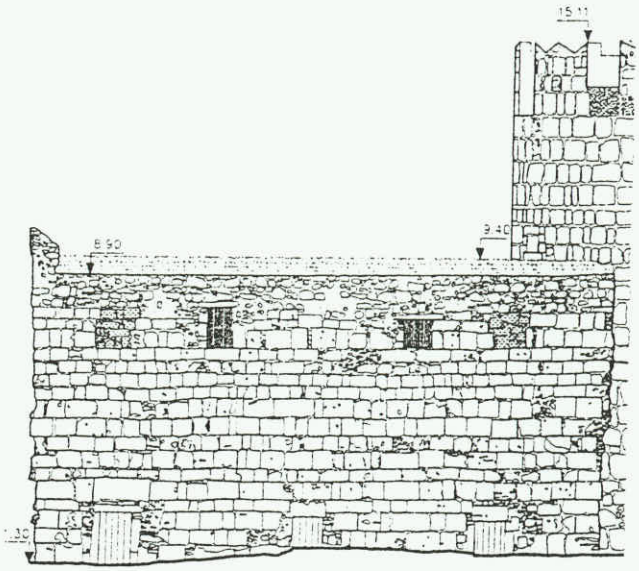

Figure 3. Part of the eastern facade of the Castle of Kos, with three different types of symbolisation for the representation of the contemporary situation

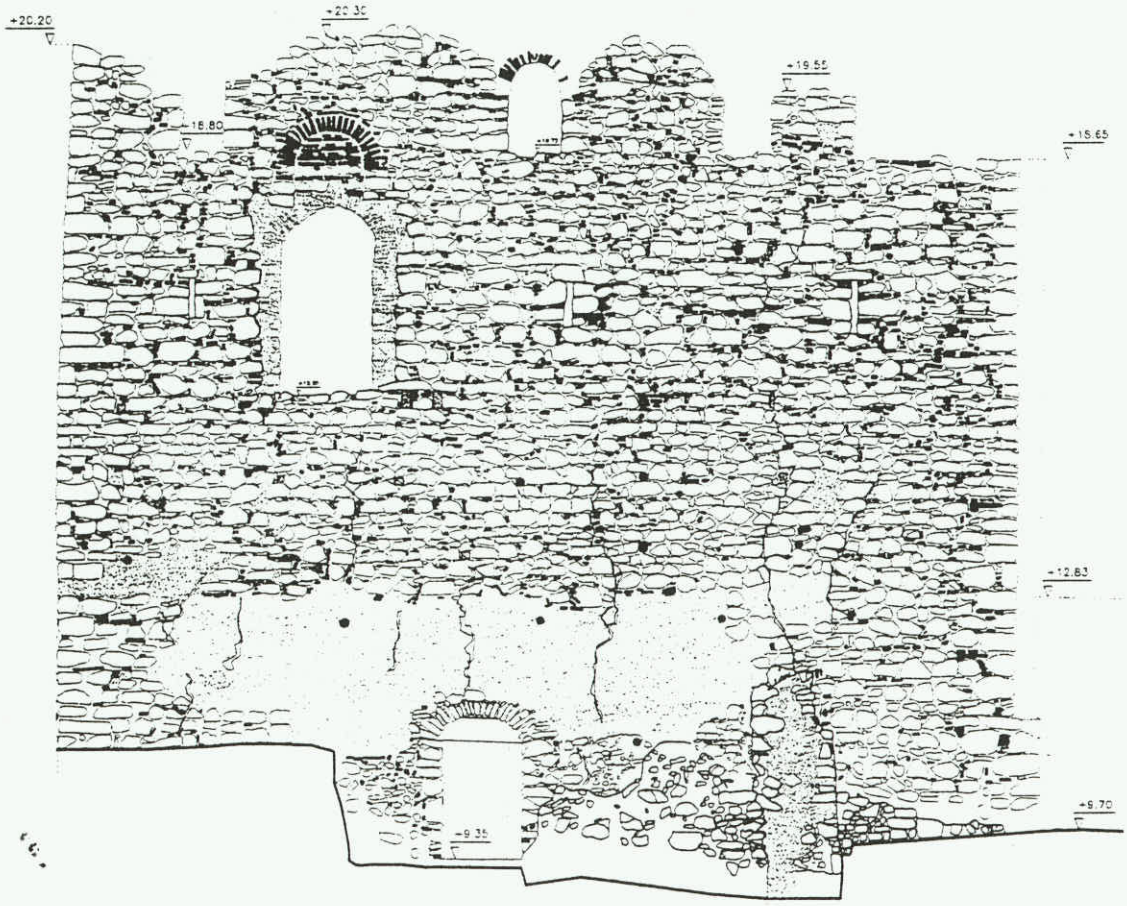

Figure 4. Eastern facade of the Byzantine tower of Nea Moni

5. The definition and the restitution of the symbols and the final editing of the plan, by participants of all four specialties.

It must be stressed that the Photogrammetrist in some of the above stages of the work, was the executant, the member who provided the technical know-how, although the result forms the topographic basis for further architectural plans for development, intervention etc.

3. DIGITAL PHOTOGRAMMETRIC METHODS

3.1 Instruments and methods for photography

Long experience of the application of photogrammetric methods to the restitution of archaeological monuments and sites, even with analog or analytical procedures, has proved the capability of the acquisition of excellent results on various scales and according to various demands (Portelanos, 1987).

The variety of problems that had to be faced for the recording of the three monuments demanded the use of almost all the facilities available for taking photographs and their restitution by digital procedures. The basic criteria for the selection of instruments and methods were low-cost instrumentation and the avoidance of time consuming methods.

The photography used the following, on all three sites:

a. Zeiss UMK 10/1318 phototheodolite, f=100 mm. This camera was selected although it is a comparatively expensive and inconvenient instrument, for its large image format 13x18 cm. In comparison with other cameras, it is more beneficial when large areas must be covered as it needs a lower number of images and consequently less scanning and image processing time. In the particular applications it covered the external facades of more than 1 km length for the Castle of Kos, 500 m for the Castle of Chios and 200 m for the Nea Moni.
b. The Rolleiflex 6006 camera fitted with a reseau, f=80 mm, format 5.5x5.5 cm, was used alternatively with the previous camera for the covering of smaller individual surfaces, for taking aerial photos etc. It is an especially 'user-friendly' and comparatively light camera, and has been used successfully in difficult situations (i.e. on a scaffold, with the bipod etc.)
c. The Hasselblad 500C/M camera with a lens of 50 mm focal length and format 5.5x5.5 cm, was used mainly in internal areas of narrow width, such as casemates and corridors of 2-5 m width, where the use of a Rollei lens would have covered too small an area of the wall.
d. The Nikon F40 amateur camera, with lens focal length of 28-80 mm, used without calibration. Initially it was programmed for use in a great number of situations for documentation purposes only. But finally it was also used for photogrammetric rectification, in addition, for reasons of completeness or for the better understanding of particular parts of the object.

The Kodak DC50 digital camera, owned by the Laboratory of Photogrammetry, was not used, despite the fact that the image scanning would have been avoided, because at that time it was not yet calibrated and tested in applications of the appropriate kind and dimensions. Of course there are references to the use of digital cameras in archaeological applications (i.e. Milella, Fiore, 1997) and this is an object of special interest for future usage.

As the location and shape of the object created significant problems during the photograph taking phase, besides the normal, terrestrial ones, photos were taken:

- by boat, from the sea, with the UMK and the Rollei, in a total 6 stereoscopic models, for the coverage of the external wall of the eastern part of the Castle of Chios. In Picture 5 one of these photos is shown.

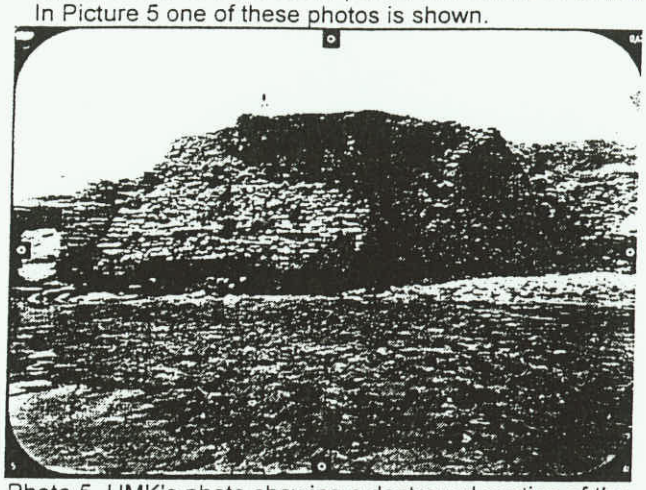

Photo 5. UMK's photo showing a destroyed section of the Castle of Chios, taken by boat

- by a make-shift scaffolding which was improvised at the Nea Moni for the photography of parts of the northern monastic cells, since the 'West Road' of the monastery is especially narrow (1.7m up to 3.3m) and on the other side of the road are two-storey cells.

In total, at all three sites the following photos were taken (besides the photos taken by the Nikon amateur camera):

- At the Castle of Kos, 65 photos for rectification and about 70 photos for stereoscopic restitution (approximately 40 models). In Figure 6, a general topographic plan of the Castle is shown, with the positions of photos taken of the facades of the wall of the Castle.
- At the Castle of Chios, about 50 photos for rectification and 30 stereomodels for the internal and the external aspects of the wall and the tower. Also, about 100 photos for the casemates and internal corridors of the tower.
- At the Nea Moni, 37 photos for rectification and 7 stereomodels for the facades.

The difficulty of the acquisition of aerial photos for the compilation of horizontal plans at scales larger than 1:200, usually limits the archaeological applications of photogrammetry in restitutions of facades or vertical intersections. This also happened in the projects under description. The horizontal plans and horizontal intersections were compiled by surveying methods except for some small sections, where the use of photogrammetry was absolutely necessary, due to the density of the required information. For example, for the compilation at a scale of 1:100 of the cobbled flooring of the Nea Moni, or the structure of the upper surface of a large staircase of the Castle of Kos at a scale of 1:50. There are few alternative solutions for aerial photography, most are exceptionally expensive and, above all, have restrictions to their applications, caused by various factors. Such solutions are:

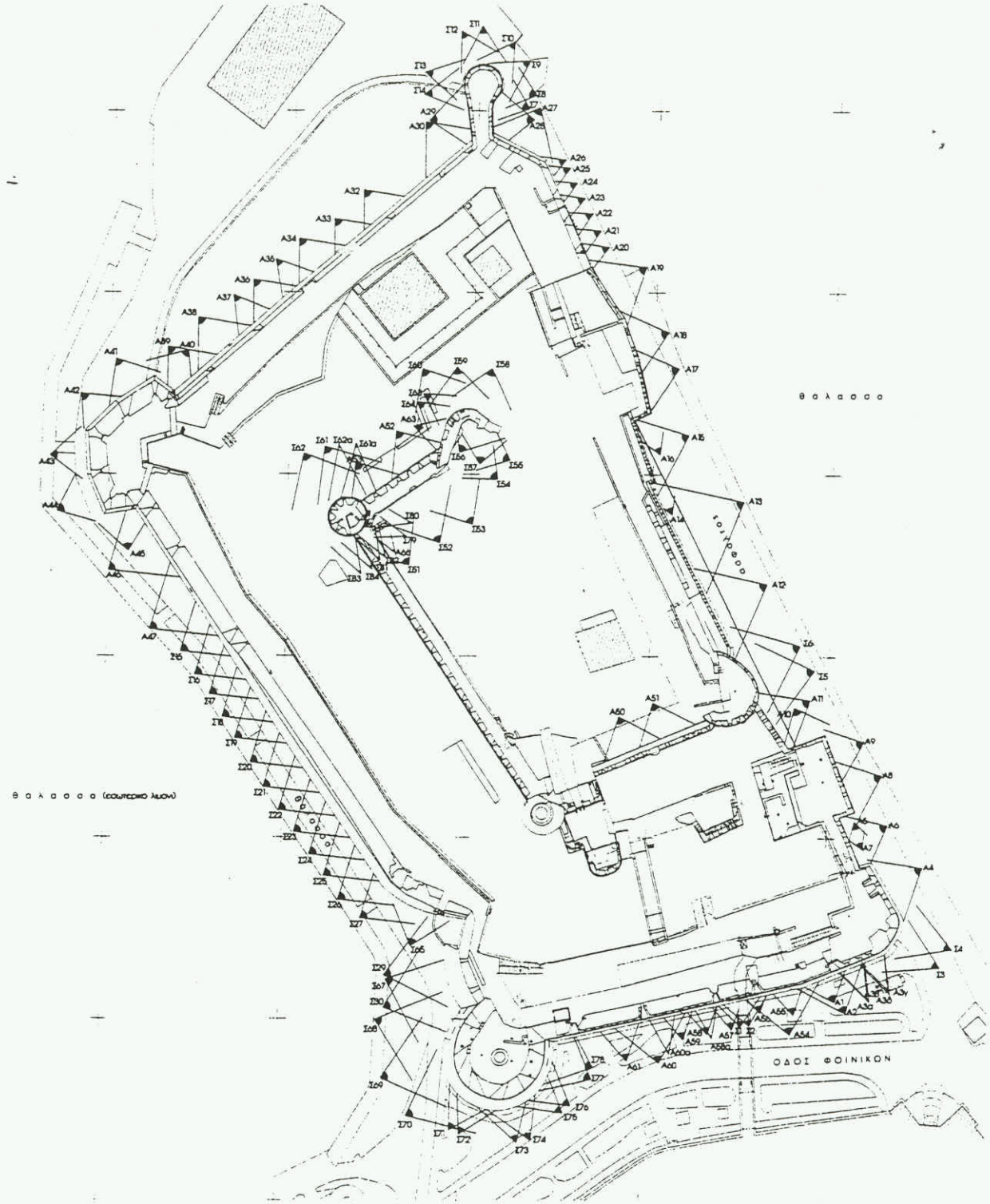

Figure 6. General topographic plan of the Castle of Kos with the positions of photos taken for the facades of the wall

- a helicopter with a properly structured mounting for the camera. It is especially expensive and it is only suggested in cases of photocoverage of large areas. Also it does not have the capability to take photos from levels lower than 20-25 m and there are restrictions in flights over urban areas etc.
- a balloon or other means of achieving height, which are usually difficult to use, especially for the acquisition of stereoscopic photos, because of the wind, the insecurity in positioning the exposure stations at the desired coordinates, the appropriate orientation of the image frame etc.
- a suitable scaffolding for access above the sections of interest, which can be applied only in special cases
- a bipod or tripod, which can elevate the camera to a level of up to 10 m above the ground. Difficulties may arise due to the topography of the area. It is not recommended for coverage of large surfaces or for the compilation of plans at scales of less than 1:100.

In the present case the use of a bipod was selected, with Rollei and Hasselblad cameras for the acquisition of photos at a level of 8 m, either for monoscopic or stereoscopic process. In Figure 7 a part of the cobbled flooring of Nea Moni is shown, which was compiled photogrammetrically (aerial photography by Hasselblad) and adapted to the general topographic plan of the monument.

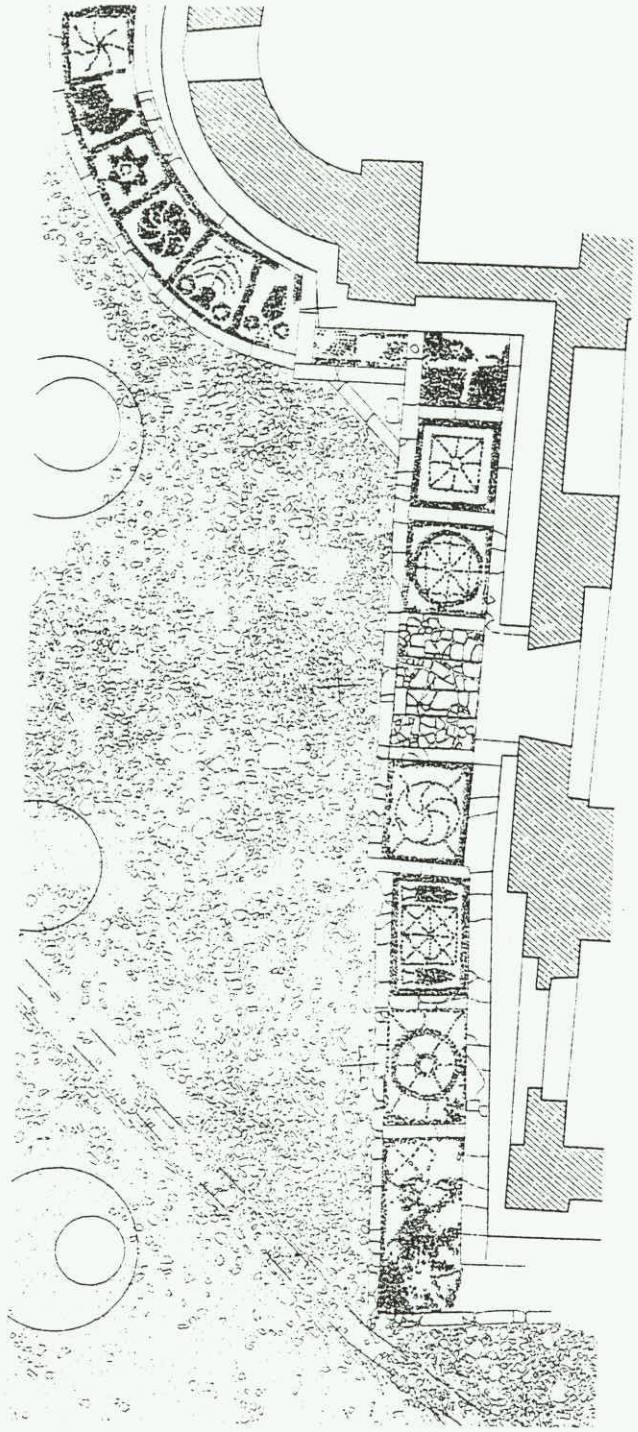

Figure 7. Detailed survey of a part of the cobbled flooring of Nea Moni

To cover the need for control points, either for terrestrial or for aerial photos, the following were used:

a. Square black and white targets, of 5x5 cm for the photos taken from distances of up to 12 m from the object and 7.5x7.5 cm for photos at distances of between 12-20 m.
b. Clearly photo-identifiable natural points, only for situations where access was impossible, such as the seaward elevations of the Castle of Chios, around the area of the parts of the castle which have been semi-destroyed or in some exceptionally steep parts of the Castle of Kos.
c. Simple wooden frames of fixed and measured sides of 2x2 m or 1x2 m, in which 8 or 5 (correspondingly) square targets of 5x5 cm were placed (Photo 8 and 9). They were used for the photography of the vertical sides of the corridors of the towers, so that all the necessary data (that is distances) for the rectifications was known. In this way, the measurement of a large number of control points was avoided (each photo covers an area a little larger than the relevant frame). In each photo either one frame is shown, so that 1 or 2 targets were measured (Photo 8), or one frame and a small part of a second frame which, without been moved from its particular position, will appear on a successive photo (Photo 9). In this last case no other measurement of control points is required, except those at the ends of the rectified photomosaic, which can be compiled.

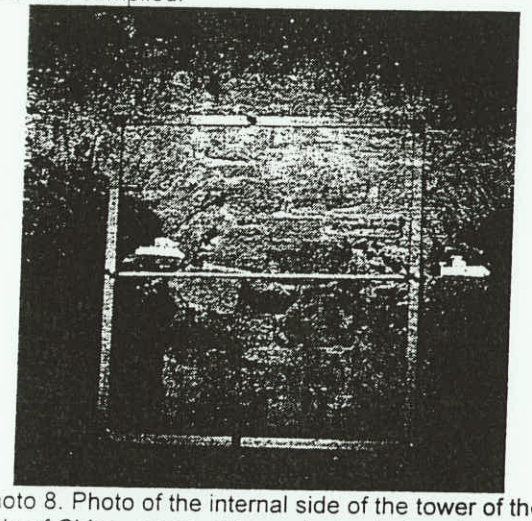

Photo 8. Photo of the internal side of the tower of the Castle of Chios -usage of frame instead of control points

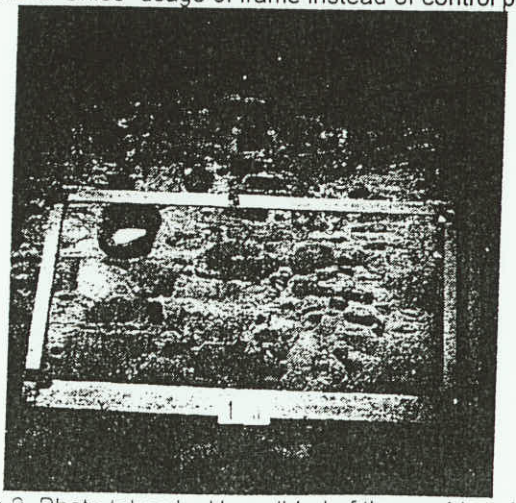

Photo 9. Photo taken by Hasselblad of the corridor of the tower of the Castle of Chios -usage of two frames

3.2 Photogrammetric processing

Since all the photographic material is in analog form (negatives and paper prints), the initial processing that must be applied is scanning, for its transformation into files of TIFF format. After some trials with calculations of check point coordinates, it was shown that for the achievement of a final accuracy of about 1-2 cm it is sufficient for the scanning to be done at a resolution of 600 dpi with a regular A4 scanner, i.e. HP ScanJet 4c, when the accuracy of control point coordinates is 1 cm and the scale of negatives (of UMK and Rollei) up to 1:150. Sufficient results (2 cm) were achieved even by rectifications that were done from a scanning, with 600 dpi, of prints 2X of photos taken by the Rollei and the Hasselblad.

The photogrammetric process that followed was executed in purely digital form. Vector plan compilation was selected as applicable, because the photomosaics or the orthophotomaps did not constitute a suitable basis which would allow further processing, for the production of i.e. special architectural plans for the pathology of the buildings etc. They do give the architect or the archaeologist the total amount of information that is contained in the initial photo, but they do not accept the volume of additional vector information that must be included in special architectural plans. The substitution of photographic image was achieved in the vector plan by detailed definition of the surface symbols -patterns (see further in chap. 4).

The methods that were applied for the compilation of plans for the geometric recording of the monuments were:

- Digital rectification, which was applied to flat surfaces, or surfaces in low relief where the accuracy of the detailed restitution was not decisive, i.e. for the masonry where there are damaged surfaces of the stones or small 'holes' due to the absence of stones. The programme ARCHIS for Windows of SISCAM was used, which has the capability of rectification by using either known control points or by using measured vertical and horizontal distances on the object. Also, it has the capability of compiling photomosaics. The restitution of the vector plans was achieved in two ways, either in ARCHIS environment or by transferring the rectified image into the AutoCAD environment through the VIMAGE programme.
- Stereorestitution in a digital photogrammetric system was used in the rest of the cases (curved parts of the wall, towers, domed surfaces, damaged areas of the facades etc.) The PC-based photogrammetric system VMAP of VTA Photogrammetric Consultants Ltd. was used, despite the fact that the SoftPlotter of VISION in Workstation of Silicon Graphics was also available. This selection was made to test the capability and performance of a cheap digital photogrammetric system in the execution of such an integrated project concerning the geometrical documentation of large monuments with an increased volume of data and significant demands in accuracy and product quality. In having the proper PC, with a powerful Pentium processor and hard disk with large storage capacity, the general conclusion is that such a solution could be selected and could be technically and financially acceptable, taking into consideration the following remarks:
  a. There is, indeed, an inferiority in operation and user-friendliness. Since the volume of data is increased and one has to deal with it every day, these two factors become of significant importance and negatively influence the judgement of such a digital system. The data structure and storage technique, and the observation system comprise the 'weak links' in the system.
  b. The accuracy and the product quality, as long as it depends on the hardware and software of the system, is absolutely satisfactory according to the technical specifications for archaeological applications.
  c. The time performance of the system is directly dependant on its functioning. So, even without any time consuming procedures during the individual steps, the total performance of the system is not the fastest possible.

4. SURVEYING AND REPRESENTATION METHODS IN A FULLY DIGITAL ENVIRONMENT

The product of the photogrammetric restitutions and rectifications, and the surveys of field measurements also, is the creation of files of drawings in digital form in CAD environment, in the present case AutoCAD. The target was to create easily changeable digital plans which would consist of not only the integrated geometrical recording of the monument, but also the flexible breakdown for further specialised studies.

The way of representing the facades and the selection of the planes of their projection comprise significant elements for the conception and utility of the drawings in complex monuments such as those involved in the project. A basic decision of the research team was the restitution of all facades -independently of their shape (curved parts at the towers or the internal corridors)- onto projection planes and not the creation of a digital development. The development is good for developable surfaces (full cylinders or cones), but in the rest of the cases, by distorting the object they can only help in special studies of the monument, i.e. for measurements in re-construction projects etc. So, in the three sites, the following were selected:

- The basic projection planes of the facades, where the whole object is shown, i.e. 4 and 2 planes for the external wall of the Castles of Kos and Chios correspondingly.
- Many additional projection planes for the more detailed representation of parts of the object, which are either projected with an angle greater than 5^g onto the basic plane (individual facades) or they are curved surfaces (one or two auxiliary planes vertical to each other).

For the execution of the tilts of the rectified surfaces to the projection planes, a special software was compiled in LISP of AutoCAD.

In Figure 10 the facades of one tower of the Castle of Kos, with the relevant plan of the horizontal drawing underneath, are shown in the selected projection planes (two basic and one auxiliary).

A significant part of the whole work was the digital editing of the drawings on the screen, the selection and inserting of proper patterns/symbols, so that the result should clearly indicate the present condition of the monument

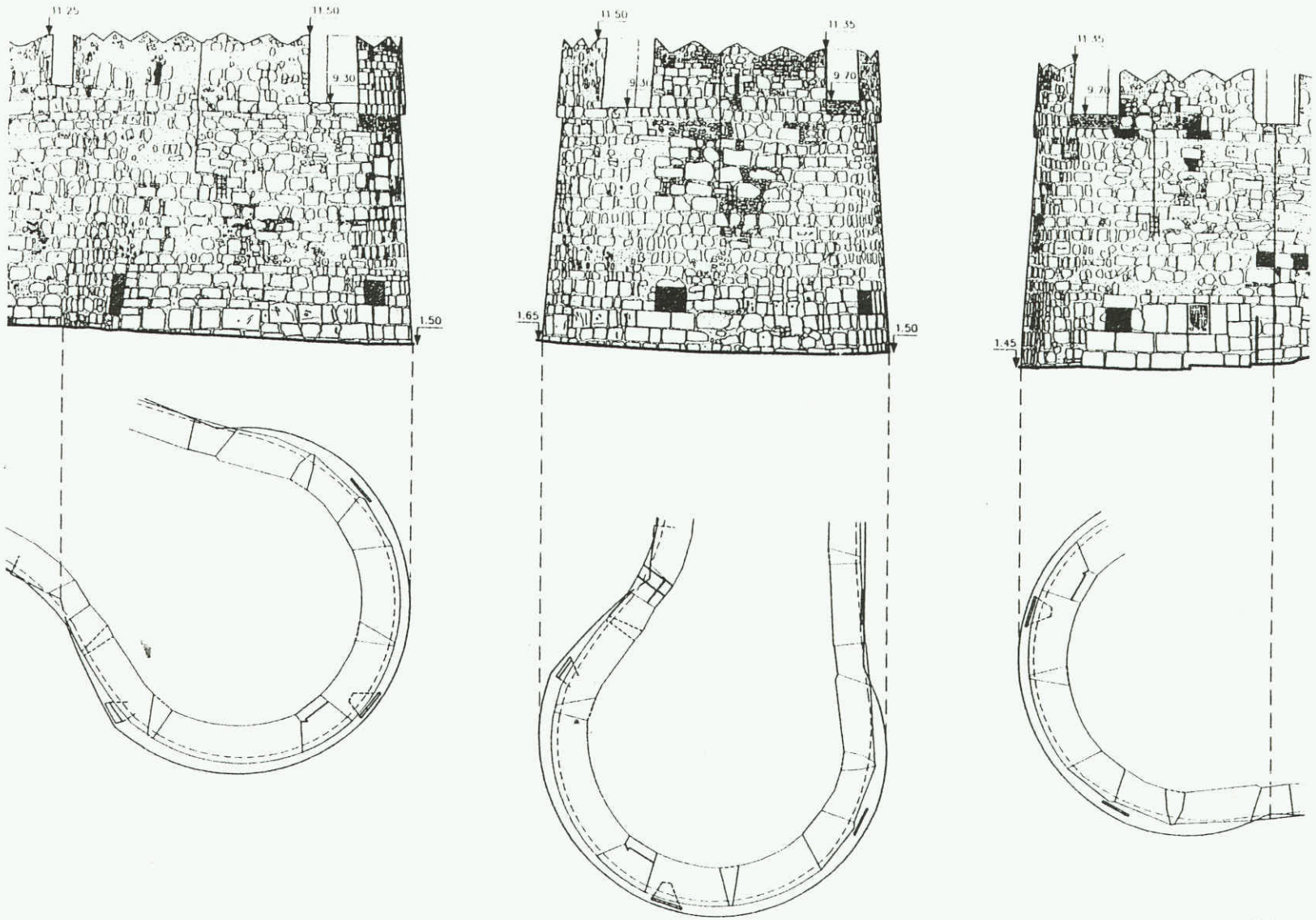

Figure 10. Facades of a tower of the Castle of Kos on three projection planes (decreased to a scale of 1:200)

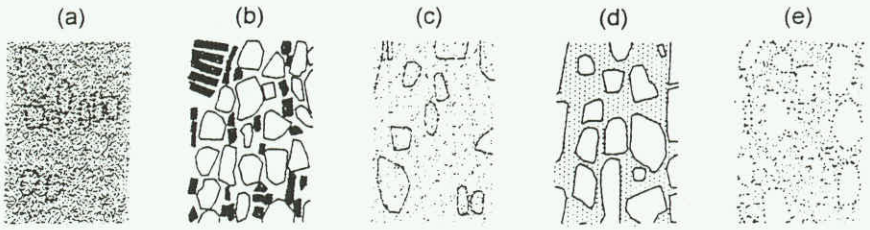

Figure 11. The 5 patterns of surface-symbols for the condition and the structure of the facade of the monastic cells of Nea Moni, for a scale of 1:50

and the phases and various technologies of its construction. The main problem arise at the facades (photogrammetric surveys), since the topographic plans have a defined typology for most of the data. The linear symbols and the surfacial patterns used, should be:

- as simple as possible in their creation, so that no time consuming procedures are necessary for their application
- recognisable and clearly defineable from each other, so that no confusion is created
- their number should be kept comparatively small, so that the drawing can be easily read
- to follow the general rules of any existing and acceptable universal typology.

It is obvious that various patterns were selected for each surveying scale (1:50, 1:100,1:200), mainly for the density of their elements and the width of their lines. In Figure 11 the five patterns for the restitution of the method of construction and the present condition of the surfaces are given, for the scale 1:50 : at (a) an area with detached stones is restituted, at (b) building with insertion of ceramics etc.

In Figure 12 a part of one facade of the external wall of the Castle of Kos is shown (decreased 50%), as derived by the application of the patterns for restitution on a scale of 1:100 for the shape and condition of the apertures, condition of the structured elements etc. In Figure 1 the shape of one facade after the application of the patterns/symbols for restitution on a scale of 1:50 is also given.

In Figure 13 the part of the facade, which in its final version is shown at Figure 2, is given without the surface patterns. The varification between the two images of the wall construction is clear. A false image impression is given by the facade of Figure 13 concerning the size and shape of the stones and there is great difficulty in understanding the type of construction (Byzantine technology in this particular case vis. 'plinth all around closed by ceramics construction').

5. CONCLUSIONS

The combination of digital photographic and field surveys provide the theoretical basis for the geometrical recording and documentation of large monuments or archaeological sites, by using low-cost hardware and software. A metric camera of small format (6x6 cm), or even a calibrated non-metric camera, a scanner (A4) with 600 dpi resolution and a PC-based digital photogrammetric system, could satisfy the needs in H/W and S/W for the photogrammetric surveys for the recording of any monument, regardless its size or complexity.

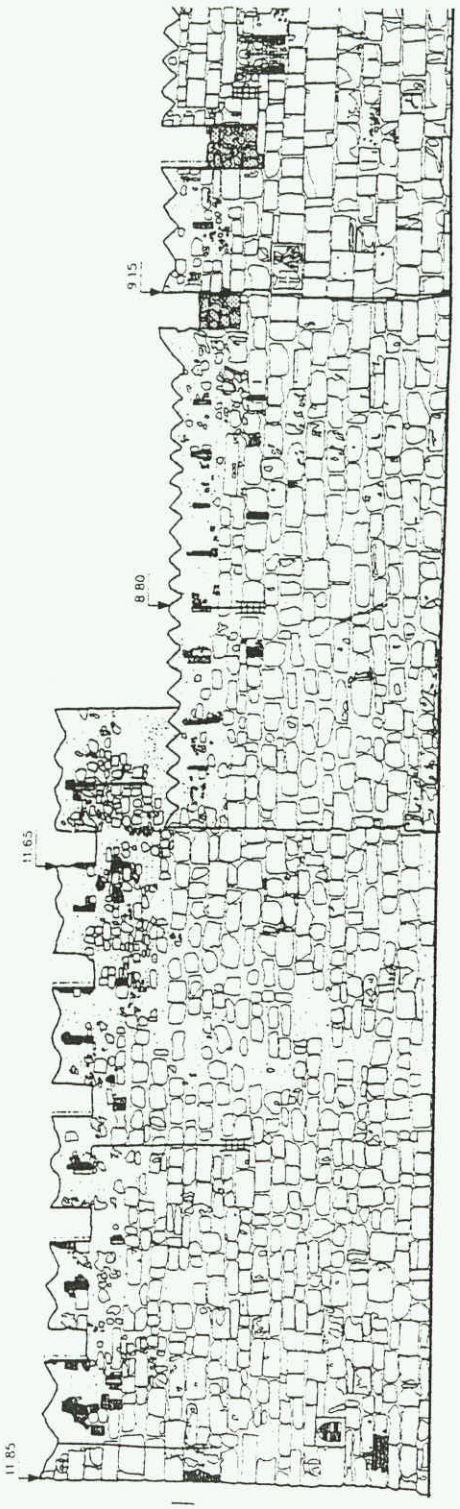

Figure 12. Part of the external wall of the Castle of Kos (decreased to a scale of 1:200)

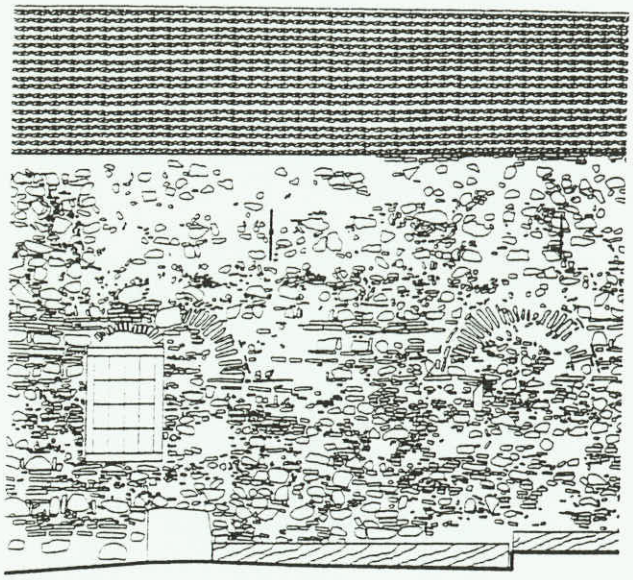

Figure 13. Part of the facade of a building of Nea Moni without using surface symbols (decreased to a scale of 1:100)

The critical points are:

- The suitable organisation of field and office work by using the capabilities of existing H/W and S/W for low-cost and no time consuming solutions.
- The composition of the working group members, where besides the photogrammetrist, not only the existence of an architect and an archaeologist but their active contribution to all phases of work is absolutely necessary.
- The need of experience and knowledge in providing integrated plans, suitable for multiple use. The CAD environment provide all necessary means for the editing and processing of digital data of topographic and photogrammetric surveys, to achieve the required symbolisation and pattern insertion digitally and in an exceptionally satisfactory way for all purposes of documentation of monuments.

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