5th INTERNATIONAL MEETING
FOR THE RESTORATION OF THE ACROPOLIS MONUMENTS

Athens, 4-6 October 2002

5th INTERNATIONAL MEETING

FOR THE RESTORATION OF THE ACROPOLIS MONUMENTS

Athens, 4-6 October 2002

New Administration Building of the National Bank of Greece
Amphitheatre of the Ministry of Culture

Editing: Fani Mallouchou-Tufano

Translation: D.Christodoulou, D.Hardy, D.Turner, L.Nika, C.Vassileiadis, C.Paraschi

Front page photograph: Socrates Mavromattis

Layout - Printing: ERGO m&p Graphic Arts Ltd

MINISTRY OF CULTURE
COMMITTEE FOR THE CONSERVATION OF THE ACROPOLIS MONUMENTS

5th INTERNATIONAL MEETING

FOR THE RESTORATION OF THE ACROPOLIS MONUMENTS

Athens, 4-6 October 2002

New Administration Building of the National Bank of Greece
Amphitheatre of the Ministry of Culture

ABSTRACTS OF THE PRESENTATIONS
SUMMARIES OF THE STUDIES

The 5th International Meeting for the Restoration of the Acropolis Monuments is co-funded by the Greek State and the European Union.

Sponsored by the National Bank of Greece

Organizing Committee

Ch. Bouras	Professor Emeritus of the National Technical University of Athens (NTUA), President of the Committee for the Conservation of the Acropolis Monuments (ESMA)
M. Ioannidou	Civil Engineer, Director of the Acropolis Restoration Service (YSMA)
M. Korres	Architect Ph.D., Associate Professor NTUA, Member of ESMA
F. Mallouchou-Tufano	Archaeologist Ph.D., Head of the Documentation Department, YSMA
C. Hadziaslani	Architect-Archeologist, Head of the Information and Education Department, YSMA
E. Papakonstantinou-Zioti	Chemical Engineer, Head of the Conservation Department, YSMA

Secretary

Ch. Papanikolaou	Administrative Staff, YSMA

MINISTRY OF CULTURE

Committee for the Conservation of the Acropolis Monuments

President	
Ch. Bouras	Architect Ph.D., Professor Emeritus NTUA
Vice-President	
P. Themelis	Archeologist Ph.D., Professor of the University of Crete
Members	
A. Choremi-Spetsieri	Archeologist Ph.D., Director of the 1st Ephorate of Prehistoric and Classical Antiquities, Ministry of Culture
D. Giraud	Architect Ph.D., Director of Anastylosis of Ancient Monuments, Ministry of Culture
M. Korres	Architect Ph.D., Associate Professor NTUA
V. Lambrinoudakis	Archeologist Ph.D., Professor of the University of Athens
A. Mandis	Archeologist Ph.D., Director of the 4rth Ephorate of Prehistoric and Classical Antiquities, Ministry of Culture
N. Minos	Conservator, Director of the Directorate of Conservation of Antiquities, Ministry of Culture
Th. Skoulikidis	Chemical Engineer Ph.D., Professor Emeritus NTUA
C. Syrmakezis	Civil Engineer Ph.D., Professor of NTUA
E. Touloupa	Archeologist Ph.D., Ephor Emerita of Antiquities
N. Valakou	Archeologist, Director of Prehistoric and Classical Antiquities, Ministry of Culture

PROGRAMME

FRIDAY, OCTOBER 4

MORNING SESSION

General information about the works

Chairman: Prof. Emer. Ch. Bouras

8.30	Registration
9.00-10.40	Inaugural Speeches
9.00	**M. Ioannidou**, Director of YSMA
9.20	**Dr. A. Choremi-Spetsieri**, Ephor of Acropolis
9.50	**Prof. Emer. Ch. Bouras**, President of ESMA
10.10	**Prof. E. Venizelos**, Minister of Culture
10.40	Coffee
11.15-14.00	Visit to the work-sites of the monuments of the Acropolis

AFTERNOON SESSION

Issues related to the surface conservation of the Acropolis monuments in general and, especially, to the conservation of the Parthenon West Frieze

Chairpersons: Dr. A. Choremi-Spetsieri - Prof. L. Lazzarini

17.00	**Th. Skoulikidis**, Methods for the conservation of pentelic marble
17.30	**C. Babanika - D. Damianos - G. Frantzi - A. Panou - A.Tsimereki**, General survey of the conservation work on the monuments and sculpture of the Acropolis
17.50	**E. Papakonstantinou - K. Frantzikinaki**, Assessment of the cleaning methods proposed for the Parthenon west frieze
18.20	**P. Pouli - V. Zafiropulos - C. Fotakis**, Combination of IR and UV laser pulses for cleaning sculptured surfaces: preliminary tests for the west frieze of the Parthenon
18.40	**Chr. Vlassopoulou**, The conservation of the Parthenon west frieze: an archaeological perspective
20.30	Inauguration, by the General Secretary of the Ministry of Culture Dr.L.Mendoni, of the exhibition "Photographs 1975-2002, from the Works on the Acropolis of Athens by S. Mavrommatis" in the Benaki Museum. Reception.

PROGRAMME

SATURDAY, OCTOBER 5

MORNING SESSION

Recent research and work in the Parthenon

Chairpersons: M. Ioannidou - Prof. C. Syrmakezis

9.00	**N. Toganidis**, The restoration project of the Parthenon in progress
9.30	**P. Koufopoulos**, The restoration project of the opisthodomos of the Parthenon
9.45	**R. Christodoulopoulou**, The west pediment of the Parthenon in relation to the opisthodomos restoration project
10.00	**E. Toumbakari**, Structural restoration of the architectural members of the opisthodomos
10.15	**A. Miltiadou - E. Papakonstantinou - C. Zambas - A. Panou - K. Frantzikinaki**, Structural restoration of the columns of the Parthenon opisthodomos with hydraulic grouts of high injectability: design and application
10.30	Coffee
11.00	**C. Zambas**, Proposal for the restoration of the north façade of the Parthenon
11.30	**L. Lambrinou**, The entablature of the north façade of the Parthenon: identification of architectural members and repositioning of architraves and capitals
11.45	**C. Paraschi - N. Toganidis**, Proposal for the repositioning of the blocks of the south wall of the Parthenon cella
12.15	**N. Toganidis - Kl. Matala**, Proposal for the repositioning of the blocks of the north wall of the Parthenon cella
12.30	**M. Mentzini**, Restoration of the Parthenon architraves and column drums with titanium reinforcements: a new approach
12.45	Questions-Comments
13.45	Coffee
14.15	**Projection of the film (in English) "The Works on the Acropolis of Athens. The People behind the Monuments"**

AFTERNOON SESSION

Recent research and work in the Propylaia. Mechanical and electrical equipment of the monuments work-sites

Chairpersons: Prof. P. Themelis - V. Chandakas

16.30	**T. Tanoulas**, The restoration project of the Propylaia in progress
17.00	**M. Ioannidou - T. Tanoulas**, Proposal for the restoration of the superstructure of the central building of the Propylaia
17.30	**C. Karanasos**, Restoration of the blocks of the superstructure on the south wall of the western hall of the Propylaia
17.45	**T. Tanoulas**, Recent identifications of architectural members of the Propylaia
18.00	Coffee
18.30	**M. Ioannidou - V.Paschalidis**, Restoration of the Propylaia beams with titanium reinforcements: a new approach
18.45	**Sp. Oikonomopoulos**, Specific requirements concerning the mechanical and electrical equipment of the work-sites of the Acropolis
19.00	Questions – comments
20.15	**Projection of the film (in English) "The Erechtheion and Time"**
21.00	Reception at the Dining Hall of the New Administration Building of the National Bank of Greece

PROGRAMME

SUNDAY, OCTOBER 6

MORNING SESSION

Recent research and work in the Temple of Athena-Nike. Activities of the various departments of the YSMA and archaeological issues

Chairpersons: Dr E. Touloupa - Prof W. Hoepfner

9.00	**D. Michalopoulou**, The restoration project of the temple of Athena Nike
9.15	**D. Giraud - C. Mamaloungas**, New conclusions on the dimensions of the temple of Athena Nike
9.30	**D. Giraud**, New observations on the structural composition of the frieze of the temple of Athena Nike and of the ancient poros temple.
9.45	**F. Mallouchou - Y.Alexopoulos - E. Lembidaki**, The information system of the documentation of the Acropolis restoration project.
10.00	**V. Manidaki**, Proposals for the restoration of the Pandrosseion and the Arrephorion
10.15	**C. Kissas**, The work of inventorying, documenting and organizing the scattered architectural members on the Acropolis plateau. The future of the scattered ancient blocks on the Acropolis
10.30	Coffee
11.00	**C. Hadziaslani**, The work of the Acropolis Information and Education Department
11.20	**A. Choremi-Spetsieri**, 1995-2002: Archaeological research on the Acropolis
12.00	**M. Korres**, Restoration and final presentation of the Acropolis plateau
12.30	Questions-Comments

SPECIAL SESSION

Special session on surface conservation of the Acropolis Monuments

(Amphitheatre of the Ministry of Culture)

Chairpersons:
Prof. Emer. Th. Skoulikidis - Prof. M. Laurenzi-Tabasso

9.00	**D. Damianos - Ch. Laskarides - G. Marakis - M. Naka - E. Tzoumousli**, State of preservation of the Parthenon architectural members: pronaos, opisthodomos, north façade
9.15	**C. Babanika - E. Frangiadaki - E. Georgiou - F. Katevas - S. Papida**, Conservation work in the Propylaia
9.30	**A. Hatzipappa - M. Loukma - A. Tsimereki**, State of preservation of the architectural members of the temple of Athena Nike
9.45	**G. Frantzi - D. Garbis - A. Maridaki**, The programme for the conservation of the Erechteion
10.00	**K. Frantzikinaki - A. Panou**, Structural restoration and conservation work on the Parthenon west frieze
10.30	Coffee
11.00	**V. Zafiropulos - P. Pouli - C. Fotakis**, Combination of IR and UV laser pulses for cleaning sculptured surfaces: laser ablation mechanisms
11.30	Discussion of specific issues: (a) coating of the monuments' surfaces, (b) biodeterioration problems, (c) conservation of poros stone
12.30-13.30	General discussion – Conclusions

14.00-15.00 Lunch at the Dining Hall of the New Administration Building of the National Bank of Greece

AFTERNOON SESSION

Discussion and Conclusions, general and specific, of the Meeting

Chairpersons: Prof. V. Lambrinoudakis – Dr. H. Kienast

15.00	Beginning of the session
17.30-18.00	Coffee
20.00	End of the session
20.00	**Projection of the films "The Erechtheion and Time" and "The Works on the Acropolis of Athens. The People behind the Monuments" (in Greek).**

ABSTRACTS OF THE PRESENTATIONS
SUMMARIES OF THE STUDIES

METHODS FOR THE CONSERVATION OF PENTELIC MARBLE*

The side effects on monuments and on historic constructions by the methods and the materials used for the structural conservation and the conservation of the surface are described, interpreted and criticized; thus, the non-damaging methods and materials were revealed. The category of damaging methods and materials was revealed by literature references and by thermodynamic and kinetic supervision, by laboratory measurements and in situ observations by the author on several historic structures in several countries.

The damaging methods and the materials follow; the non-damaging ones were selected for the conservation of Pentelic marble on the Acropolis monuments. Thus:

a. Conservation of the surface

1. Cleaning

I. The use of instruments, dry and wet blasting, ultrasounds, water of high or low pressure, spraying of water or water vapor, ion exchange resins, acid or alkali solutions, solutions of ammonium bicarbonate or carbonate, E.D.T.A., biological pack are not suggested.

II. Microblasting, sorptive pastes, Lasers (Excimer UV), and inversion of gypsum (author's method) are only suggested.

2. Consolidation

I. $Ba(OH)_2$, fluor- and fluorosilicate compounds, Meyer glue, Waterglass, hydraulic lime, polymers are not suggested.

II. Inversion of gypsum, reinforced lime (author's method) are only suggested.

3. Protection

I. All materials of a.2.i. are not suggested.

II. Only reversible acrylic polymers, pigmented with n-semiconductors (author's method) are suggested.

b. Structural Conservation

1. Metals

I. Stainless Steel (when chloride ions are present in the atmosphere), Bronze and Brass are not suggested.

II. Titanium (author's suggestion) and stainless steel in absence of chloride ions (not in the present case) are suggested.

2. Consolidation.

I. The materials of a,2, i. are not suggested.

II. ii. White cement with quartz-sand and restricted quantity of sulfates (for pentelic marble with low porosity), the method of reinforced lime, cement with reinforced lime are suggested.

III. It is evident that the selection between non-damaging methods and materials and the conditions of their applications depend on the type of construction materials; thus, it is indispensable to know their identity, present state and properties, and to realize the accelerated laboratory tests of their effectiveness.

Th. Skoulikidis

Professor Emeritus of the NTUA, Member of the Committee for the Conservation of the Acropolis Monuments

** Summary of the volume Th. Skoulikidis, Methods for the Conservation of Pentelic Marble, Athens 2002*

GENERAL SURVEY OF THE CONSERVATION WORK ON THE MONUMENTS AND SCULPTURE OF THE ACROPOLIS

Work on the conservation of the surface of the monuments as well as of the sculptures that belong to them began systematically in 1986 under the supervision of the Committee for the Conservation of the Acropolis Monuments (ESMA). The interventions, done in coordination with the restoration project, can be divided into rescue and systematic interventions and cover the whole range of works for the conservation of the surface (consolidation of the surface, removal of old mortar and clamps, structural restoration of fragments, filling in of small cracks and voids).

In this papers a presentation will be made of current practices, the materials and methods that are used as well as the methods for recording and documenting the interventions (mapping, photography, electronic archiving). A brief account will also be given of the state of preservation of the architectural members. Finally, the works are being conducted by a large team with various specialities (conservators, conservation technicians, marble stone-cutters) and carried out with the assistance of scientists from other fields (chemical engineers, civil engineers, biologists, etc.) as part of wider research programmes.

C. Babanika, D. Damianos, G. Frantzi, A. Panou, A. Tsimereki
Conservators, YSMA

THE PARTHENON WEST FRIEZE: A STUDY OF CLEANING METHODS*

Introduction

The blocks of the west frieze were removed from the Parthenon and taken to a special laboratory at the Acropolis Museum during 1992-93. After a lengthy period during which the best conservation methods were assessed, the treatment (commencing in 2000) was divided into two stages. The first stage included consolidation of the surface, removal of the bronze dowels and plasters from earlier treatments and the reattachment of fragments. The second stage, focusing on the aesthetic retrieval, comprised of the cleaning of the surface and the sealing of cracks and gaps. Once these interventions have been completed the west frieze will be exhibited at the New Acropolis Museum and will be replaced on the Parthenon by copies.

Condition

Knowledge of the substrata beneath the polluted crust and the state of its preservation are of great importance for the choice of the cleaning method.

The deterioration of the west frieze is attributable to a combination of mechanical, physical and chemical factors along with atmospheric pollution, the microclimate and the microstructure of the marble. Cracking, sugaring, flaking, the detachment of fragments and the reduction of the monochromatic surface layers can be observed. The deposition of soot and suspended particles has modified the colour in places that were not washed by rainwater.

Two monochromatic surface coatings can be distinguished over 33% of the sculptured face of the west frieze. These are observable as a) an orange-brown skin and b) a beige layer. The lower orange-brown layer (a) has a total thickness that ranges between 30-100μm and is described as an *epidermis* (skin). This layer has adhered to the surface very well, and its main feature is the presence of calcium oxalates. The beige layer (b) covers the *epidermis*, and is described as a 'coating'. According to the analysis it is a thin, artificial layer about 80-120μm thick, comprised mainly of calcium carbonate. These surface layers preserve original tooling traces and indicate the original surface. They can thus be characterized as historical documents and should not be removed by the cleaning process.

Soot deposits and black crusts cover the west frieze surface. The layers of the deposits vary in thickness and composition. There is a thin layer *of loose deposits* up to 100μm thick, consisting mainly of gypsum, calcite, organic compounds and traces of other minerals and metals. There is also a *homogenous compact crust with good adhesion to the surface*, up to 150μm thick and *dendritic black crusts* of a greater thickness consisting of recrystallized and reprecipitated calcium carbonate in dentritic formation and a mixture of gypsum, aluminium silicate compounds and other atmospheric and mineral particles.

Principles of the cleaning process

The aim of the west frieze cleaning process is to achieve the best aesthetic effect and reveal original details of the relief, the monochromatic layers and of the tooling traces that are now covered by black crust and soot deposits. The cleaning techniques will be carefully selected, taking into account the following criteria:

- The speed of the process should be controllable.
- It should allow the widest possible preservation of the noble patina and the gypsum layer.
- It should not cause direct or indirect damage to the substrata.
- It should not generate by-products that may affect future preservation by remaining on the surface.

Cleaning methods

After a study of the cleaning methods by Professor Th. Skoulikidis, the ESMA approved methods for evaluation were microblasting, inversion of the gypsum layer into calcite, application of absorptive poultices and laser cleaning.

- The microblasting method was tested by using aluminium oxide (Al_2O_3) 10-88μm in grain size and glass spheres 0-50μm in grain size.

** Summary of the first part of the Study for the Restoration of the Parthenon, vol.7, Athens 2002*

- The application of absorptive poultices was investigated by using bentonite, sepiolite, talc, and paper pulp prepared with deionized water saturated in calcium carbonate.
- Inversion of gypsum into calcite. This method is based on the transformation of gypsum ($CaSO_4$) into calcite ($CaCO_3$). The solution used was potassium carbonate (K_2CO_3) 0,3M saturated in calcium carbonate.
- Laser cleaning was investigated in collaboration with the Foundation for Research and Technology, Hellas-Institute of Electronic Structure and Laser (FORTH-IESL), where the system has been designed and built especially for use on the Acropolis monuments.

Experimental stage

Preliminary applications of the cleaning methods were initially performed on newer marble additions (dating to the 1960s) from the west frieze. This was continued on fragments of sculptures from the Acropolis Museum and on architectural members. Finally, the cleaning methods were applied to small areas of the west frieze blocks.

Quantitative and qualitative tests were performed to evaluate the effects of the cleaning methods, on both the substrata and the encrustation (colorimetry, XRD, SEM-EDX, stereomicroscope, polarizing microscope, etc).

The degree and efficiency of the applied cleaning methods were shown to be mainly dependent upon the thickness and genesis of the crust as well as on the type of substrata. In terms of the substrata (marble, monochromatic surface layers) and the crust morphology the following cases are observable on the west frieze surface:

1. Loose deposits (of soot and dirt particles) on the marble substratum.
2. Loose deposits (of soot and dirt particles) on the monochromatic surface layers.
3. Homogenous, compact crust with good adhesion to the marble surface.
4. Homogenous, compact crust on the monochromatic surface layers.
5. Dendritic black crusts on the marble surface.
6. Dendritic black crusts on the monochromatic surface layers.

Results and evaluation of the cleaning methods

Loose deposits on the marble substratum

Microblasting, with aluminium oxide in small grain size, yielded good results. The disadvantages of this method are that it is not fully controllable and requires additional safety precautions for the operator.

The absorptive poultices, with sepiolite and solution saturated in calcium carbonate, remove the depositions under controlled conditions. However this method leaves an unpleasant opaque layer on the surface.

The inversion of gypsum into calcite proved to be a more suitable method where the consolidation of the gypsum layer is necessary before the cleaning process.

The laser cleaning method was successful through combining the action of the ultraviolet and infrared radiation, while the cleaning depth can be controlled by varying the number of pulses applied. This is a very important advantage as it allows control of the aesthetic result.

Homogeneous compact crust in good cohesion on the marble substratum

Microblasting, with aluminium oxide in small grain size, achieved good results, yet with the drawbacks described above.

The absorptive poultices, with sepiolite and solution saturated in calcium carbonate did not achieve a satisfactory cleaning effect.

The inversion of gypsum into calcite method did not yield satisfactory results.

The combination of ultraviolet and infrared laser radiation was efficient to remove such encrustation. In some cases it was found that the additional application of infrared radiation, on the areas that had already been cleaned by the

combined radiation resulted in a clearer aesthetic result. In addition it was ascertained that the simultaneous wetting of the surface with a water solution saturated in calcium carbonate supported the cleaning process.

Dendritic black crust on the marble substratum
Microblasting, with aluminium oxide, in small grain size (10μm), resulted in removal of the encrustation to a certain degree. Still the result is considered non-homogeneous and risky for the underlying marble surface.

The absorptive poultices were found inefficient to remove such encrustation.

The best laser cleaning result was achieved under the following conditions: infrared radiation at relatively high fluences, repeated wetting with a thin layer of water solution saturated in calcium carbonate. The process is time-consuming. It was also found that removal was easier if an absorptive sepiolite poultice was applied before the laser treatment.

Monochromatic surface layers
Microblasting, with aluminium oxide in small grain size, was found insecure as the whole procedure is not controllable and consequently there is a danger of removing traces of the monochromatic surface layers.

The absorptive poultices, with sepiolite and solution saturated in calcium carbonate, removed the depositions under controllable conditions. The chromatic result is considered moderate as the monochromatic surface layers may loose their vividness.

The laser cleaning method, with infrared radiation ensures a very acceptable chromatic aesthetic result as it enhances the colour of this layer.

Conclusions

The main conclusion of this study is that one primary method should be used for the cleaning of the west frieze of the Parthenon, which could be supported by the other methods. Although various cleaning methods can be efficient for individual cases of crust and substrata, the parallel and simultaneous application of more than one method on adjacent areas leads to non-uniform cleaning results.

The laser cleaning method fulfils this requirement as it was proven to be efficient in all cases. The controllable character of this method is deemed to be a very important advantage, as it is possible to determine the energy density thresholds that will ensure that the substrata will remain intact. Moreover, it was proven that this method met the criteria for safe and efficient cleaning, in addition to preserving the gypsum layer and not causing any discoloration or structural non-homogeneity. Furthermore, it reveals the details and the historical traces and information on the surface.

FORTH-IESL is developing a prototype laser system with the following characteristics:

- Operation along two wavelengths (IR at 1064nm and UV at 355nm) with the possibility of using the two beams individually or in combination, and in various ratios of energy densities.
- Homogeneous beam profile in its exit from the artificial articulated arm.

An important issue is on-line monitoring and control during the cleaning process. Such monitoring and control methods should be non-destructive and able to control the parameters of the criteria that can ensure an optimum result.

E. Papakonstantinou
Chemical Engineer, Head of the Conservation Department, YSMA
K. Frantzikinaki
Conservator, YSMA

COMBINATION OF ULTRAVIOLET AND INFRARED LASER PULSES FOR SCULPTURE CLEANING

THE APPLICATION OF THIS INNOVATIVE METHODOLOGY ON THE SURFACE OF THE ACROPOLIS MONUMENTS AND SCULPTURES *

Introduction

FORTH-IESL, in close collaboration with the Committee for the Conservation of the Acropolis Monuments, has investigated the possibility to apply laser cleaning methodologies on the Acropolis monuments and sculptures. The aim of this intervention was to remove unwanted encrustations, accumulated on the stone due to the atmospheric pollution, without any discoloration or structural damage to the original surface. Experiments on original surfaces that present the same deterioration problems as the west frieze of the Parthenon, were based on fundamental research performed at FORTH-IESL as well as in collaboration with the Committee for the Conservation of the Acropolis Monuments.

The laser cleaning technique

The use of laser radiation for the removal of unwanted layers from the surface of artworks exposed to the atmospheric pollution is a well-defined process that has been extensively studied since its first implementation, in the 1970s. The main advantage of this cleaning technique is its self-limiting character, which ensures that the original surface remains intact as well as the possibility to control effectively the extent and depth of the interaction area. The facts that no significant waste materials are generated throughout the cleaning process, as well as that there is no risk to the operator, if basic health and safety rules are followed, are considered very important parameters.

The laser cleaning mechanisms and the innovation of the employed system

The removal of unwanted encrustation by means of the fundamental radiation of a Q-switched Nd:YAG laser (1064 nm) is essentially achieved through *photo-thermal* mechanisms. In this case the dark encrustation absorbs the infrared laser radiation several times more intensively than does the calcitic stone substrate and therefore the energy threshold for the removal of the superficial layer is significantly lower than that required to remove the substrate material. Appropriate laser focusing, to adjust the energy density of the laser in a specific range, ensures the selective and *self-limiting* removal of the encrustation without the slightest damage to the stone. When the applied laser energy density is lower than the laser energy density threshold necessary for the removal of the encrustation material, *selective vaporisation* of the embedded dark-coloured airborne particles occurs, which affects slightly the main crust body. The gaps resulting from the removal of the dark-coloured particles, as well as the change of the absorption spectra of the remaining encrustation, leads to the impression that the final surface is discoloured (*"yellowing"*).

The removal of unwanted layers by means of ultraviolet radiation is controlled by photomechanical mechanisms. Material removal takes place in discrete steps while it was found that ultraviolet radiation is absorbed by the dark particles/ encrustation to the same extent as by the gypsum layer or underlying stone. In such case the thickness of the material and the fluctuation that this may have throughout the surface, is of major importance in order to achieve a homogeneous surface cleaning. Such a drawback gets noteworthy in the case of thick crusts of irregular thickness, especially those originating from the re-crystallisation processes.

To avoid discoloration and structural damage problems the FORTH-IESL research team suggested combining the action of the two discrete laser ablation mechanisms. This was accomplished by the simultaneous use of two laser beams of different wavelengths, whose pulses are temporally and spatially overlapped. The energy densities of the two beams are set to a specific ratio. According to this scheme FORTH-IESL has developed a prototype laser system, which in its initial state, has been tested successfully on the Acropolis site. The technical characteristics of the laser system, which has been used for the preliminary trials, as well as the requirements of the new system, currently under development, are presented in detail.

Conclusions

The application of the prototype laser system that combines the simultaneous action of the two discrete laser-based removal mechanisms has been in general successful. It was shown that such an intervention could remove the

** Summary of the second part of the Study for the Restoration of the Parthenon, vol.7, Athens 2002*

unwanted layers in a controllable way, with no discoloration or surface damage phenomena to the original stone surface. The experiments have been extended to all the possible substrates and encrustations present on the surface of the Acropolis monuments while a significant number of methodologies, laser parameters (number of pulses, energy density of the applied radiation etc.) and beam combinations (varying "ultraviolet to infrared radiation" ratios) have been tested. The results are described in detail in the relevant reports while a brief summary is presented here:

- There is a unique set of parameters ("ultraviolet to infrared radiation" ratio, applied energy fluence and number of pulses) that may result to acceptable results for every encrustation and substrate.
- The combination of the infrared and ultraviolet radiation at relatively low energy fluences (F_{IR}= 0,6- 0,8 J/cm^2 and F_{UV}= 0,15- 0,3 J/cm^2 for the *loose deposits* and F_{IR}= 0,8- 1,2 J/cm^2 and F_{UV}= 0,2- 0,4 J/cm^2 for the *homogeneous compact crust*) as well as a moderate number of pulses (10-50) give very successful results with no discoloration problems to the underlying *marble* surface.
- For the *dendritic black crusts* on *marble* it was found that most acceptable results were obtained with infrared laser pulses only, with energy fluences that lay beyond the 1,8 J/cm^2 The number of pulses is closely related to the thickness of the crust while in several cases the application of a thin layer of water was found to enhance the cleaning process.
- The use of ultraviolet radiation or any combination of ultraviolet and infrared radiation may cause discoloration to the underlying *monochromatic surface layers.* The use of infrared radiation alone at 0,5 to 0,8 J/cm^2 and 2-10 pulses results, macroscopically, into acceptable cleaning of the *loose deposits* and the *homogeneous compact crust*. In the case of the *dendritic black crust* it is necessary to increase significantly the fluence of the applied radiation, fact that may affect the underlying layers.
- It was possible to combine different laser cleaning methodologies to adjacent areas of the surface to be cleaned with no profound colour or structural differences.
- The laser cleaning result to areas with intense relief was very successful.

Dr. P. Pouli, Dr. V. Zafiropulos, Prof. C. Fotakis
Foundation for Research and Technology - Hellas, Institute of Electronic Structure and Lasers

THE CONSERVATION OF THE PARTHENON WEST FRIEZE: AN ARCHAEOLOGICAL PERSPECTIVE

The conservation of the Parthenon west frieze is being conducted since 1999 in a laboratory organized in the Acropolis Museum, where the blocks have been housed after their dismantling from the monument. The work has been undertaken by a team of conservators of the Conservation Department, according to the instructions of the Conservation Sub-committee of the ESMA and the collaboration of the First Ephorate of Prehistoric and Classical Antiquities.

The work has been conducted on all fourteen blocks of the frieze (W III-XVI) and focused on three matters: a) the structural restoration of each block by reassembling the fragments which belong together, b) the conservation treatment of the blocks and their sculptural decoration, by removing the modern marble completions of the corners, cleaning the mortars and metal elements of previous interventions, as well as the eroded ancient clamps and dowels, and consolidating the precarious parts, c) the performance of tests for the cleaning of soot deposits which will be realized on the west frieze in the next stage of the project, according to the approved study.

Further evidence about the older interventions has been provided by drawings newly discovered in the Acropolis Museum old archives, documenting the conservation treatment given to the west frieze by museum technicians, under the supervision of John Meliadis in 1958-60. The material has facilitated the current work in some cases and completed the history of interventions on the monument.

Moreover, the removal of the modern completions has made possible the examination of the frieze fragments in the Museum storeroom, which have been attributed by the scholars to the missing parts of the west frieze.

Chr. Vlassopoulou
Archaeologist Ph.D., 1st Ephorate of Prehistoric and Classical Antiquities

THE RESTORATION PROJECT OF THE PARTHENON IN PROGRESS

The restoration projects of the Parthenon currently in progress are: The restoration of the pronaos of the monument in accordance with the approved study has been completed to a large degree. Additional small completions were added to the 6th column (from the N) during the intervention in order to make it more stable. The restoration of the entablature of the pronaos will be completed once the SE anta has been restored. A patina is being added to the completions in new marble to the columns of the pronaos so as to decrease any variance in colour that may arise.

On the north side of the monument, on the section restored by N. Balanos, increasing widening of the gaps between the members, breaking, fractures to the edges of the column drums and slight shifting of the sections were observed. This led to the decision to prop up the restored area of the eight central columns. A study for the rearrangement of the column drums was also compiled as well as a preliminary study for the restoration of the entablature. The reassessment of the seriousness of the problems led to a reconsideration of priorities and an immediate rescue intervention was conducted on this part of the monument, after approval by the Central Archaeological Council of the Ministry of Culture.

This is the largest and most difficult project in the whole of the Parthenon restoration works. The dismantling of around 235 members is foreseen as part of this project. Once they have undergone conservation, they will be placed in their new positions according to the approved studies. 13 triglyphs, 13 metope backers, various scattered blocks from other architectural members, 12 frieze blocks and 18 *diazoma* blocks have already been dismantled.

Twenty-four architrave blocks were also removed. In the earlier intervention, the transversal cracks of the architrave were treated by carving on the back of most of them so as to create a deep horizontal cavity into which a pair of double-T-shaped metal beams was wedged. The corrosion of these metal elements, however, created second-generation horizontal fractures, with the result that the members broke into 9-10 pieces. There was almost no marble at all on the four central architrave blocks aside from a flake of marble incorporated into a short beam of concrete with metal double-T-shaped beams. In order to restore the member to its required height its upper part had been completed with rubble material, stones cavered by mortar on the upper surface. The incorporation of architectural members of various provenance into the architrave was also confirmed. With the removal of the mortar coatings it was ascertained that several completions in the areas of the clamps do not belong to these particular members, something that makes the definition of their correct sequence even more difficult.

No particular problems arose during the dismantling of the columns, save in only a few cases. The same completions of cement and unified mantles of iron reinforcements had been added to successive drums, whilst within them were found limestone cores, or other marble members, capable of bearing the weight of the column.

In this current restoration project, the completions that had been added to the members are being replaced with exact marble ones, as outlined in the approved study for their arrangement. The purpose of this intervention is to restore the columns to their correct height and to recover, as far as this is possible, the original form of the entablature. It is foreseen that the work will be completed by 2004.

In line with the approved programme, 22 architrave blocks, 6 *diazoma* blocks, 2 column capitals and 1 column drum were removed from the opisthodomos of the monument and are currently being structurally restored. Four column capitals and the column drums directly beneath them as well as the anta-capital of the NW anta were also restored *in situ* on the monument. The copy of the west frieze is also currently under production, whilst all the members to be placed beneath it are ready for positioning. This work is programmed to be completed by 2003.

Finally, the partial restoration of the long side walls of the cella as far as the second course has been approved. This work is programmed to be completed by 2004. The studies for the full restoration of the south and north walls have been completed and will be presented during the conference.

N. Toganidis
Architect in charge of the Parthenon Restoration Project, YSMA

THE RESTORATION PROJECT OF THE OPISTHODOMOS OF THE PARTHENON

Work for the structural restoration of the opisthodomos of the Parthenon began again in spring 2001 after a hiatus of six years. The main purpose of the first phase of the work was the removal of the west frieze and its transfer to the Acropolis Museum (1991-1993). Work was then limited to the structural restoration of the architectural members of the cornice blocks, the *diazoma* and two architrave blocks (1993-1995). This was then followed, after a long period of research, by the injecting of four columns of the opisthodomos by the conservators (1997-1998). The purpose of the current programme is to complete the work for the restoration of the members and to reassemble the area of the west porch and the ceiling of the *west pteron* by the end of 2003. Despite the various problems that arise during the works, the programme is proceeding at a satisfactory rhythm and with only minor deviations from the initial timetable. Necessary structural reinforcements led to the decision on the part of the ESMA to expand the interventions to a further seven members in the area of the juncture between the north side of the opisthodomos and the west wall, as well as to the anta-capital of the NW anta of the cella.

In association with this speaker, responsibility for the works has been taken on by the architect Rosalia Christodoulopoulou, who is in charge of documentation and of the worksite, and by the structural engineer Eleni-Eva Toumbakari, who is responsible for the structural problems of the members of the opisthodomos. A work team of experienced marble masons headed by Francesco Alexopoulos is carrying out the works for the safe dismantling of the broken architectural members, the structural restoration of their fragments and their completion, wherever this is deemed necessary, with new marble.

The recent interventions included the removal of 22 architrave blocks (of which four were in many fragments and dangerous), two column capitals, large sections of the other four as well as around 12 other architectural members. A portion of the members removed has been replaced and 5 architrave blocks and other members have already been repositioned. At the same time, the plaster cast team is progressing with the complex task of reproducing the frieze sculptures; all the moulds have been prepared and the casting of the sculptures with artificial stone is under way.

As is to be expected the works also resulted in certain discoveries that enrich our knowledge of the monument and help maintain undiminished the interest for all who study it. The most important of these was the discovery of wooden *poles* that were preserved *in situ* in an excellent condition. Many new details have also been garnered for the intervention of N. Balanos a century ago.

P. Koufopoulos
Architect Ph.D., MA York University, Assistant Professor of Patras University, Technical Consultant of the YSMA

THE WEST PEDIMENT OF THE PARTHENON IN RELATION TO THE OPISTHODOMOS RESTORATION PROJECT

The question posed, at a time when the work for the repositioning of the structurally restored members of the entablature of the Opisthodomos porch is underway, is to what extent the restoration of part or all of the west side of the Parthenon is a precondition for the restoration of the ceiling of the west wing.

As part of the ceiling restoration project, it has already been decided to reposition the members that have been removed - free beams, half-beams. The addition of new pieces - most of which were ready from the time of A. Orlandos - to take the place of missing members is also foreseen, with the addition of identified ancient fragments. Work for their structural restoration has already been carried out on the majority of members that were removed in 1994. Similar work ought to begin for the members that will receive them on the west side. As for the porch of the Opisthodomos, the already structurally restored frieze crown blocks (*thranos*) will follow after the positioning of the frieze, upon which the members of the ceiling will stand.

From the investigation (using the published bibliography and *in situ* observations) of the methods of construction and clamping of the surviving members of the west façade, it has been confirmed that the area of the west façade on which the ceiling will stand - the inner epistyle, the *diazoma* with the L-shaped cutting and the frieze crown block - is not directly connected to the rest of the entablature. This area can undergo *in situ* interventions without its members being dismantled, whilst it lies at a relative distance from the pediment above the frieze crown block.

From the observations on the levels of erosion and distortion of the entablature and the two pediment fronts resulting from natural wear-and-tear (3rd-century fire, earthquakes) and earlier interventions (Balanos, Orlandos, conservators of the 1970s), it was ascertained that the members of the said area are in a better state of preservation, in comparison with the rest of the pediment, with small-scale detachments, mainly in the areas with the dowels and clamps. This arises from the bad quality of the marble and natural wear-and-tear, and almost not at all from earlier restorations.

As such, restoration work can begin independently of the remainder of the west façade, in the zones of the outer epistyle, *diazoma* and frieze crown block. The area study, made possible by the removal of the west *pteron* ceiling members, produced interesting information on the construction history of the monument, and indicated the necessary restoration work for the individual members.

The first two courses of epistyle and *diazoma* will be completed in those fragmentary areas of the dowels with the upper courses with new marble that will be attached *in situ*. The upper course of frieze crown blocks will be removed so that, aside from a correct completion of the *diazoma*, the existing fragments can be attached and, most likely, others attributed to them. Ancient and modern clamps will be removed, the surviving painted decoration will be cleaned of soot, and the particularly fragmentary areas with dowels be restored with new marble. The removal is made necessary by their having become disconnected from the *diazoma* with the L-shaped cutting, with the shattering of the plasters that held them in place. The pronounced eastward curvature of the course will be restored. It is foreseen that the south section of the course will be completed with new members, just as Orlandos did on the north section in around 1960. This will most probably also be done at other points, in the positions of those members which it is considered best to remain in the museum so as to protect their uniquely well-preserved painted decoration.

R. Christodoulopoulou
Architect, The Parthenon Restoration Project, YSMA

STRUCTURAL RESTORATION OF THE ARCHITECTURAL MEMBERS OF THE OPISTHODOMOS

The subject of this presentation is the main civil engineering activities undertaken for the structural restoration of the opisthodomos of the Parthenon from June 2001 until September 2002. These activities are presented according to the type of architectural member.

A. Stability of the stylobate-column system

The difference in the opisthodomos project with those being carried out concurrently on the pronaos and N. colonnade lies in the fact that the column drums are not being dismantled here. It was ascertained, however, that the third (OK3) and fourth (OK4) columns oscillated far more than the first two (OK1, OK2). This movement was attributed to the deformability of the foundation beneath the stylobate, which consists of poros blocks. The causes of this oscillation were explored through the application of test loading. From the results of the test loading, it appears that the cause of the movement that has been observed is the deterioration of the interface between the stylobate and the rest of the foundation, which is believed to have been caused by environmental factors. No particular deformability of the foundation was noted with the application of the selected load level. This test, under certain conditions, is an excellent way of testing the foundation as well as the quality of the bedding of the ancient column drums.

B. Architrave blocks

The main activity during the period under discussion was the structural analysis and dimensioning of the reinforcement of the architrave blocks. In this paper, the classification of the architrave blocks according to their type of failure is presented. A new method for treating architrave blocks with many fractures will then be analysed. As far as we know this is the first time that this method is being applied. It involves the simulation of the fragments with finite volume elements and the application of capacity design for various limit-state situations (mainly in- and out- of – plane bending). The dimensioning of the reinforcement is done by integration of the stresses developed on the fracture surface in question. A brief discussion of the related theoretical issues will be given.

C. Copies of the sculptures of the west frieze

For the production of the copies of the west frieze a study and design of the artificial stone were carried out. The latter exhibits very good to high mechanical strength and very limited porosity and water permeability. As a result, the resistance of the materials to environmental actions is expected to be high. The casting of a series of sculptures showed that these compositions easily reproduced the surface details of the reliefs.

E. Toumbakari

Structural Engineer Ph.D., Msc Leuven University,The Parthenon Restoration Project, YSMA

STRUCTURAL CONSERVATION OF THE COLUMN OF THE PARTHENON OPISTHODOMOS WITH HYDRAULIC GROUTS OF HIHG INJECTABILITY: DESIGN AND APPLICATION

The columns of the opisthodomos of the Parthenon had e a multitude of cracks, primarily due to the damage provoked by the great fire of the 3rd century AD. The width of the majority of these cracks was less than a millimetre, and only a few of them reached locally a width of one or two centimetres. Instead of dismantling the columns, the *in situ* structural conservation by hydraulic grout injections was decided, as this would involve the least intervention to the monument.

The objective of this intervention was to fill in the best possible way the very fine cracks, while maintaining the structural independence of the column drums, thus preserving the articulated structural system of the columns. Therefore, it was considered necessary to design and apply two different types of hydraulic grouts, providing different levels of structural strength: one for the drums, able to develop strength and adequate bonding with the ancient marble, so that the cooperation between their fractured pieces be re-established, and one for the areas of the joints between the drums, of a lower strength to avoid bonding of the in between surfaces.

The significance of the monument, as well as the difficulty and particularity of such an intervention made necessary a series of studies and investigations in the laboratory and on the spot, in order to design the two most suitable hydraulic grouts. The ingredients were white cement, very fine pozzolana and water in the right proportions; appropriate devices were used for their mixing. In addition to the required strength and bonding characteristics, the grouts had to satisfy all the appropriate criteria regarding high injectability into fine cracks at a low pressure, compatibility with the marble, and durability so that under no circumstances would they have a negative effect on the ancient architectural members. Pilot applications on old and new marble members assisted the laboratory research and contributed to the design of the whole intervention. Special equipment for grout mixing and injection application, meticulous preparation of the columns and control of the grout and injection quality during the application, as well as systematic recording secured the best possible sealing of the cracks.

In this paper the methodology of the design, the most important results of the comparative parametric studies for the selection of the optimum compositions, the basic principles of the *in situ* production and application, the quality control of the injections and the extent of crack filling will be presented and commented upon..

A. Miltiadou, *Civil Engineer Ph.D., Head of the Laboratory of Restoration Materials and Techniques, Directorate for the Restoration of Byzantine and Post-byzantine Monuments, Ministry of Culture*
E. Papakonstantinou, *Chemical Engineer, Head of the Conservation Department, YSMA*
C. Zambas,*Civil Engineer Ph.D.*
A. Panou, K. Frantzikinaki*, Conservators, YSMA*

STUDY FOR THE RESTORATION OF THE NORTH FACADE OF THE PARTHENON*

The north and west sides of the Parthenon together constitute the most familiar picture of the Parthenon not only for the visitor to the Acropolis as soon as he passes though the Propylaia, but for the viewer from most points in Athens, or for the traveler approaching it by the modern network of national highways. The aspect from the northwest today gives the completest picture of the monument, because the western part is the best preserved and the north side has been restored. The study of the changes effected to the north colonnade forms part of the general study of the Parthenon restoration made by M. Korres and Ch. Bouras in 1983.

1. Structural damages and restorations.

The two great historical disasters suffered by the Parthenon were the torching of the building by the Herulians (267 AD) and its blowing up by Morosini in 1687.

In all the depictions of it after 1687, large masses of earth can be seen in front of the north side of the Parthenon and between the standing columns, from which project the drums of the eight columns and the architectural members of the entablature, which were thrown down by the explosion. The clearing of the ruins around the monuments was begun in the first years after the establishment of the modern Greek state, under the supervision of the first ephor, L. Ross, and subsequently of K. Pittakis.

The blunders in the restoration of the north side of the Parthenon began with the reconstruction of the columns of the peripteral colonnade and the walls of the cella by K.. Pittakis and A. R. Rangavis (1842-1844). Two columns were completely restored, and three partially, on the north side.

The restoration of the north colonnade by N. Balanos was started in 1923. The progress of the work was not without its setbacks. It was interrupted in the years 1923 and 1924 owing to the financial recession, and in 1927 and 1928 by the intervention of W. B. Dinsmoor, whose measurements demonstrated that the restoration so far had been faulty. Light has been shed on this matter by the recent publication of the Dinsmoor archives by F. Mallouchou -Tufano. In 1929 the restoration was continued, after the dismantling of two of the already restored columns in order to rectify the most obvious mistakes, and the work was completed in 1930. The columns from the 4th to the 11th (from NE corner), the architrave and a large part of the entablature were restored. For the first time the restorations of this period made use of reinforced concrete to fill in the gaps.

The damage caused by the oxidization and expansion of the steel clamping elements was already obvious ten years after the restoration (J. Meliades 1943).

The most serious damage was to the entablature. The steel girders embedded in the mass of marble blocks oxidized, expanded and split the marble. An indication of the continuing destructive effects of the oxidized clamps is the fact that even though in 1973 and 1974, before the ESMA was formed, many cracks had been filled and dangerous fractures strengthened with bronze rods over a large area, in many of these cases the recent fillings failed.

The most ruinous damage to the columns has been caused by the steel clamps and the steel reinforcements in the concrete patches. The clamps cause the drums to split, but even worse is that they exert an uplifting force on the superimposed drums, open up the joints and create a general instability in the columns. The steel reinforcing rods in the concrete are as a rule anchored in the marble. The rods have oxidized and in many places split the concrete and the marble at their anchoring points. The capitals were pieced together from fragments and marble patches with steel clamps. The clamps on the outside were replaced in 1974 by bronze ones, but the invisible ones on the inside have oxidized and caused fresh cracks.

In 1996 computational investigations of the seismic behaviour of columns were carried out at the National Technical University of Athens within the framework of the "Environment programme" of the European Union, using the UDEC computer programme. These were confirmed by experiments on the shaking table of Earthquake Engineering Lab with a marble model of a column on a scale of 1:3, which showed once again the complexity of the phenomenon and the great sensitivity of the response of a freestanding articulated column to seismic strain, especially when the contact between the drums is disturbed.

** Summary of the volume Study for the restoration of the north façade of the Parthenon, Athens 2002*

The general conclusion is that the entablature and the columns of the north side of the Parthenon are in an unstable condition.

2. Documentation.

Systematic measurements of the columns of the colonnade on the north side were made in the past by F. C. Penrose to investigate their refinements, by W. B. Dinsmoor, H. Schleif and N. Balanos for the purposes of restoration, and by A. Orlandos for the documentation of the monument. The considerable differences between their measurements made it necessary to repeat them with great precision.

To measure the diameters a special gauge was designed and made. This is an aluminum frame consisting of perforated rods of concave rectangular section and oblique struts, which combines slight weight with adequate rigidity. The gauge measures differences approximating to 1/10 mm, unaffected by temperature conditions.

For measuring heights a mechanical gauge was also used, which was accurate to 1/20 mm.

All the measurements were entered in comparative tables and on Excel for Windows sheets. For each drum the order, height, and top and bottom diameters were entered, and with the appropriate functions the reduction and level of each joint were calculated. The tables are accompanied by diagrams which show in elevation the section of the shaft of each column and the drums differentiated by color. On the computer sheets it is possible for any changes to be entered and for all the factors of the column to be automatically adjusted by the programme.

Axonometric drawings on a scale of 1:10 were made of the drums and capitals of eight restored columns; on them were recorded the macroscopic geological characteristics of the marble members, the superficial cuttings, the loss of mass, the various kinds of breaks, the damage, the cracks, the different additions of unrelated fragments or cement, the oxidized clamps and the steel reinforcements, and the different kinds of wear and surface corrosion.

The measurements of the columns on the north side confirmed once again the matchless precision of the construction of the Parthenon. In the course of the perimetric checking of the intermediate column drums no differences were found greater than 1/10 mm; in other words the accuracy of the construction is of the order of 1/10,000! The measurements also yielded new evidence for the plan of the columns.

Systematic measurements and observations were also made of the flutes of the columns. A special method was used to survey the flutes both at the lower ends of the columns and at other different levels.

In the Parthenon the flutes of the columns of the peripteral colonnade have an elliptical section at their lower ends. The ellipse was drawn and carved with great accuracy two centuries before Apollonius wrote his *Conics*. This was yet another refinement of the columns of the Parthenon, which had an important effect on their aesthetic appearance, since it affected their chiaroscuro.

The investigation showed that with special compasses having two templates at the ends of the two arms, the section could be determined at every point. This instrument is most useful for finding the position of small broken fragments on which parts of the flutes are preserved, and for distinguishing fragments of the peripteral colonnade from other fragments coming from the inside colonnades.

3. Restoration mistakes and their theoretical correction.

The measurements and their mathematical elaboration showed that the 1930 restoration was not correct. In the diagrams of the sections of the columns distortions are apparent which were due to misplacement of the drums. The greatest distortion is to be observed in the 8th column, even though the insertion of a complete concrete drum between the first and third and the addition of two large patches to the fourth and fifth drums prevent the distortion from being immediately visible.

The orientation of the drums is haphazard and in many cases drums have been pieced together with fragments from other columns in the building. The new drums and the patches as they appear today have three different tints, due to the coloured and the plain concrete and the plaster coating of the 1973-1974 work.

The general conclusion is that the problems of the 1930 restoration consist not only in the severe structural damage, but also in the serious restoration blunders and the bad workmanship, which disfigured the appearance of the monument.

The evidence used to find the original positions of the column drums was as follows:

- metrical data: their diameters and heights and the sections of the flutes.
- the cuttings on the surface of the drums.
- the positions of the cracks.
- the shape of the fracture surfaces.
- the surface erosion.
- the damage to the edges of the flutes.

The metrical evidence alone would have been enough, if all the drums had survived in good condition. However, the gaps and the bad state of preservation of some of them, which permit only approximate and not precise measurements, made this a difficult problem. Dealing with the metrical evidence and checking the alternative solutions were greatly facilitated by the computer work sheets for each column and the diagrams. Each worksheet makes it possible to move a drum together with its metrical data (height and diameter) to the location of another one in the same sequence, on the worksheet of another column. In accordance with the functions that have been set up, the diagrams of the sections and the drums are automatically modified along with the intermediate levels and the overall height of the shaft. In other words, the results of every transfer are checked without the need for any other action and with complete control.

The cuttings on the surfaces of the columns existed before the latter were blown up. They correspond chiefly to the points and lines of contact of annexes built up against them at a later time. The prolongation of a mark from one drum to another is clear evidence of their contiguity. Equally, in cases where the same annex has left marks on two adjacent columns, these marks must be compatible.

The crossing over of a crack from one architectural member to another is a phenomenon frequently observed in the Parthenon. The strong friction stresses between the contiguous surfaces in many cases allows the passage of a crack from one drum to an adjoining one. The fracture surfaces also exhibit morphological continuity in some instances.

The pitting erosion (or alveolar decay) of north-facing surfaces is a safe criterion of the correct orientation the drums. This criterion was also used to position the stone blocks of the Erechtheion wall, where it was necessary to segregate those blocks that belonged to the north wall. There are numerous shallow pitting cavities 2 to 10 mm in diameter on the surfaces of the drums; they were formed preferentially along the joints, the fine cracks and the bedding of the marble blocks, while in other cases they form different random patterns on the surface. They are due to the attachment of microorganisms (mosses) over many centuries.

A careful examination of the drums revealed that while the edges of the flutes in the areas of the pitting erosion are preserved in good condition, those on the opposite sides show considerable damage of the arrises. The former are on the outside, facing north, while the latter are on the inside. This can be explained by the fact that at the time of the explosion the walls were the first to collapse and the stone blocks were hurled against the columns with the force of cannonballs, knocking them down. The impact caused the multiple damage to the flutes on the inside, while the outside flutes fell against the roofs of the buildings or onto the soft earth fill on the north side of the Parthenon.

A column drum and capital in the British Museum (Nr. 207 and 350 respectively) belong to the north colonnade. At the invitation of the Museum authorities these were drawn to scale, and their position and orientation were identified. The capital belongs to the 10th column and the drum is from the top of the 6th.

Lastly, a drum in the 11th row, which was not used in the 1930 restoration and is now on the south side, also came from the north colonnade.

Thus we find that of the 88 drums and 8 columns of the north side, 4th to 11th:

- 14 are in situ.
- 63 are well preserved or to their full height.
- 7 are preserved as large fragments.
- 4 are missing.

After examining all the data and carrying out many trials, the problem of correcting the 1930 restoration was resolved. The solution has the following features:

- All the drums of the four columns, 6th, 9th, 10th and 11th have survived. The total height of each shaft is the same as the original (9574±4 mm).
- Of the 11 drums that are new or not preserved to their full height, 5 are belong to the 4th column. Of the remaining 6, 2 are assigned to 6th, 2 to 7th and 2 to 8th. This is a "hard" solution; the problem is simplified if we distribute the "gaps" between the 8 columns.
- The profiles of the columns are regular and very close to the curves of the columns in situ.
- The surface cuttings are found concentrated on the columns in the central section, that is between the columns 7th and 11th. This accords with the evidence of the illustrations. The picture by J. Carrey in 1674 clearly shows the existence of large buildings in the centre of the colonnade before the explosion.
- The columns exhibit a morphological continuity. The distribution of the damage and the longtime surface deterioration give the impression that the columns sustained most of their damage while they were still standing or at the moment of their collapse, and not afterwards.

4. The proposal and its rationale.

It is proposed that there should be a reconstruction of the restored columns and a correction of the 1930 restoration. In particular that:

- The eight restored columns should be dismantled and the concrete additions and oxidized steel clamps removed.
- The concrete patches should be replaced by Pentelic marble inserts and some new inserts should be added, which should be fixed to the drums with titanium reinforcements.
- The drum at present on the south side should be restored to its proper place.
- The capital Nr. 350 and the column drum Nr 207 should be reclaimed from the British Museum and restored to their places.
- The columns with their drums and capitals should be restored to the places where they stood before the explosion and with their correct orientation.

The dismantling is necessary in order to remove the disastrous internal steel clamps, and it is desirable, because it makes it possible to carry out a long-term restoration; it would also be useful, because the restoration of the columns will be corrected with respect for the original nature and the historical phases of the building and with a regard for its aesthetic integrity.

The marble inserts will ensure that the restoration has a long life. And there is no question of them deceiving either the researcher or the visitor to the monuments, since the ancient marble blocks bear the marks of time.

The additions of marble the patches have been given careful consideration; their purpose is not to fill all the gaps or restore the original surface in its entirety, but to ensure stability and to fill the crevices which break up the surface and drastically mar the shapes.

Restoring the cohesion of the shapes is possible in the case of the Doric columns with their shallow flutes and sharp arrises. A successful example of filling in gaps without breaking the continuity is the restoration of the

columns of the west corner of the south wing of the Propylaia by A. Orlandos (1957). In the 5th column of the south side of the Parthenon the large marble insert in the first drum is accommodated to the surface of the break without spoiling its shape.

An obligation to restore the architectural members to their original positions is implicit in the Charter of Venice, but it could not in any case be more binding than in the case of the Parthenon and especially its columns, whose drums possess a unique identity, an unparalleled individuality of their own. Positioning them at random would be to disrespect the monument.

The cuttings left by the later annexes on the columns may not have the significance of the original characteristic of the columns. They are, however, an additional constituent of their individuality. They too in a material way express the age of the building and are reminders of its history.

The total dismantling of the eight previously restored columns creates temporarily a serious aesthetic problem and raises an ethical question. It can only be justified by completing the work in the shortest possible time. There is no doubt that the work of restoration in accordance with the specifications that have hitherto been observed is costly and time-consuming. One of the objects of the study is how to minimize the time and expense of the work, bearing fully in mind all the issues connected with the project.

C. Zambas
Civil Engineer Ph.D.

THE ENTABLATURE OF THE NORTH FACADE OF THE PARTHENON: IDENTIFICATION OF ARCHITECTURAL MEMBERS AND REPOSITIONING OF ARCHITRAVES AND CAPITALS

The history on an intervention

At the International Conference organized in Athens in 1931 on the "Conservation of Monuments of Art and History" Balanos had the opportunity to present his most recent work: during 1923-30, he had completed the restoration of the central section of the colonnade of the North *Pteron* of the Parthenon. Although he has been considered the person who "corrected" the errors of the interventions by Pittakis and Rangabé during the Othonian period and although his intervention promised endurance through time and against criticism, the need to "reopen the File: North Colonnade" has proved unavoidable in our days.

The central section of the North *Pteron* that was damaged by Morosini's explosion in 1687 included 8 columns, 27 architrave blocks, 19 triglyphs, 24 metopes, 46 backers and 63 cornice blocks. The fractured pieces of these members lay around the Parthenon for two and a half centuries. Through collection and "patchwork," Balanos restored the majority of these members, with supposedly scientific although in essence aesthetic criteria. Often misleading and perhaps fatal, his interventions misrepresented the evidence and did not hesitate in distorting the form for the sake of aesthetic results. The erroneous position of the members raises again today the question of the scientific re-examination of the available evidence.

Object of the current intervention

The dismantling of the restored sections of the entablature, completed in June 2002, provides the opportunity for the completion of the study of the members, which were preliminarily studied by C. Zambas, and the forming of a full proposal for their correct repositioning on the monument. The purpose is to gather and evaluate all the parameters, to exhaust all possible solutions, and the most complete restoration of the form - the search, that is, for the original *harmony* of the monument.

A section of the study, eight of the architrave blocks that bridge the 9 inter-column spaces from the 3rd to the 11th column in sets of 3, will be discussed.

Architrave blocks and capitals and their reassembling

As basic construction principles, the structural independence of the architectural members of the ancient temple and its articulated construction are complemented by the "individuality of the structural unit." Each "unit" bears, in addition to its basic classification, particular features that define its specific and unique position on the monument, marks of its history and evidence for its structural incorporation on the building. Such traces, such as the cavities of clamps and dowels, side inclinations, height variations and many more often hint at construction secrets large and small or provide proof for where the member abutted. Others, such as surface erosion and other forms of damage, indicate position. The ascertainment of variations is often far easier than providing measurements for them and also easier than the clarification of their structural logic.

In following this rule, the external north architrave blocks and capitals provide a variety of details that help in the codification of 12 parameters. These provide criteria for a comparative identification and also a theoretical arrangement of these members in their original places.

L. Lambrinou

Architect-Archaeologist, MA Building Conservation, The Parthenon Restoration Project, YSMA

STUDY FOR THE RESTORATION OF THE SOUTH WALL OF THE PARTHENON*

FIRST PART: Historical evidence of the walls

The first part of this study refers to the misadventures of the Parthenon throughout the centuries and the consequences that these inflicted on the cella walls. The interventions of the restoration and conservation programmes are mentioned until the year 1975. Among them, the most important was the restoration carried out from 1841 to 1844, during which 300 blocks where replaced conventionally in various positions on the north and south walls of the cella.

After 1975, the Committee for the Conservation of the Acropolis Monuments (ESMA) supervised a series of projects: the collection and identification of 400 disiecta membra from the walls, the dismantling of the side walls 1992-93 and the systematic accurate measurements and photographic documentation of all the stone blocks, in order to restore them to their correct positions on the building.
The above are referred to in the chapters below:

A1. Historical introduction

A2. The interventions carried out by the ESMA on the Parthenon

A3. The works carried out by the ESMA on the side walls of the cella of the Parthenon

A4. The documentation of the blocks of the cella

SECOND PART: The architecture of the cella walls

The second part of this study analytically presents the structure and architecture of the side walls of the Parthenon and their present condition. This part includes the following chapters:

B1. The present condition of the in situ section of the south wall

B2. The architecture and structure of the side walls of the Parthenon

B3. The successive stages in the preparation of each block and the methods involved in their positioning
This chapter explains the methods used for the preparation of the surfaces of the walls of the temple and the structural continuity of the building, the means used for the transportation, the positioning and the joining of the blocks and the chronological order of their positioning, cutting and final dressing to achieve a perfect armonia.

B4. Architectural refinements: *Entasis*, diminution (*meiosis*), curvature

B5. New evidence about the structure of the walls that were uncovered during this study
The condition of the building, due to the structural damage in the general area of the west part, resulted in interesting new discoveries and information. The deformations and displacements of the preserved in situ west part of the south wall, especially in the area where it meets with the west door wall, resulted in the shifting of the wall westwards and also the opening of the vertical joints of the blocks, thus revealing new information. This briefly, consists of:

- the conclusion that each course differs in height from the other courses. The gauge measurements indicated differences of approximately 0.1 mm, a fact that is taken advantage of, in order to differentiate and classify the blocks. At this point the supreme precision of the construction of the Parthenon, is confirmed once again.
- the fact that there is a vertical tracing line (*simeia*) carved in the middle of the upper surface of a certain group of blocks, that served as a guideline for the positioning of the above last laid blocks.
- the existence of a slight lowering (*epikope*), of 0.4 mm, in the middle of the upper surface of some blocks, leading to differentiations of heights.
- the observation of a slight inclination of the head-ends of some horizontal clamps of double T shape, (above the fifth course), thus providing a simple reinforcement of the joints.

** Summary of the Study for the Restoration of the Parthenon, vol.6, Athens 2002*

- the validation of former studies related to the sequence of the laying of blocks in each course and also their positioning with reference to the antae blocks.

THIRD PART: The proposal for the repositioning of the blocks of the south wall of the Parthenon

In the third part of the study, the methodology of the procedure is described, in order to establish the original arrangement of the scattered and dismantled blocks of the south wall of the cella. This part consists of the following chapters:

C1. The code used for the blocks of the side walls of the cella of the Parthenon
This follows the general coding of the architectural members of the Parthenon set out in the "Study for the Restoration of the Parthenon" by Ch. Bouras and M. Korres of 1983.

C2. The criteria used in the research of the original positions of the blocks of the south wall
These consist of separating the blocks first into headers or stretchers, and then, depending on the type of the erosion due to the weathering of their outer surface, they are classified into blocks belonging to the north or south wall. The classification of each block according to its height, the precise estimation of the matching of the cuttings or the traces of the clamps, dowels, auxiliary dowels and crowbars used for positioning the block, the direction of the laying of each block and the traces of corrosion or fragmentation of the marble noted at the breaks and joints. In some cases the fractured surfaces exhibit morphological continuity caused by the strong friction stresses between contiguous surfaces, a phenomenon frequently observed in the Parthenon. The final dressing by the study of the chiseling traces of the tools on the upper surface of the adjoining blocks, are the final evidence of the correct position of the neighboring block.

C3. The methodology used for the rearrangement of the blocks
The methodology used in solving this 3D jigsaw puzzle, consists of the use of computer assistance, as well as the use of traditional methods. All the measurements were entered in comparative tables on Excel for Windows sheets. The traditional methods consist of evaluating, comparing and combining all the collected data of the ancient material systematically. The groups of blocks with special characteristics were observed, the rehearsal of trial combinations of architectural members on the ground were studied, especially in the indicative characteristic area where the partition wall and the south wall of the cella meet.

C4. The analytical presentation of the proposal for the repositioning of the blocks of the south wall of the cella

C5. The distribution of the remaining unidentified blocks and their positioning
The organization of the pairs and groups of blocks that could not be positioned in continuation of the restored courses could be placed in conventional positions. The majority supports this proposal, since few would prefer to leave these original ancient blocks abandoned on the ground, involving their responsibility for their further decay and interference on the surrounding site. Their positioning would not cause any visible discrepancies, improving the appearance of the monument and fulfilling its original structure and form with its ancient material. The principle of reversibility of the positioning of the blocks is also evident, any time their original positions are secured in the future.

FOURTH PART: The new proposal for the restoration of the south wall of the cella

In the fourth part of this study, the proposal of the restoration of the south wall is presented. It contains the following four chapters:

D1.The theoretical principles of the proposed restoration of the side walls of the cella
The new restoration of the previously restored parts of the side walls of the Parthenon is unavoidable mainly for scientific reasons: the correction of the errors of the past restoration in relation to the positioning of the blocks and the re-integration on the monument of a large additional quantity of ancient architectural members recently identified (328 blocks).

The benefits of the new restoration are evident: the improvement of the appearance of the walls, the recovery of their authentic structure, of their architectural character and of their aesthetic refinements. Also, the better

preservation of the walls is ensured, and therefore the prevention of the further decay of their scattered ancient members by their re-integration on the monument. After the proposed restoration the static efficiency of the walls will be improved to withstand seismic action. At the same time, by the restoration, the unique and dominant in the Parthenon artistic character will be accentuated, its ruins will become more legible and the cultural impact of the whole monument will be increased.

D2. Specific problems that arise in relation to the theoretical principles of the proposed restoration
The proposal for the restoration of the south wall of the Parthenon meets all the principles of a correct intervention: the original architecture and structure of the wall are obtained, the original positions of the blocks are recovered, the amount of new marble blocks required is limited to the necessary percentage for the restoration of the original ones.

The proposed restoration, as well as all the other works on the Acropolis since 1975, follows the theoretical principles of the Charter of Venice of 1964, enriched with the additional principles derived from the specific structural character of the classical monuments, that of the distinct "dry masonry" constructive system. These additional principles are: the reversibility of the interventions; the preservation, during operations, of the autonomy of architectural members and the respect for their basic original structural function; the limitation to a minimum of changes to the appearance of the monument and, finally, the self-conserving of the ruins of the monument by restoring its ancient material. Additionally, in the Acropolis restoration works, the same construction material is used as in antiquity: Pentelic marble is applied for the integration of ancient fragmented blocks or for the substitution of missing ones. This results in a harmonious and at the same time distinguishable integration of new and ancient material.

D3. The proposal for the restoration of the south wall of the Parthenon
The recent identification of additional scattered ancient material leads to a larger restoration of the south wall of the Parthenon, amounting to 57% more than the previous one. The proposal predicts the repositioning in their original places of 254 blocks in the SW part of the south wall (corresponding to the 85% of this part of the ancient wall) and of 57 blocks in the area of the SE anta of the wall (corresponding to the 75% of this part of the ancient wall). Furthermore, various groups of 45 in all contingent blocks have been identified. The original position of these groups of blocks on the wall cannot be identified for the time being. A proposal can be formulated regarding the courses, in which they might belong to. The repositioning on the wall of all the identified scattered ancient material leads to the recovery of the wall in the state it was preserved after the explosion of 1687 and just before the Greek War of Independence, which had been depicted in contemporaneous drawings e.g. of R. Dalton, J. Pars and, above all, W. Gell.

D4. Alternative proposals for the restoration of the inner face of the south wall
The original form of the inner face of the south wall is not clear because of the virtually complete destruction of the surface of the blocks. Furthermore, due to the thermal fracture caused by the ancient fire of the 3rd c. a.D., most of the interior blocks of the stretcher courses (2nd, 4th, 6th etc.) have become formless, loosing their identity. The missing inner stretchers amount to 62. Their replacement on the monument by new marble is essential, in order to support the above courses.

For the restoration of the inner face of the south wall the following alternative proposals are presented:

I. The full reconstruction of the fragmentary inner face of each block and the replacement of the missing blocks with new Pentelic marble, by using the traditional method. This proposal truly recreates the original architecture, recovers the sculptural character of the surfaces of the monument, restores its structural efficiency and redefines its inner space. At the same time it does not contradict the already in use traditional building methods of the Acropolis restoration project. It also presents the following characteristics: a high percentage of new marble blocks, an aesthetic problem due to its color and surface texture, in sharp contrast with its neighboring ancient ones. It eliminates the historical testimonies of the ancient fire. According to the present available means, this proposal is highly cost and extremely time-consuming. It could be implemented following a reasonable time-schedule only by the use of a new laser scanning method for mechanical reproduction of the fragmentary marble surfaces of the blocks, which the ESMA is already examining.

II. The anastylosis of the preserved blocks of the south wall with the completion with new marble of those blocks in need, to recover the structural efficiency of the wall. This proposal equals the full reconstruction with new

marble of the three first courses above the orthostates to their full width, by the traditional means. It is useful to keep in mind that new ones replace all the inner othostates. Above the fourth course it is proposed that 47 burnt inner stretchers, which have survived, are repositioned and that, where the remaining 23 blocks are missing, new ones will replace them. Of these 47 ancient blocks, some will be supplemented with new marble accordingly, depending on the quantity of their original mass preserved, in order to ensure their structural efficiency. The inner face of the 23 completely new marble blocks could be naturally hewed, without final dressing, as it is naturally extracted from the quarry. This type of surface presents advantages regarding the adaptation of the new blocks to the ancient wall, since their natural, geological, rough surface resembles, in colour and texture, the burnt inner surface of the neighboring ancient blocks.

This proposal has the great advantage of less use of new marble in proportion to the ancient. Thus, it is better from a restorational and an aesthetical point of view (closer to the prevailing theoretical and restoration principles) and is also practically less time-consuming in its implementation. At the same time it clearly distinguishes, by the complete restoration of the lower section of the wall, its original architecture and its sculptural character, without creating sharp contrast between ancient and new material. In addition, this proposal respects the already established, in the general visual memory, appearance of the inner space of the Parthenon, since the larger part of the interior face of the wall retains the well known image of the burnt surfaces ever since the middle of the 19th c. a.D. This solution, it is reminded, has already been adopted and employed for the now completed Erechtheion project for the south and north cella walls. Proposal II, complete with a static sufficiency study, secures the structural efficiency of the wall, with the appropriate supplements placed in the necessary positions.

III. Restoration of the inner face of all the blocks of the south wall by the use of a framework, of fine dimensions made of titanium. This framework will be fixed on the fractured surfaces of the blocks. With this alternative solution, it is proposed to replace the missing inner blocks of the stretcher courses by the preserved fragmented blocks, in conventional places. These 43 inner stretchers, from the total 95 preserved (the other half for the north wall) will be repositioned. The framework will reconstruct and redefine the original shape and width of the blocks. It will consist of thin sheets of titanium that will be cut accordingly to complete the fragmentary upper and lower surfaces of each block. These sheets of titanium will be connected on the inner burnt face of each block by titanium rods of specific cross-section and of high shear resistance. The individual frame of each block will be connected with each other by means of special joints, so that the principle of the individuality and autonomy of each architectural member of the monument is preserved: the wall will remain a polylithic structure and not turned into a monolithic one. This solution also ensures the indispensable structural cohesion and the ability to withstand seismic action. Due to this, a special design and calculation of this framework is needed.

Having obtained the framework, there are two alternatives:
a) A reconstruction of the face of each block with pentelic marble panels of 4 cm. thickness.
b) The covering of the framework with a special stone simulating mortar of 5 cm. thickness to avoid cracking.

This proposal, with the use of an elegant framework to recover the thickness of the wall under restoration and to ensure its static efficiency is truly a daring solution. It presents great advantages regarding time and cost and it bears the seal of the technology of our time. At the same time, it is far from the traditional methods used until now in the restoration of the Acropolis monuments. On the other hand, it is a solution structurally clear and sincere, that preserves the traces of the historical damages of the inner face of the cella walls and does not need the new marble creating the well-known resulting aesthetic problems. The continuous presence of the framework, like a light and refined scaffolding, on the inner face of the cella, creates the sensation of a transitional phase of the wall, which conveys the ruinous character of the monument, while simultaneously it constantly reminds the interventions taking place today. Also, the reversibility of this proposal is evident and the possibility of adding new fragments on the wall of the cella in the future is obvious.

The alternative "a" sustains the advantages of time and cost, and contradicts the unpleasant and daring presence of a permanent titanium framework – however elegant and refined its design might be. This alternative recreates the original sculptural character of the cella wall, although it appears to be scenographic.

The alternative "b" benefits even more than "a" concerning time and cost saving. It subtracts the unpleasant optical impression of the framework on the ancient wall and it also recreates as well the sculptural character of the inner

face of the wall. It is a solution even more sincere, simple and clearly distinguishable than alternative "a", and also enables the reversibility of the intervention. It is essential that in order that this solution gives a successful aesthetic result, the artificial stone mortar must be of high quality, with stable performance, avoiding cracks and its colour be harmoniously matched with the ancient blocks.

Depending on the psychology, but also on the aesthetics, of those who will make the final decision and hold the responsibility for the intervention on the monument, all solutions could be realized, depending on what they decide, either a more conservative and traditional solution or a daring and more radical one. Once again it must be reminded that for the restoration of the monuments there are not absolute rules and axioms, but mediation of diverging opinions, compromises and the respect of a general frame of theoretical principles and directions. All of the proposals present the above features in their own way. In any case the existing part of the south wall represents the 25% of its volume and with the proposed restoration the 75% of its original extension is to be recovered.

It is also proposed to partially restore the partition wall of the cella, for reasons of reminiscence of its unique significance in relation to the Acropolis Monuments. It has already been decided that the first orthostate block towards the south flank wall will be replaced by new marble. Its restoration up to the fourth course above the orthostate is proposed, where the original block of the partition wall is preserved. Another alternative would be to restore the openings of the doors of the christian phase of the partition wall, since their exact dimensions are known by the traces on the floor. A rough chiseling, as it was during the christian phase, is proposed for the surface of the new marble blocks, which will be used in the didactic restoration of these doors.

C. Paraschi
Architect, The Parthenon Restoration Project, YSMA
N. Toganidis
Architect in charge of the Parthenon Restoration Project, YSMA

PROPOSAL FOR THE REPOSITIONING OF THE BLOCKS OF THE NORTH WALL OF THE PARTHENON CELLA

This study is based on the theoretical principles outlined in the 1983 "Study for the Restoration of the Parthenon" by M. Korres and Ch. Bouras. In line with this, the study for the restoration of the N. wall constitutes the seventh restoration programme.

Two earlier studies have been conducted by N. Toganidis on the side walls of the cella of the Parthenon (1989 and 1994). These included the recognition and classification of the ancient material, as well as proposals for conservation and restoration.

After approval by the Central Archaeological Council of the Ministry of Culture in 1997, the partial restoration of the N. wall was begun, including the completion and the new arrangement and repositioning of the blocks of the toichobate and the orthostate courses.

A. Structural composition of the cella walls

The walls are made up of seventeen horizontal courses, with the 1st lying above the *orthostate* and the 17th, the last, below the entablature. The interlocking of the N. wall with the transversal wall is done with the penetration of the blocks of the transversal wall in the north, in the stretchers and the orthostate to the depth of a few millimetres, whilst in the headers to the thickness of about one header.

B. Criteria

The basic criteria for the recognition of the original position of the blocks of the N.wall are the deterioration of their face, the height, the positions of the cavities of the clamps and dowels, the direction of the laying of the blocks, as well as details located in the final working of the upper surface of the blocks and in the traces of the deterioration.

C. Classification of the blocks on the basis of the criteria

D. Conclusions and new evidence about the structure of the north wall that arose during the study

a. Concerning the direction of the laying of the blocks, it was ascertained that a last laid block was positioned in the 1st, 3rd and 17th courses next to the anta. The same is perhaps true for the 4th, 5th and the 12th courses, whilst the 2nd, 13th, 14th, 15th and 16th courses have a direction of laying the blocks towards the west anta.

b. Particularities during the joining of the blocks: Horizontal and vertical reinforcement in the joining of the blocks was observed, in the area of their interlocking with the blocks of the transversal walls, as well as in the 16th and 15th courses, where the terminating block was positioned.

Conclusions

The blocks identified during this study allow restoration of the N.wall so that it can reacquire the form it had at the beginning of the 18th c.

The definition of the original position of the architraves would be made possible with the identification of the outline of the lower surface of the Ionic frieze and of the traces of pitted corrosion on the upper surface of the architrave course.

N. Toganidis
Architect in charge of the Parthenon Restoration Project, YSMA
Kl. Matala
Draughtswoman, The Parthenon Restoration Project, YSMA

RESTORATION OF THE PARTHENON ARCHITRAVES AND COLUMN DRUMS WITH TITANIUM REINFORCEMENTS: A NEW APPROACH

As is well known, in recent years (from 1975 onwards) a particular method for the design of the structural restoration of fractured ancient members of the Acropolis monuments has been developed using titanium bars and cement mortar. This concept and its practical application limited the extent of the intervention on the ancient material in comparison with earlier methods. It also provides future researchers with a base for further approach to the static behaviour of the monuments and therefore to the development of the method for the restoration of the monuments.

It is necessary to remember, however, that the design and carrying out the structural interventions on the monuments is a task with special requirements. These requirements arise from the general rules of restoration, the particular characteristics of the building system, the nature of the building material (marble is anisotropic and not homogenous) and its state of preservation.

Therefore, a particular philosophy of approach is required, considering also that the scientific data available internationally today cannot be considered sufficient. For this reason, a continual attempt to improve our methods needs to be made, as our experience increases with constant practical application over time and the observations made through this.

The method adopted for the restoration of fractured architectural members through the joining of their fragments (and/or completions of new marble) with titanium bars can be chosen from two different philosophical approaches: the attainment of the total bearing capacity of the original member (this was previously applied to bent members) or the attainment of the bearing capacity that corresponds to the greatest stress that the member can take.

Today, as a result of a long series of calculations, it is accepted that it is not possible to attain the total bearing capacity of the original members (this involves a large quantity of titanium that it is impossible to be applied to the existing cross-sections of the members due to their size and the variation of their shape or the great loss of original material). The attainment of the strength that corresponds to the greatest stress that the member can take (either axially or laterally loaded) is therefore preferred.

The definition of the reinforcement of the theoretical model of each member is achieved for the actions as a whole.

The architraves (the restored structural members) are simulated with built-up beams made of marble and titanium bars. Hypotheses are posed that take into account the nature of the materials as well as the support and the conditions of the members. In order to confirm the method a model of the most fractured architrave of the North colonnade of the Parthenon was constructed on a scale of 1:2. All the details of the geometry, cracks, discontinuities and geological stratification of the original were simulated, and the model beam was reinforced using the reinforcements resulting from the theoretical calculations. The assumptions were then checked by submitting the specimen to bending using both uniformly distributed loading as well as three-point-bending with concentrated linear loaded with the aid of a stiff hydraulic loading frame of maximum capacity of 600 tons.

The main structural characteristic of the Acropolis monuments is the free support of each individual architectural member. In particular, the only constraint between the column drums is dry friction.

In order to make the column drums act as a unity again, a different process for the calculation is proposed here. It is based on the already-existing desing principle to avoid overturning of the piece that is to be joined from the member, taking also into account the critical condition of the surface of the drum.

The advantage of this method is that its hypotheses result in a general algorithm that was verified in praxis. The results are in good agreement with the surface of the upper side area of the unit that is to be joined (which sustains the load from above), its position within the drum, the height of the unit (i.e. this is the overturning lever arm) and, of course, the loads from above. This at the same time reduces significantly the amount of reinforcement to be used, and therefore also the ancient material that would otherwise be lost.

M. Mentzini
Civil Engineer NTUA, The Parthenon Restoration Project, YSMA

THE RESTORATION PROJECT OF THE PROPYLAIA IN PROGRESS

After the "4th International Meeting for the Restoration of the Acropolis Monuments" in May 1994, the restoration project for the Propylaia has proceeded as follows:

Work for the identification of fragments from the ceiling coffered slabs began in September 1994 and was completed in 1995. The study for the restoration of the south side of the East Stoa was submitted in 1996 and was approved by the Committee for the Conservation of the Acropolis Monuments. Work for the identification of 55 Ionic column capital fragments was carried out. In 1997 the fragments of architectural members of the South Wing were studied, drawn and divided into groups of fragments from the same members, giving a comprehensive knowledge of the material of the south wing. Beam fragments from the Central Building were studied, divided into groups of fragments from the same beams and divided into two categories, the beams from the East Stoa and the beams from the West Hall. In the same year a plaster copy of the Ionic column capital from the Balanos restoration was made and the scaffolding from the dismantling of the ceiling of the Central Building began to be taken down. The construction of the scaffolding on the south side of the West Stoa was completed and dismantling of the section of the south wall of the East Stoa that had shifted was begun in November.

The intervention on the south side of the East Stoa continued in 1998. The architrave was initially removed, after which removal of the wall blocks that had shifted took place. For the purposes of the works, railtracks were laid down along the east side of the stylobate for the transportation of the dismantled architectural members from the area of dismantling to the area of the bridge crane. The anta capital was dismantled first, and traces of erosion and modern interventions were made much clearer than before. During dismantling of the south wall much important information came to light for the processes and building techniques used by the ancients as well as for the behaviour of the wall during its later history. It also became clear that Balanos had made interventions only to the architrave and the anta capital of the south side of the East Stoa. The dismantling of blocks - 38 in total - in the south wall that had shifted was completed in November 1998. This was followed by the conservation of the dismantled blocks, construction of completions in new marble and repositioning. The restoration of the south wall was completed in June 2001.

The study for the restoration of the superstructure of the Central Building was submitted in April 2000. It was approved by the Committee for the Conservation of the Acropolis Monuments and subsequently by the Central Archaeological Council in the summer of the same year.

The scaffolding for the dismantling of the remains of the Balanos restoration was raised between the summer of 2001 and January 2002. The worksite was adjusted for the needs of the new works. The dismantling of the remains of the Balanos restoration begun on 16 February 2002. The study foresaw the dismantling of 89 architectural members yet during the dismantling it was ascertained that Balanos had also dismantled and repositioned architectural members that until then had been preserved in situ in the superstructure of the north wall (something that he did not mention in his book). This increased the material to be dismantled by 30% and it is foreseen that a total number of at least 125 members will be dismantled. Alongside the dismantling, which has almost been completed, the study, documentation, conservation and disassembly of the dismantled architectural members is also being carried out.

The supply of marble for the completions of the ancient architectural members and the construction of new architectural members in new marble has begun. The marble for the construction of two new Ionic column capitals that will be incorporated into the new restoration has also been purchased. Working of the two new Ionic column capitals has progressed quite a way. In addition, the process of restoring the large marble roof beams as well as the construction of new marble completions for the beams has also begun.

It must be clarified that from 1994 until today, alongside the interventions that have already been briefly described, work has constantly been conducted for the conservation of the dismantled material on the ground, removal of the iron attachments from the Balanos restoration, and the restoration of fragments with titanium bars and cement.

T. Tanoulas
Architect Ph.D., in charge of the Propylaia Restoration Project, YSMA

RESTORATION OF THE SUPERSTRUCTURE OF THE CENTRAL BUILDING OF THE PROPYLAIA*

Authentic form of the superstructure

The East Portico had two pediments, one above the horizontal Doric entablature surmounting the hexastyle Doric colonnade, and the other above the door wall. The ceiling had ten beams oriented east-west. Of the two outer beams, one of the long sides was seated on the *thranoi* of the north and south sides of the East Portico. Each of the intervals between the beams was covered by ten coffer slabs, each consisting of an integral beam and coffers. There are three coffers on each of the slabs covering the north and south intervals between the beams, and two coffers on those over the other intervals.

The West Hall had only a single pediment on the west facade. Its ceiling rested on three pairs of Ionic columns supporting two Ionic architraves oriented west-east, and there were corresponding Ionic architraves at the corresponding levels of the walls and the backers of the entablature of the west facade. On these Ionic architraves were seated 21 free beams running from north to south. The intervals between the beams were covered by coffer slabs (13 above the side aisles and ten over the central passageway), each consisting of two coffers enclosed by an astragal. The interval between the east beam and the door wall was narrower than the others and was covered by slabs bearing a rectangular coffer and a double *ouraniskos*, while the interval between the west beam and the backer of the west entablature was even narrower and was covered by slabs with a coffer and an elongated *ouraniskos*.

Modifications to the superstructure of the central building from ancient times to the present day

The greatest modification to the central building of the Propylaea was its remodelling in the 15th century as part of the palace of the Florentine dukes of Athens, though this work consisted mainly of additions.

The first major changes to the classical superstructure of the central building of the Propylaea were carried out in the period of Turkish domination. In 1640, a gunpowder explosion blew up a large part of the ceiling and other features of the superstructure, mainly in the east part of the West Hall and probably also in the East Portico. In the early 18th century, the Turks removed the west part of the superstructure, that is, the horizontal entablature of the west facade and the pediment, as well as the west part of the ceiling of the West Hall, the capitals and upper drums of the Ionic columns (except of the westernmost ones that kept the top drums), along with the corresponding architrave blocks. Towards the end of the 18th century, the Turks removed the capitals and upper drums of the four central columns of the west facade.

After the creation of the modern Greek state, the medieval and Turkish additions were demolished, the surviving members of the superstructure of the central building were assembled together, though unhappily, they represented only about one fifth of the total architectural material of the superstructure. In the years 1835-36, Alexandros Rizos-Rangavis placed seven marble blocks and a cornice on top of the south wall of the West Hall, without using clamps or binding mortar; these members were placed not in their actual, but in similar positions.

At the same time, building material from the monument, more specifically from the superstructure of the central building, was studied, particularly by the architects F.C. Penrose, R. Bohn, W. Dörpfeld and W.B. Dinsmoor. Details drawn from these studies, and oral observations made by the last two scholars, were used by N. Balanos during his major restoration project between 1909 and 1917.

Balanos's intervention was confined to the column capitals and entablature of the East Portico and the superstructure of the north-east part of the monument. The four uppermost drums of the fourth and fifth columns from the north in the East Portico were replaced in their original positions, as were marble blocks from the south-east anta. The second capital from the south, which had been removed by Elgin's men, was replaced by a new one, while the others, the east sides of which were badly damaged, were rotated through 180 degrees and restored with new marble.

The parts of the superstructure of the East Portico that were restored: the outer marble blocks of the architraves over the two intercolumniations in the south part of the facade; the outer blocks, backers and inner blocks of the

* *Summary of the Study for the Restoration of the Propylaia, vol.2, Athens 2002*

three architraves in the north part of the facade; the frieze of the north part (including the part corresponding to the central intercolumniation); the entablature of the north facade; the part of the coffered ceiling corresponding to the two northernmost intervals between beams, together with the corresponding beams, inter-beam slabs, *thranoi* and wall architraves; the cornices corresponding to the three northernmost intercolumniations; the corresponding north part of the pediment; the raking cornices; and part of the tiling of the north-east corner of the roof, together with the corresponding parts of the *sima*.

The following were restored in the West Hall north aisle: the part of the coffered ceiling corresponding to the two easternmost intervals between beams, with the corresponding beams, inter-beam slabs and wall architraves; and the easternmost column of the north Ionic colonnade (in which only one drum was made of new marble), together with its capital and the architrave block which connected it to the door wall. In these restorations, Balanos made wide use of new material and iron reinforcements, which were enclosed in cement or lead. He also dressed the break surfaces of most of the authentic fragments so that even those that did not belong with each other could be fitted together.

The serious problems caused by the oxidisation of the iron connecting and reinforcing elements densely distributed amongst the restored parts of the monument began to become apparent in the 1940s. The problems involved in the conservation and restoration of the Propylaea were examined by the Committee for the Conservation of the Acropolis Monuments in 1979, and in 1981 and 1982 architectural members in the south part of the entablature of the East Portico were taken down, conserved, and replaced, using titanium clamps and dowels, on the basis of a study prepared by the architect A. Tzakou and the civil engineer M. Ioannidou.

In 1989, the Committee for the Conservation of the Acropolis Monuments and the Central Archaeological Council of the Ministry of Culture approved the study by the architect T. Tanoulas and M. Ioannidou to take down the parts of the ceiling restored by Balanos. Between June 1990 and July 1993, the following parts were removed: in the East Portico, 20 coffer slabs, three beams, and the corresponding inter-beam slabs; in the West Hall, 26 coffer slabs, two beams, one wall beam and the corresponding inter-beam slabs, the Ionic capital and the corresponding Ionic architrave.

In 1996, studies were submitted by T. Tanoulas and M. Ioannidou for the removal and reconstitution of the south side of the East Portico of the Propylaea. On the basis of these studies, the parts of the south wall that had become displaced were dismantled, along with the architrave linking it to the south-east column, and also the eight marble blocks that had been restored by Al. Rizos-Rangavis in 1835. A total of 38 marble blocks were removed, conserved, and replaced in position, using titanium clamps and dowels (in place of the original iron ones) and a mortar based on white cement.

In 2000, the Committee for the Conservation of the Acropolis Monuments and the Central Archaeological Council approved the study by T. Tanoulas and M. Ioannidou for the restoration of the superstructure of the central building of the Propylaea, which is published in the present volume.

Present condition of the architectural members in the superstructure of the Propylaea

The restoration of the superstructure of the central building requires the removal of those parts of Balanos's restoration that were not taken down during the 1990-93 intervention, since they contain a large number of iron connecting and reinforcing elements, the progressive rusting of which has already created cracks in the marble, and will continue to do so in the future. These parts include 105 architectural members that are numbered and described in the text of the present study and in Table I. The removal of these architectural members began in February 2002; 98 members have already been removed, and it is envisaged that the process will have been completed by the time the present study is printed.

However, there are also parts of the monuments still *in situ* that exhibit serious problems requiring detailed study and action.

a. The main lintel of the central building consists of two blocks; the one at the east has a crack roughly through the middle which has caused the two large fragments of the lintel to subside by about 7 mm at the position of the crack. The Committee for the Conservation of the Acropolis Monuments and the Central Archaeological Council

have decided that the east block of the lintel should not be taken down, but should be conserved and consolidated *in situ*.

b. The central triglyph, with the integral socket for the corresponding metope of the entablature, at the west end of the superstructure of the north wall, is badly cracked along the veins of the marble, which run roughly parallel with the north face of the entablature. The way in which it might be consolidated requires a detailed study.

The present condition of the architectural members currently outside the monument

a. Coffer slabs

The fragments produced by the disassembling of the coffer slabs restored by Balanos, together with approximately 870 further fragments of coffer slabs gathered together on the ground, were studied by a group of four experienced marble-workers, who identified fragments that came from the same authentic slab. This investigation yielded a much larger number of coffer slabs capable of being restored than that actually restored by Balanos. In the case of the East Portico, it produced ten such slabs with three coffers and 16 slabs with two coffers, which will be used in the impending restoration. In the case of the West Hall, investigation produced 216 groups of adjoining fragments of coffer slabs. For the restoration of the ceiling of the West Hall, 23 coffer slabs with two coffers were chosen, and 23 coffer slabs with one coffer and a double *ouraniskos*.

Of the 72 coffer slabs that will be restored in the ceiling, twelve consist exclusively of ancient marble, 36 of 80-98% authentic material, 13 of 60-75% and eleven consist of 40-55% authentic material. The fragments are connected together by means of titanium rods and cement. The process of connecting adjoining fragments from the West Hall and adding pieces of new marble to them to produce coffer slabs capable of being restored has been completed.

b. Beams

In recent years, investigation of all the preserved material belonging to beams has produced groups of adjoining fragments and demonstrated that almost all the surviving beam fragments come from the East Portico, with the exception of one large beam fragment from the West Hall, and two smaller fragments that have no features by which they can be assigned specifically to either the East Portico or the West Hall.

Of the total of eleven groups of adjoining fragments, five consist of 70-100% authentic material, three of 45-60%, and the other three of 20-30%. The preserved authentic material of each beam will be supplemented by new marble to create eleven beams that will be used in the new restoration. There is also a beam broken into two pieces which will not be used because it is badly worn and its bearing capacity is greatly reduced. The beam fragments will be connected together by titanium rods and cement.

c. Inter-beam slabs

The following are in a fairly good state of preservation: three of the originally four inter-beam slabs from the north and south intervals between the beams in the East Portico, six inter-beam slabs (three of them almost complete) that could belong to the middle intervals between the beams either of the East Portico or of the West Hall and four smaller fragments (two of them adjoining) that could come from any part of the ceilings and will be supplemented with new marble so that they can be used in the impending restoration as inter-beam slabs for the interval between the beam of the door wall and the easternmost beam of the West Hall.

d. Ionic capitals

The capital used in the Balanos restoration was formed of four authentic fragments that belonged to four different capitals. Before it was disassembled, a plaster cast of it was taken and measured drawings were made by the architect T. Tanoulas. The fragments of the capital used in the Balanos restoration were studied in conjunction with the 59 fragments preserved on the ground. The total material was divided into six groups corresponding to the original six Ionic capitals. Provision needs to be made for space in the new Acropolis Museum in which to display the cast of the capital from the Balanos restoration, photographs and drawings. The fragments of the authentic material should be displayed incorporated into fully restored capitals made of cement or some other material, in such a way that they can readily be removed for use in further research.

e. Drums of Ionic columns

Of the drums of the Ionic columns of the Propylaea, the following are preserved on the ground: two eighth drums (ΑΑΔ 5.679, ΑΑΔ 5.680), five ninth drums (ΑΑΔ 5.161, ΑΑΔ 5.160, the top surface of which has crumbled, ΑΑΔ 5.162, ΑΑΔ 5.163, ΑΑΔ 5.171), two tenth drums (ΑΑΔ 5.681, ΑΑΔ 5.682) and two twelfth drums (ΑΑΔ 5.683, ΑΑΔ 5.684).

A fragment carried off by Lord Elgin and now in the British Museum belongs to a ninth drum, according to measurements taken by the architect T. Tanoulas; only the top seating surface is preserved, and it most probably belongs with the Ionic column drum fragment ΑΑΔ 5.160 that lies in the Propylaea.

f. Ionic architraves

A fairly large proportion of the material belonging to Ionic architraves is still in the positions in which it was placed by Balanos. Neither the fragments on the ground nor those still incorporated in the wall architraves are large, and after they have been disassembled a study should be undertaken before any final proposals are advanced regarding their incorporation in the new restoration.

g. Architectural members from the Propylaea built into the south fortification wall of the Acropolis

Some architectural members from the Propylaea are incorporated in the base of the south wall of the Acropolis, to the south of the area of the Brauronion and the Chalkotheke. The following have been identified: 13 coffer slabs from the West Hall, three coffer slabs from the East Portico, six *thranoi* from the east side of the door wall, eleven *sima* fragments, one wall block and eight parts of wall blocks, three fragments of projecting parts of cornices from the central building, two fragments of projecting parts of cornices from the wings, four fragments of projecting parts of raking cornices of the central building, and one fragment of an *orthostate*. No decision has yet been taken to remove these architectural members. However, the proposed new restoration is not affected by whether or not these members are removed from the south wall.

Proposed restoration of the superstructure of the central building of the Propylaea

The objectives of the proposed intervention are as follows:

- Dismantling of the remaining parts of the Balanos restoration in order to remove the iron connecting and reinforcing elements from them and conserve them.
- Restoration of the monument to a level of readability not less than that of the Balanos restoration, using modern tried-and-tested technology (titanium connecting and reinforcing elements, surface conservation).
- Use of authentic material from the ceilings of the monument newly identified during the current restoration work on the Propylaea, in order to improve the restoration.
- Every architectural member will include only adjoining fragments of authentic material. In supplementing them, no use will be made of ancient material, as in the Balanos restoration; only new marble will be used for this purpose.

The proposed restoration envisages the use of the large quantity of newly identified authentic material from the beams and coffer slabs, the aim being to display the ceilings, which have always been the most admired feature of the architecture of the Propylaea, to best effect. Since it is impossible to establish the exact original position of the authentic members of the ceiling, the preserved authentic members will be placed in positions which, though not necessarily the original ones, will undoubtedly be similar. The implementation of this principle means that the larger part of the authentic material of the beams will be restored in the East Portico; in the case of the West Hall, where only one large fragment of the ceiling beams survives, the restoration of the beams will require a larger proportion of new marble, in order to exploit the large number of Ionic coffer slabs.

In the East Portico it is proposed to restore beams ΔI, ΔII, ΔIII, ΔIV, ΔV, and ΔVI, which are demonstrably from the ceiling of the East Portico (the numbering in Latin numerals reflects the order in which they will be placed in position, from north to south). The half-beam ΔVIII will, of course, be placed at the north end of the ceiling. The fullest part of the restoration should be at the north end, where most of the authentic material of the superstructure

is preserved, so that the structural and morphological connection between the elements of the superstructure will be completely clear.

Thus, the Doric coffer slabs to be restored will be placed in the three northernmost intervals between beams. The most completely preserved beams will be placed in the area in which the coffer slabs will also be placed. The two northernmost intervals between the beams that will be restored will be completely covered, and the third from the north will be partly covered. The three southernmost intervals between beams will not be covered by coffer slabs, but the presence of the beams will be enough to suggest the ceiling, so that those entering the East Portico by way of the central door will have the feeling that they are in a roofed area.

The restoration of the six free beams in the East Portico requires the continuation of the *thranoi*, the *epikranitis* and the wall architrave for several metres to the south, using mainly new marble. The architectural members made of new marble for the Balanos restoration will be conserved and used in the new restoration.

The restoration of the beams in the middle of the East Portico, and the infrastructure needed for it, require serious attention to the problem of the cracked eastern block in the central lintel, which will have to bear the weight of the marble blocks to be placed on it.

In the West Hall it is proposed to restore the area restored by Balanos and extend it to the south, so that visitors passing through the middle of the West Hall will be able to walk beneath part of the ceiling of the central passageway. The feeling of a roofed space will continue into the East Portico in accordance with the proposal just described above.

There are several reconstituted coffer slabs with a large content of authentic material available for a restoration of this kind. In the north aisle, the beam ΔX will be placed in the position of the easternmost beam, and beam ΔVIII will be placed in the position of the second beam from the east. The position of the easternmost beam over the central passageway will be occupied by a beam made of new marble. The positions of the second beam from the east over the central passageway will be occupied by beam ΔXI. The beams of the door wall will be made entirely of new marble. The restoration of the Ionic architraves will certainly require a significant proportion of new marble. It is essential to continue the *thranoi* to the south and on the west side of the door wall, and to test the strength of the west block of the central lintel. In order to restore the east Ionic column, the eleventh drum, and possibly the tenth, will have to be made of new marble. It has been decided that the Ionic capitals to be used in the impending restoration will be made of new marble.

The projected proportions of authentic material are about 78% in the East Portico and about 50% in the West Hall, that is a proportion of about 64% authentic material in the restoration overall. This is equal to the proportion of authentic material used in the Balanos restoration. However, the proposed restoration is an improvement over the Balanos restoration in the extent to which it will restore the monument closer to its full form, in the correct assignment of the parts restored, and in the handling of the material from an archaeological and technical point of view. Moreover, the technology used in the new restoration is far superior to that used by Balanos. From a statics point of view, the proposed restoration of the ceilings will ensure the dynamic functioning of the rigid diaphragm, significantly improving the monument's resistance to seismic tremors.

M. Ioannidou
Civil Engineer, Director of YSMA
T. Tanoulas
Architect Ph.D., in charge of the Propylaia Restoration Project, YSMA

RESTORATION OF THE BLOCKS OF THE SUPERSTRUCTURE ON THE SOUTH WALL OF THE WESTERN HALL OF THE PROPYLAIA

The subject of this paper is the identification of the original positions of the blocks of the eighteenth, nineteenth and twentieth courses of the south wall of the Propylaia Western Hall, as well as a proposal for their repositioning. This study can contribute to the greatest possible use of the monument's extant original material, the ultimate goal being to increase its legibility.

The original arrangement of a total of eighteen blocks was explored. Of these, eight (four marble blocks from the nineteenth course, three from the twentieth and a cornice block above) were found in the south wall, although in random positions as a result of Alexandros Rizos Rangabé's intervention in 1835-6. Nine marble blocks were found on the ground within the Central Building and in the wider area to the south of the Propylaia. In addition, a marble block from the eighteenth course is now in the British Museum; its position was investigated through measured drawings and designs executed by Tasos Tanoulas.

The first significant damage to the structure of the Central Building of the Propylaia came in 1640 as a result of the explosion of the gunpowder that the Turks had stored in the West Hall. The earliest representations of the interior of the West Hall by foreign travellers date from the early 19th century and show the south wall as being preserved to the height of the *thranos* blocks (eighteenth course). The first four *thranos* blocks from the east appear in these drawings.

The dismantling of the eight blocks of Rangabé's restoration was done in November 1997, during the works for the structural restoration of the south wall of the East Stoa. The blocks were then carefully documented along with those on the ground with which they shared common characteristics. The features that were compared and which helped in the identification of their original direction of placement, as well as of their original position were the following: a) the positions and depth of the sockets for horizontal and vertical clamps, b) the positions of the pry holes and the cuttings of the auxiliary dowels, c) the way in which the blocks of the twentieth course were joined to the Ionic crown wall epistyle as well as to the cornice blocks above.

With the gathering and comparison of the evidence, the following observations were made: The extant cornice block was the first to be positioned from the east. On the twentieth course the positioning of the blocks was done from west to east. In the nineteenth course, the blocks were positioned in a west to east direction, whilst on the eighteenth course the *thranos* blocks were positioned in both directions. The four *thranos* blocks in the south wall have been placed in an east to west direction. The *thranos* block in the British Museum was placed fifth from the east and was the last to be positioned (key-stone), whilst the rest were placed from west to east.

This study proposes the repositioning of the first cornice block from the east, the repositioning of five out of seven blocks of the twentieth course and the reconstruction out of new marble of the first L-shaped marble block from the east, the latest intervention being essential so that the cornice block can stand upon it. Five out of the six marble blocks of the nineteenth course are proposed to be repositioned and the first from the east, also an L-shaped block, to be reconstructed out of new marble, so that the superstructure blocks can stand upon it. Finally, the three *thranos* blocks (eighteenth course) should be repositioned, whilst it is proposed that a faithful copy in new marble be temporarily placed in the position of the missing *thranos* block now in the British Museum. For the remaining three blocks, it is proposed that they be repositioned after the completion of the research in the corresponding blocks of the north wall. The dismantling of architectural members from the Central Building north wall, as part of the work for the replacement of a section of the roof of the Central Building of the Propylaia that is currently being conducted, will contribute greatly to the completion of this study.

C. Karanassos
Architect, MA of Rome University, The Propylaia Restoration Project, YSMA

RECENT IDENTIFICATIONS OF ARCHITECTURAL MEMBERS OF THE PROPYLAIA

Within the context of the Propylaia restoration project, a large part of the architectural material was examined and many fragments that belong together were recognised. The identification of fragments from beams, coffered slabs and inter-beam ceiling slabs is presented in the "Study for the Restoration of the Superstructure of the Central Building of the Propylaia". In this paper a synoptic account of the identification of the material from the Ionic column capitals, from the large tile of the south niche and from the South Wing of the Propylaia will be presented.

A. The four large fragments, with which Balanos recomposed the column capital he restored did not originally belong together. This capital provided however an excellent model for the study of the geometry of the Ionic column capitals of the Propylaia, and so before being disassembled it was measured and drawn and a cast was made of it. Using the characteristics of the most complete fragments, the geometry of the Ionic column capitals of the Propylaia was studied and life-size representations were made. The disassembling of the Ionic column capital from the Balanos restoration meant that its fragments could be studied along with those that had already been collected at the Propylaia work-site. The study of 78 fragments meant that they could be divided into six groups, the fragments of which belonged together and which correlate to the six Ionic column capitals of the Propylaia. These groups have been documented with detailed drawings on a scale of 1:5 and with photographs.

B. At the "4th International Meeting for the Restoration of the Acropolis Monuments" a reconstruction of the roofing method of the two niches between the Central Building and the side wings of the Propylaia had been presented. Each niche was roofed with a marble cover in the form of a giant single tile with dimensions of 4.5m x 2.7m x .302m. This was supported upon jutting sections of the cornices of the wings and of the corresponding east wall of each wing. The reconstruction then had been based on the evidence of two fragments of the cover of the south niche and two fragments of the cover of the north niche, whilst other features were reconstructed on the analogy of other tiles from the roofs of the wings. Three other large fragments of the cover of the south niche have been identified since 1995, and these confirm the reconstruction proposed in 1994 with only slight differences.

C. In 1997 the investigation of the architectural members was focused on the study of the material of the South Wing of the Propylaia. The fragments had earlier been identified in terms of the type of member, which they came from, by Bohn, Dörpfeld and Tanoulas. The recent study, conducted by a team of marble-workers headed by G. Vidos, meant that the fragments could be moved, and ordered into groups of correlating pieces. The result of this study is a sure knowledge of the material of the South Wing of the Propylaia, a fact that will in the future allow the restoration of the superstructure with the original architectural members and with the addition of only a small amount of new marble.

T. Tanoulas, *Architect Ph.D., in charge of the Propylaia Restoration Project, YSMA*

RESTORATION OF THE PROPYLAIA CEILING BEAMS WITH TITANIUM REINFORCEMENTS: A NEW APPROACH

Project for the restoration of the superstructure of the central building of the Propylaia

The majority of the architectural members that are being used in the restoration are fragmented. Before being repositioned on the monument, each member is structurally restored through the addition of the fragments that belong to it, using new marble wherever this is necessary. In addition to the form, the original strength of the member is also restored. In cases where total restoration requires excessive reinforcement and subsequently great subtraction of ancient material, the original strength of the member is partially restored so that the member's resistance is sufficient against all possible actions. The joining together is done using white Portland cement at the interface of the joint and titanium bars to receive the tensional and shearing stresses.

The members are supported on the monument in a statically determined way (beams simply supported), through unilateral contact conditions. Each member can thus be examined isolated from the rest of the structure. Static analysis is done for each member separately; no static analysis of the entire monumental structure is necessary. During the design of the joining together of small architectural members, e.g. coffer slabs, the qualitative criteria, for the determination of the position, the number and the cross-sectional area of the reinforcement bars, are critical. For the large members, beams and architrave blocks, critical are the internal forces that occur at the interface of the fragments, due to the large span and heavy loads placed on them. In addition to the permanent actions, the restoration also takes into account accidental actions, such as seismic excitation and temperature rise, as well as possible combinations of actions. As permanent actions we consider the dead weight of the members, the weight of the members that it is foreseen will be positioned above as part of the current restoration project, as well as any weight which will possibly be positioned in any future restoration. The actions in the phase before the final repositioning of the architectural member on the monument, its transport and storage are also taken into account when these differ from the above-mentioned actions.

In order to examine the strength of the member, the working stresses in the position of the restored crack are compared with the permissible working stresses of the materials, compressive for the marble and tensile for the titanium. The calculations are made with the assumption of elastic linear behaviour for the marble and bilinear elastoplastic stress-strain relation for the titanium. The elongation of the titanium is limited so that the tensile stresses do not exceed the yield stress in order to avoid remaining deformation.

Apart from the elastic deformations of the beams, which are not particularly important due to the large marble cross-sections of the architectural members, especially important is deformation due to the relative movements (rigid body movement) of each fragment. These deformations can become especially great and visible to the naked eye, something that is not acceptable on a monument. In order to limit them, the titanium reinforcement system includes bars with an appropriate anchorage system, such as will permit the imposition of axial tensional constrained elongation to some of the bars. The strain value is determined by the tensional forces that occur to the titanium due to the permanent actions. This reduces the total elongation of the titanium bars due to working, loading and, in consequence, the deflection of the restored beam, since part of the final elongation is given initially. Prior its final repositioning, the beam remains restored on the ground for a lengthy period and under supporting and loading conditions identical to the real conditions. The behaviour of the beams is observed during this period and the tensional strain is readjusted, if necessary, always using the specially designed anchorage system. The member is ready for its final repositioning once it has exhibited the majority of creeping and relaxation phenomena, so that its statical condition in its final position can remain quasi stable.

M. Ioannidou
Civil Engineer, Director of the YSMA
V. Paschalidis
Civil engineer, The Propylaia Restoration Project, YSMA

SPECIFIC REQUIREMENTS CONCERNING THE MECHANICAL AND ELECTRICAL EQUIPMENT OF THE WORKSITES OF THE ACROPOLIS

Special fixtures for the joining together of broken marble members

The problem: Joining together large and heavy sections or new marble completions to the architectural members. Joining together is preceded by successive approaches and withdrawals of mating surfaces and of their working for a good match. The parts are finally blindly drilled to receive the titanium reinforcement bars. It is clear that all these movements must be done easily and quickly, maintaining the same axis and the contact position.

The solution: The marble pieces that will be joined together are placed on a fixed and a travelling table respectively with horizontal surfaces at the same level, and able to support heavy loads. The travelling table must be able to move with its surface at the same level and free from transverse displacements.

Machine for the rough working of column drum flutes

The problem: One special, and particularly large, task of the restoration work is the working of the surface of the column drum completions and of entirely new drums. The *in situ* working of the flutes is a delicate and laborious task, which can be speeded up through mechanical rough working.

The solution: The drums are tapered with a diameter within 1400-1800 mm, a height less than 1100 mm, and (for the Parthenon) 20 geometrically-precise flutes. The tapered drum to be worked is placed and aligned on a horizontal rotating table, with marked divisions of 20 equal arcs and an adjustable zero-point. The cutting is effected with disk blades of various diameters, with adjustable cutting depths into the marble. The cutting head moves up and down a slightly inclined adjustable slide beam (adjustment range $\approx 1^\circ$ off vertical), which is set parallel to the respective generatrix of the tapered drum. Two disk rotation speeds are available, whilst the speed of the movement up and down can be continuously regulated. The flute thus created has the form of a circular segment but the layer left behind allows *in situ* final working by hand to achieve the special form of the flute. The same machine can be used as a vertical lathe for the initial cutting of the tapered drum.

Special tongs for the (dis-) assembly of the building blocks of the S. wall of the Propylaia

The problem: A large section of the S. wall of the Propylaia had to be disassembled so that its blocks could be structurally restored and repositioned in their correct positions. Their interlocking allows them to be removed only vertically upwards, without any points of attachment, the only available surfaces being the inner and outer faces, but with limited clearances to the scaffolding.

The solution: Special tongs were constructed taking advantage of the almost standard thickness (transverse dimension) of the marble blocks. This allowed the construction of a strong pair of tongs of limited length and height, so that it does not extend much beyond the sides of the block. The grabbing, holding and hoisting of the block is done only by the friction between the self-aligning shoe-pads (made from special rubber) of the tongs and the smooth sides of the block. The pressure between the pads and the sides the result of the block's own weight, through the lever mechanism of the tongs.

Computer Network

The problem: YSMA keeps all data concerning the restoration works in a computer data base. Access to this data base is allowed to many computers.over a wide geographical area, with several physical obstructions between them. The exchanged digital information, including texts, drawings and photographs, means large files. This requires high-speed connections, not effectively supported by the public telecommunications circuits.

The solution: The establishment of a local area network (LAN Ethernet) which, however, is subject to the physical obstructions and long distances (> 100m) between some nodes of the network. The UTP/STP cable network is thus enhanced by RF bridges between those nodes, where a cable connection is not possible: Erectheion (Acropolis North Circuit Wall) - Polygnotou 10, and Erechtheion (lightning arrester mast) - Parthenon works

Sp. Oikonomopoulos

Mechanical and Electrical Engineer, in charge of the electromechanical support of the Acropolis Restoration Works, YSMA

THE RESTORATION PROJECT OF THE TEMPLE OF ATHENA NIKE

The Ionic temple of Athena Nike, with two prostyle colonnades, one at each end, was designed by the architect Kallikrates around the second half of the 5th century BC and built between 427/6 and 424/3 in a prominent position, southwest of the Propylaia of the Acropolis.

The corrosion and structural problems observed on the monument meant that it had to be restored, work for which was begun on 6.10.2000. During the past two years, once the necessary infrastructure work had been completed, the following works were carried out:

- Dismantling of 292 architectural members.
- Removal of mortars and lead castings (*molibdochoeses*).
- Removal of the iron clamps of the earlier restorations by Ross, Schaubert, Hansen and Pittakis (1835-47) and by Balanos and Orlandos (1935-1940).
- Dismantling of newer completions made in Pentelic marble or with ancient marble from the scattered pieces on the Acropolis.
- Creation of plaster casts for the carving of a negative fracture joint on the new complementary marble member, with the aid of a pointer and pantograph.
- Dismantling of a slab of reinforced concrete with an irregular polygonal shape, a thickness of 31 cm and an area of $10m^2$, beneath the cella and its metal supports due to the progressed deterioration.
- Dismantling of a concrete slab, 50 cm thick and with an area of $30m^2$ which was surrounded by the blocks of the 1st and 2nd levels of the *krepis*. During the removal of this additional material, marble fragments were identified and attributed to the blocks of the *krepis* that had not been completed with new marble but with cement.
- Structural consolidation of small related fragments with white Portland cement.
- Structural consolidation of related fragments with reinforced titanium, for the structural restoration of the architectural members.
- Systematic measured drawing of architectural members and courses.
- Cross-referencing of measurements to determine the original dimensions of the temple. Completion of the investigation to determine the shape of the cella at the height of the architrave and of the moulded base of the wall, after a trial recomposition of the above layers on the *krepis*.
- Levelling after land-survey and plotting of the *euthentiria* from points of the surrounding environment.
- Documenting of details of the earlier limestone temple.

The project for the restoration of the monument will be accomplished with the repositioning of the architectural members structurally restored and the replacement of the joints. First, a new bridge crane will be installed and a composite structure consisting of a slab of reinforced concrete and steel will be constructed, upon which the temple will be restored.

D. Michalopoulou
Civil Engineer in charge of the temple of Athena Nike Restoration Project, YSMA

NEW CONCLUSIONS ON THE DIMENSIONS OF THE TEMPLE OF ATHENA NIKE

One of the issues which still awaited its final resolution with the new dismantling of the architectural blocks of the temple of Athena Nike was that of the precise shape of the cella. A. Orlandos argued that he noted a disharmony in its shape, which is irregular. He attributed this disharmony to the speed with which the temple was erected by the ancients. The temple was restored with this irregular shape in 1940.

With the new restoration, which began in October 2001, the systematic drawing and photographing of all the courses that comprise the temple as well as of its isolated architectural members is being done for the reassembly of the temple of Athena Nike. The purpose of this process is:

The study and documentation of the accuracy of the conclusions of the second restoration of the monument, by N. Balanos and A. Orlandos (1936-1940).

- The study of the ancient architectural members during this process in order to draw useful conclusions for the most accurate re-assembling of the blocks of the temple, which was dismantled from the foundations.

Problems were observed both during the detailed study which preceded the intervention as well as during the dismantling of the monument in respect to the inaccurate positioning of and additions to architectural members, the reuse and incorporation into the monument of dispersed material, the existence of open joints between the members and, in particular, carvings on architectural members, especially the architraves, which had altered the monument's original dimensions. The above inadequacies transformed the geometry of the temple, which now appeared irregular, with a discrepancy in the length of its sides that reaches a height of 3.4 cm between the north and south side of the epistyle, a significant difference given the small dimensions of the monument.

It was ascertained that the carvings on the joints of the members of the architraves date from the period of the completion of the first restoration of the temple by K. Pittakis (1843-1844) and result from the inaccurate positioning of the architraves of the north side by Ross, Schaubert and Hansen and by K. Pittakis on the rest of the monument.

In addition to the structural restoration of the members, the new programme for the restoration of the temple of Athena Nike provides the opportunity for all the necessary changes to be made, so that the monument will approximate as far as possible its original form and geometry, goals which had been posited as preconditions for success in the preceding restoration study. The conclusions which arose from the detailed measurements and the combination of a variety of other details were based upon and verified by the trial recomposition of the moulded base of the wall and the architraves, work which had already been completed before we proceeded to the dismantling of the *krepis*.

The interventions for the restoration of the monument to its correct dimensions as well as the levelling of the *krepis* as foreseen by the study may be small-scale interventions, unnoticeable to the average viewer. They are, however, important for rendering the correct geometry of the temple and the restoration of its optical refinements.

D. Giraud
Architect Ph.D., Director of Anastylosis of Ancient Monuments, Ministry of Culture
C. Mamaloungas
Architect, MA of NTUA, The temple of Athena Nike Restoration Project, YSMA

NEW OBSERVATIONS ON THE STRUCTURAL COMPOSITION OF THE FRIEZE OF THE TEMPLE OF ATHENA NIKE AND OF THE ANCIENT POROS TEMPLE

The poros temple of Athena Nike

The dismantling of the temple of Athena Nike provided the opportunity for the reconsideration of questions relating to the architecture of the classical temple and the earlier poros *naiskos* found in the Nike bastion in 1937.

With the removal of the concrete from the cella floor, the unexplored sections of the poros temple were freed. It was ascertained that the surfaces of the masonry blocks are still preserved in an excellent condition, both on the interior and exterior of the cella and that there are no signs of corrosion that could be attributed to the burning of the temple during the Persian invasion of 480 BC. The poros base of the *xoanon* of Athena Nike remains *in situ* in the NW corner of the cella. Its different orientation and its general state of preservation make it clear that it is older than the cella environment. Only its upper surface, which originally jutted out from the clay floor, has been exposed to fire. The conclusions drawn from this re-examination of the finds are:

A. The base of the *xoanon* is a remnant of an older temple of Athene Nike, perhaps from the time of Peisistratus. This was a small, partially open-air shrine with wooden columns and roof. It was burned during the sack of the Acropolis by the Persians, along with its inscribed poros altar.

B. Ten years after the battle of Plataia, a new poros temple with a different orientation was built by Cimon around the sacred base of the *xoanon*. This temple consisted of a cella without columns, in order to house the old *xoanon* of the goddess which the Athenians had saved during their flight, and an altar to the east.

C. The cella of the new poros temple was built with three successive courses of Aigenitian stone. Of the two *in situ* courses, only the lower course retains its exact height. Of the third course one anta block preserves its height. Two proposals as to the length of the temple can be made from the composition of the scattered blocks and those still *in situ*. Of these, the shorter cella appears to be the correct one, as it matches the foundation of the anta to the south-east.

The building structure of the frieze of the classical temple in correlation with the architraves

Once the frieze and the architraves of the temple had been dismantled, the architectural members were accurately drawn both individually and as a whole in order to record the precise positions of the clamps and dowels. It was ascertained that the slight variations in the distances between the clamps and dowels and the external surfaces of the members, in combination with their precise lengths, indicated the unique positions occupied on the architraves by the blocks of the south and north sides of the frieze which still preserve their original thickness. These building traces, which are being examined together for the first time in combination with the restored length of the architraves, provide the only credible evidence with which the original position of the frieze blocks and the manner in which the sculpted decoration was developed can be determined. Once the new evidence for the measurements have been combined, the restoration of the temple will be completed with the positioning of the frieze of Athena Nike on the architraves. The conclusions from this on-going research are:

A. The arrangement of the blocks of the south and north friezes using only the evidence of the direction of the horses of the Persian riders from west to east is not confirmed by the building traces. The way in which every member has been joined onto the architraves reveals, in a way that cannot be misinterpreted, the exact position of each member on the north and south epistyle of the temple.

B. Of the surviving members of the north and south friezes, only three preserve traces of the way in which they were fastened on the epistyle. The other two, along with two other members of the west side lost their original thickness - and therefore valuable evidence that would have indicated their original positions - when Elgin turned them into slabs of around twelve centimetres, to facilitate their transport to Scotland. On these, the only valuable remaining detail is their length, in combination with the sockets of the dowels and the faint traces of wear left by the members when they were joint to the architraves.

C. The arrangement of the architrave blocks by A. Orlandos in 1940 was correct and no inaccurate positioning was noted. As a result of the reduction on the original length of some of the members during the completion of the first

restoration of the temple by K. Pittakis in 1844, the original total lengths of the north and south sides were lost. This resulted in the inaccurate interpretations of the shape of the cella and temple as irregular. The new study for the resetting of the members of the frieze takes into account both the restored length of the epistyle on which a significant reduction in the original length was ascertained, and the restored total length of this upper course of the monument.

D. Giraud
Architect Ph.D., Director of Anastylosis of Ancient Monuments, Ministry of Culture

THE INFORMATION SYSTEM OF THE DOCUMENTATION OF THE ACROPOLIS RESTORATION PROJECT

From the outset, the ESMA has paid particular weight to the methodical documentation of its interventions. The documentation of the works includes photographs, drawings, records in day-journals, reports, studies, cinematographic material, etc. The constantly-increasing number of documents led in 1988 to the computerisation of the information of the material so it can be better used. The progress of technology and the new design demands led in 1996 to the acquisition of new software with an entirely new structure. The data is now organized on the basis of the architectural members themselves, so that they can be used in the execution of the works.

The new electronic database for the documentation of the Acropolis restoration works is made up of an archive of the monuments and their architectural members and an archive of the photographs, drawings, plans and texts. These archives are linked so that each member can be accompanied by all the documents relating to it. The archive of architectural members includes information on the type of each member and its position on the monument, its special structural characteristics, on the traces of the historical phases, previous restorations and the contemporary interventions of the ESMA, the characteristics of and the conservation interventions on the surface of the member. The document archive includes the necessary information on the document and its digital image. As an important feature of the database, we note the ability to correlate the documents with every piece of information that is described in the archive of members. Finally, the software has the ability to tailor complex information, search criteria and to export the results in listed form.

The Acropolis Restoration Service's information infrastructure recently underwent improvement, with the comprehensive networking of the YSMA's computers. This has made the database available at the work-sites as well as making it possible to instantaneously update it. This has reduced the problems caused by the time difference between the production of a document and its being recorded into the database, whilst the presence of the researchers has contributed to the enrichment and increase in the trustworthiness of the data. In addition, the observations of the staff in the technical offices of the work-sites posed new demands for the development of the application, making it more useful for the execution of the works.

A presentation of the application will be made at the conference, using the example of the documentation of the restoration of the temple of Athena Nike, where computerised documentation was carried out almost from the beginning of the works.

F. Mallouchou-Tufano
Archeologist Ph.D., Head of the Documentation Department, YSMA
Y. Alexopoulos
Information Technology specialist, Documentation Department, YSMA
E. Lempidaki
Archaeologist, The Athena-Nike Restoration Project, YSMA

PROPOSALS FOR THE RESTORATION OF THE PANDROSSEION AND THE ARREPHORION

The small temple of Pandrossos is exceptionally important, as this is where Athena's olive tree, the *pankyphos elaia*, was. Its few remains, poros foundation blocks and marble blocks from the *krepis*, provide important information on the east edge of the stoa, which extended to the north of the forecourt with the olive tree, as well as on a contemporary propylon. With the construction of the Erechtheion, this humble earlier sanctuary was attached to the west side of the refined temple. Access was now through a small door in the north porch, whilst the *krepis* of the west side of the Erechthion was widened for the creation of a passageway to the Pandroseion.

The foundations of a building complex can be discerned further to the west, in contact with the Acropolis North Wall. This complex is probably related to the religious ritual of the Arrephoria mentioned by the sources, and to the stay of the Arrephoria maidens. The foundations belong to three different chronological phases and are laid out in three different directions. This *palimpsest* of the foundations and its correlation with the surfaces of the North Wall indicate the existence of successive building programmes. The first building phase, of which all the traces of its delicate working are still vivid, was limited to the natural relief of the rock. The second building phase, reusing material from an earlier building, was carried out haphazardly and is related chronologically to the construction of the opposite section of the Nrth Wall with the historic reuse of the entablature from the ancient poros *neos*. The latest phase, the solid foundation walls of which are still in place, appears to have been part of a costly programme of modification of the terraces directly associated with the construction of the Erechtheion.

The preservation of the ancient topography of the Acropolis rock to the west of the Erechtheion as far as the North Wall is closely related to the preservation of the remains of the sanctuary of Pandrossos and the house of the Arrephoroi, as well as to the restoration of the terraces and the interpretation of the original relationship between monuments and ground. The remains of the Pandrosseion will be protected through their repositioning on stable foundations. The restoration of the forecourt terrace will clarify not only the position of the temple, which is today difficult to discern, but also the way in which it was incorporated into the west side of the Erechtheion. The fragile poros foundation blocks of the house of the Arrephoroi will be filled in and thus protected from continual deterioration, whilst the earth will be adjusted to a suitable level and form, showing the successive historical phases of its construction.

V. Manidaki
Architect, MA of the NTUA, The Acropolis Circuit Wall Project, YSMA

THE WORK OF INVENTORYING, DOCUMENTING AND ORGANIZING SCATTERED ARCHITECTURAL MEMBERS ON THE ACROPOLIS PLATEAU. THE FUTURE OF THE SCATTERED ANCIENT BLOCKS ON THE ACROPOLIS

The Committee for the Conservation of the Acropolis Monuments recognised from the outset the need to document and order the thousands of ancient fragmented architectural members dispersed on the Acropolis plateau.

The exhaustive survey of the stone piles that had been created on the Acropolis from as early as the era of K. Pittakis and L. Ross was a concern of the Committee. The purpose of the programme, which began in June 1977 with the first inventory of the scattered members conducted by the architect T. Tanoulas, is the identification and use of the architectural members on the Acropolis monuments that were undergoing restoration, as well as the identification of fragments of inscriptions and sculptures, some of which could be used to complete already known ancient pieces. In addition to this, the identification of other architectural members from buildings on and off the Acropolis would enrich our knowledge of them.

Twenty-five large stone piles have been created at various points of the Sacred Rock. The contents of twenty stone piles have been inspected so far and over 15,000 fragments have been inventoried.

The systematic study since 1995 of the stone piles on the Acropolis and some of its slopes has produced many fragments of various architectural members from the monuments: 197 from the Parthenon, 65 from the Propylaia, 4 from the Erechtheion, 91 from the Pre-Parthenon, 64 from the stoa of Eumenes, 7 from the Doric and Ionic stoas of the sanctuary of Asklipeios, 3 from the Theatre of Herodes Atticus, 30 from Building H or the Ur-Parthenon, and over 500 from the *Archaios Neos*. In addition to the above members, a very large number of fragments from sculptures, inscriptions and commemorative monuments were identified, some of which belong to already-known and important ancient pieces, such as the two fragments from the stomach and back of the horse of the Persian rider in the Acropolis Museum.

The lack of the necessary space for the deposition, storage and protection of these thousands of fragments, as well as for their systematic study and conservation, makes their removal from the Sacred Rock essential. Moreover, many originate from movable and immovable monuments of the lower city. Their removal will assist the work for the highlighting of the Acropolis monuments and will make a substantial contribution to the final appearence of the archaeological site, when the restoration work is completed.

C. Kissas
Archaeologist Ph.D., in charge of the Inventorying, Documenting and Organizing the Scattered Architectural Members Project, YSMA

1995-2002, THE WORK OF THE ACROPOLIS INFORMATION AND EDUCATION DEPARTMENT

There is much interest in the restoration work being carried out on the Acropolis, both among the scientific community and the general public. In order to keep the general public informed, publications and presentations take place as part of a wider policy. As such, members of the YSMA produced a small, synoptic book, the regular publication of *The Acropolis Restoration News* began, and a detailed web page created on the Internet. The production and editing of publications, exhibitions and films about the works continue.

Each year the President of the ESMA presents an analytic report on the works to a large audience of the "Association of the Friends of the Acropolis". A detailed article on the work-sites is published in each issue of the Friends' bulletin *Anthemion*.

There is a great interest from schools. Since 1994, as part of our educational programmes, around 15,000 pupils have participated at special programmes of the Acropolis with the help of our booklets *A Day on the Acropolis in Search of the Goddess Athena, A Day on the Acropolis with the Texts of Plutarch and Pausanias, Let's Go to the Acropolis, and Let's Go to the Acropolis Peripatos*. In addition, 20,000 pupils have learnt about the Parthenon Frieze at the Centre for the Acropolis Studies with the help of the booklet *A Day with the Parthenon Frieze*.

Applications from schools for the educational programmes are so great however, that we soon decided to invest in both the teacher and the educational material. We collaborate with the teacher with educational seminars (attended by 5,000 teachers since 1994), the organization of educational Exhibitions, special Conferences (the 7th Conference on *Teachers and Programmes about the Acropolis* will take place in spring 2003), the Proceedings of which are published.

The educational material includes posters, booklets and Museum Kits, intended for both the pupil and the teacher. Since 1994, three books and twenty educational booklets have been published in over 100,000 copies, in both Greek and English. A teacher's Pack for the Acropolis, which allows the teacher to organize the visit of the pupils to the Sacred Rock, has been sent to over 2,500 school and libraries in Greece and abroad.

Since 1994, the Service's 20 Museum Kits (with seven subjects) have travelled to 2,100 schools and have been used by around 130,000 pupils throughout the country. This is a composite material, the goal of which is to familiarise pupils as well as the general public with ancient art and architecture and with the large conservation and restoration projects taking place on the Sacred Rock.

The experience gained from their decade-long use and distribution led in 2001 to the production of a new generation of Museum Kits in a large number of copies. Although their subjects are distinct, these four new Museum Kits can also form a unit. The picture of a wonderful ancient sanctuary (*Let's go to the Acropolis* Museum Kit) where gods were worshipped (*The Dodecatheon* Museum Kit) within grand temples (*A Greek Temple* Museum Kit) decorated with unique art and sculptures (*The Parthenon Frieze* Museum Kit) help the pupils to approach the world of antiquity in a pleasant and creative way. By September 2002, 650 Museum Kits had been donated to educational bodies.

The Information and Education Department of the YSMA, in collaboration with the 1st Ephorate of Prehistoric and Classical Antiquities, is working on the new prospects that are opening up today with the restoration work on the Acropolis, the building of the new museum and the reorganization of the Centre for the Acropolis Studies.

C. Hadziaslani
Architect-Archeologist, Head of the Information and Education Department, YSMA

1995-2002: ARCHAEOLOGICAL RESEARCH ON THE ACROPOLIS

The following works were carried out on the Acropolis and the surrounding archaeological area: clearing and developing the excavation sites as part of the project of the Unification of the Archaeological Sites of Athens, conservation and restoration work on the monuments and the ordering of dispersed archaeological material. Much evidence was gathered on the form and the different phases of the Acropolis monuments, as well as a large number of fragments. Many of these were identified with, attributed or joined together to various architectural members and statues from the Acropolis. In addition to completing many ancient members, the attachment of these fragments provided new details on the original form of many well-known sculptures and contributed to their comprehension and restoration.

More specifically, attributions and attachments were made to:

- Architectural members of the *Hekatombedon*, the *Archaios Neos* of Athena and to other archaic buildings of the 6th-century BC Acropolis, as well as to members from the classical monuments (Parthenon, Erechtheion. temple of Athena Nike, Propylaia).
- Figures from the Parthenon pediments and frieze.
- The friezes of the Erechtheion and the temple of Athena Nike
- To free-standing statues and votive reliefs.
- Inscriptions (decrees votif and honorary).

All the above finds are being studied and most of them are already being presented by the Ephorate's scientific staff at colloquia, conferences and in publications.

In addition to the above papers of the finds, a large number of Greek and foreign scientists has published articles or monographs on the Acropolis and its monuments, demonstrating the undiminished international interest in these important works of Greek antiquity. The subjects relate to the history of the Acropolis and its monuments, their architecture, attributions and completions to the architectural members and especially to the sculptures, stylistic analyses and new interpretative approaches to the sculptural decoration of the monuments, in particular the Parthenon frieze.

It is clear that the research of the past few years has greatly furthered our knowledge of the Acropolis, this monumental whole, unique in its symbolism and technique, that classical Greek antiquity bequeathed to the world.

A. Choremi-Spetsieri
Archeologist Ph.D., Director of the 1st Ephorate of Prehistoric and Classical Antiquities, Member of ESMA

RESTORATION AND FINAL PRESENTATION OF THE ACROPOLIS PLATEAU

Even before the Great Excavation (1885-1890) it had become clear that the soil of the Acropolis in the fifth century was levelled. The level of the Museum roof is at the same height as the *euthentiria* of the Parthenon as P. Kalkos, the museum's architect, had perhaps considered the possible restoration of the soil after the archaeological works. The necessity of this had been noted first by Klenze in 1834, and later by P. Kavvadias, director of the Great Excavation: *Once the rock is uncovered, it will be necessary to draw or wherever necessary photograph it and the surviving ruins, and then the excavated area should be filled in in such a way so that the fill will shape the plateau of the Acropolis so that it will look as far as possible as it may have done during the 5th century...* For various psychological, technical, scientific and financial reasons this work has unfortunately still not been completed.

The negative aspects of this are:

- Erosion of the fragile foundation blocks of the monuments, including the Acropolis Circuit Wall.
- The inability of the rainwater to run-off from the plateau surface. It then drains down towards the fills, creating serious damage to the rock, the foundations and the Wall.
- Inability to make proper use of the area around the monuments for standing and walking visitors, and finally
- Depriving the monuments of the suitable system of reference for their correct conception as self-contained works of art and as part of a wider whole.

For these reasons, the ESMA considers the restoration of the Acropolis plateau to be absolutely necessary.

The conclusions in relation to the soil in the classical period are as follows:

- The surface of the Acropolis plateau was divided by walls into separate shrines which reached as far as the outer Wall and as a rule communicated with each other only via the Panatheniac Way or the road to the north. Despite the unevenness of the Acropolis and despite their differing origins historically, these shrines were approximately square or rectangular in shape with two right angles. Five of these had a length of around 43m., the same that is as the *Archaios Neos* and the interior of the Parthenon (without the partition wall of the cella).
- It was not possible to walk freely along the length of the Circuit Wall due to the dividing walls between the shrines.
- Each shrine was levelled individually (and at its own level), usually accomplished with fills and, less often, by rock cutting.
- The final surface was filled with earth of a suitable composition and covered not only the areas that had been filled in, but also the adjacent horizontal areas of the rock, which as a rule were not visible. Substantial residues of this covering still indicate its composition.
- The terrace of the Parthenon, the largest of all, determines the level of the soil as far as the North Circuit Wall. The sections of the Parthenon terrace furthest to the east and the south, planned just like those in the north, were never built. Construction of the eastern and higher part of the South Wall was terminated approximately four metres lower. Along the length of this truncation, the soil remained for centuries incomplete and irregular, with inclining layers of marble chips and abandoned, partially visible, surplus marble from the temple.

Proposals:

1. Repair of the central road, as it was restored in 1976 with a similar restoration of the north road.
2. Restoration of all the levellings and terraces after the completion of the necessary studies and after the completion of any work being carried out on the monuments. The final layer will resemble that of antiquity. Ancient buttresses should be restored wherever necessary.
3. The new surfaces should follow the initial slopes for unimpeded rainwater run-off.

4. The plans of the buildings, whose the foundations only are preserved, should be indicated on the restored surfaces of the soil.

5. The restoration of the soil to the east of the Parthenon should be combined with the restoration of the foundations and the *krepis* of the circular temple of Rome and Augustus.

6. The restoration of the soil to the north side of the Museum should be combined with the construction of small buildings at its perimeter, so that the building will become underground without any loss to its natural lighting and ventilation.

7. The ground and structural form of the shrine of Pandion to the east should be restored. This will be made possible by dismantling the triangular section of the museum and reconstructing the north wall of the monument, demolished in 1948. The Mycenean Wall to the east should remain visible.

8. The man-made shaft-like openings for the display of earlier structures to the south of the Parthenon will be redesigned and newly constructed.

9. The boundaries (especially the partition walls) of the shrines will be indicated on the restored surfaces, and respected as far as possible. The approaches will be situated at the confirmed, or the most likely, position of the gates. Other approaches required to facilitate movement will exist only where they are absolutely necessary and it will be indicated that they are added features and not part of the original form.

10. Full or extensive restoration of the bases of the large votif monuments (of Conon and Timotheus, of the general Cephisodotos, of the Attalids on the South Circuit Wall - with surviving blocks).

11. The bases of those monuments, where traces of the initial position are preserved although not the blocks, should be indicated on the ground.

12. The bases of those monuments of which plenty of blocks remain, although their exact position is uncertain (e.g. the ex-voto of Chairodemos in the Brauroneion) should be exhibited in their restored state, yet with the accompanying statement that their position is uncertain.

13. The bases of great monuments of which plenty of blocks remain, although their position is completely unknown (e.g. the base of the chariot of the Pronapes' ex-voto) should be exhibited in their restored state in the current museum or in its storerooms with the transfer of the collection to the new Acropolis Museum.

14. The scattered blocks will be reassembled, some in the museum, others outside and others not on the Acropolis.

15. Restoration of the area in front of the Propylaia, especially the access areas.

M. Korres
Architect Ph.D., Associate Professor NTUA, Member of the ESMA

STATE OF PRESERVATION OF THE PARTHENON ARCHITECTURAL MEMBERS: PRONAOS, OPISTHODOMOS, NORTH FACADE

The subject of this paper is the presentation of the state of preservation of the surface of the architectural members of the Parthenon on the three sections of the current restoration project (Pronaos, Opisthodomos, North Façade).

A brief historical account of the main events that have contributed, directly and indirectly, to the creation of the present appearance of the temple will be given.

The Parthenon bears all the forms of erosion that are to be encountered on the monuments of the Acropolis. Their type and extent differ in accordance with their position and orientation, since the effect of the destructive factors has not been the same over the whole of the surface of the temple.

The characteristic examples on each section will be presented and compared in order to reach some conclusions as to the extent of the effect of each factor on the various points of the monument. Answers are also given to questions such as: "Why are the painted surface layers preserved primarily on the west façade of the Opisthodomos and not at all on the section of the north façade which is undergoing restoration?" and "Why does the pitted corrosion appear almost exclusively on the north façade?" A comparison of earlier documentary material (photographs, plans and drawings, journals etc.) with today's observations and methods of documentation also assists in this.

D. Damianos, Ch. Laskarides, G. Marakis, M. Naka, E. Tzoumousli
Conservators, The Parthenon Restoration Project, YSMA

CONSERVATION WORK IN THE PROPYLAIA

The Propylaia was built in white Pentelic marble with foundations of yellowish limestone, whilst the use of grey Eleusinian stone as a decorative feature is characteristic.

The marble of the Propylaia is characterised by geological heterogeneity (non-calcitic inclusions, veins), which is responsible for differential erosion of the marble matrix and multiple flakes. A similar state of preservation is not encountered to such a degree on the other monuments of the Acropolis.

Conservation work is dictated by the restoration interventions. The restoration interventions are supported by pre-consolidation works and systematic conservation interventions of the surface of the architectural members, either *in situ* or after they have been dismantled. Interventions are also carried out on architectural members that are not included in the restoration programme but are seriously weathered.

The interventions can be divided into:

- rescue interventions, including pre-consolidation, temporary consolidation of structurally damaged sections of the surface and the collection of extant fragments and flakes.
- systematic interventions, including the documenting (plans and drawings, photography) of erosion and of the remains of previous interventions, mapping of the traces of the painted decoration and carvings of different eras as well as removal of old mortars, filling in of cracks, structural restoration, sealing, cleaning and consolidation.

The materials used in the interventions are inorganic and reversible. They have shown good behaviour over time and have been approved by the ESMA.

A time schedule is being followed for the parts of the monument, where surface conservation is being carried out.

These are:

1. The east façade of the East Stoa

2. The entrance wall of the Central Building.

3. The lintel of the entrance wall of the Central Building - east block.

4. The north wall of the West Hall.

5. Ionic column.

6. The south wall of the East Stoa.

7. The Stoa of the North Wing.

8. The Ionic column capital from the Balanos restoration.

9. Coffers from the ceiling of the Central Building

The Conservation team includes the marble masons L. Michalakos and I. Doulias, the conservation technicians E. Drakopoulou and Y. Kyrkos, and the undersigned conservators.

C. Babanika, E. Frangiadaki, E. Georgiou, F. Katevas, S. Papida
Conservators, The Propylaia Restoration Project, YSMA

STATE OF PRESERVATION OF THE ARCHITECTURAL MEMBERS OF THE TEMPLE OF ATHENA NIKE

During the third restoration project of the Temple of Athena Nike, the monument was completely dismantled for the structural restoration of the architectural members. This provided the opportunity for a detailed survey of the deterioration of the marble. The subject of this paper is to present the state of preservation of the architectural members of the temple.

The forms of deterioration that are being recorded are similar to those on the other Acropolis monuments. In addition to the effect of the deterioration agents on the marble, the extensive interventions that were executed during the previous two restorations play a significant role.

The present state of preservation of the marble elements of the temple is due to the combined effect of different causes of deterioration and the position and orientation of the architectural members on the monument.

A. Hatzipappa, M. Loukma, A. Tsimereki
Conservators,The Temple of Athena Nike Restoration Project, YSMA

THE PROGRAMME FOR THE CONSERVATION OF THE ERECHTHEION

Systematic conservation work was begun on the surface of the Erechtheion in 1995 on a decision of the ESMA. The problems that we are dealing with today are the results of the gradual transformations of the building during the passage of the centuries.

Conservation campaigns during the history of the monument were largely correlated to two significant events: the fire that broke out during the classical period and the resultant thermal degradation of the building blocks and the sieges of the Acropolis during the Greek War of Independence at the beginning of the 19th c., during which many structural changes were made to the monument.

In addition to the above extrinsic causes of erosion, there are also several intrinsic factors, primarily the mineralogical heterogeneity of the marble, responsible for differential erosion and delamination. Large cracks and internal voids are also characteristic of the condition of the marble blocks. These forms of deterioration are mostly evident on the lower segments of the interior elevation of the south wall of the Erechtheion.

In terms of conservation, the materials used in the earlier interventions also create significant problems. Unsuitable mortars have been used in the past, such as grey cement and Meyer cement, as well as a variety of metal nails (bronze and copper), the removal of which endangers the integrity of the building material.

The conservation programme for the surface of the Erechtheion for the period 2000-2006 includes systematic interventions on the interior elevation of the south wall. A representative example of the treatment of one particular block from this area with specific problems will be presented. Extensive fragmentation and the propagation of large cracks into adjacent blocks necessitated the use of a hydraulic grout. Particular attention was paid to the removal of older mortars as well as to the detachement of eroded flakes, aiming, as always, at minimal loss of original material.

G. Frantzi, D. Garbis, A. Maridaki
Conservators, The Erechtheion Surface Conservation Project, YSMA

STRUCTURAL RESTORATION AND CONSERVATION WORK ON THE PARTHENON WEST FRIEZE

The deterioration of the west frieze is attributable to a combination of mechanical, chemical and physical factors. Cracking, flaking, the reduction of the original monochromatic surface layers due to acid rain, the loss of mass, sulphation and the deposition of soot, suspended particles as well as black crust can be observed. Earlier interventions, with the effect of the seiling mortar by-products and the plastic repair, have also contributed to the surface deterioration.

After approval of the preliminary study for the conservation of the frieze by the ESMA and the Central Archaeological Council of the Ministry of Culture, systematic interventions began on the blocks of the west frieze in 1999.

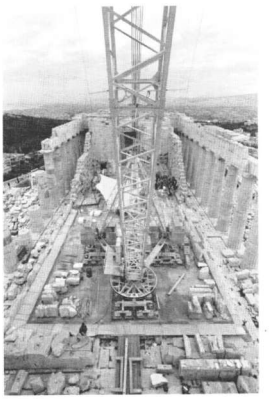
The programme of interventions involves the following stages:

- Structural restoration of the blocks with the structural consolidation of the large delaminations, the grouting of cracks, the removal of materials used in the previous interventions, the consolidation of the surface with the structural restoration of smaller fragments, and the sealing of flakes. The structural restoration works are at the stage of completion.
- Aesthetic restoration with the cleaning of the surface, filling in of discontinuities with mortar, and the application of an artificial patina to the new marble additions.

A research programme was carried out at the same time with the purpose of ascertaining the most suitable method for the removal of the soot deposits and the black crust.

The blocks of the west frieze will not be replaced on the monument once these interventions have been completed. They will instead be exhibited in the new Acropolis Museum and copies in artificial stone will take their place on the monument.

K. Frantzikinaki - A. Panou
Conservators, The Parthenon Restoration Project, YSMA



USEFUL INFORMATION

MEETING'S VENUE

The *5th International Meeting for the Restoration of the Acropolis Monuments* takes place:

- New Administration Building of the National Bank of Greece, Aiolou & Sofocleous Str., Athens
- Amphitheatre of the Ministry of Culture for the special session on October 6th, 20-22, Bouboulinas Str., Athens

REGISTRATION DESK

Friday, October 4, 2002	08.30-12.00 & 17.00-21.00
Saturday, October 5, 2002	08.30-21.00
Sunday, October 6, 2002	08.30-21.00

OFFICIAL LANGUAGE OF THE MEETING

The official language of the Meeting is Greek with simultaneous translation in English.

CONGRESS SECRETARIAT

Triaena TOURS & CONGRESS A.E.
15, Mesogion Ave.
115 26 Athens, Greece
Tel. +30 10 749 93 00
Fax. +30 10 770 57 52
E-mail: congress@triaenatours.gr
http://www.triaenatours.gr