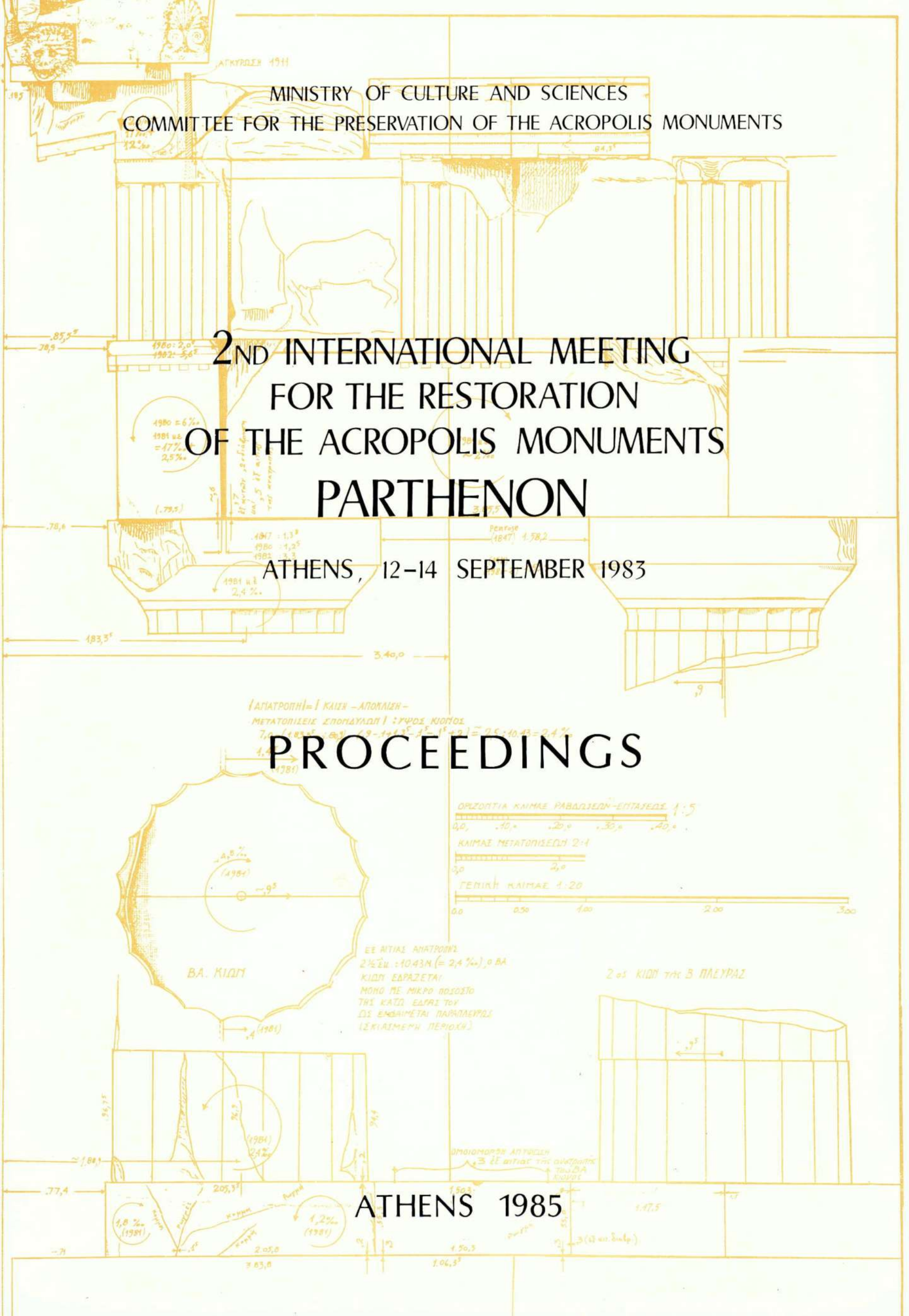

MINISTRY OF CULTURE AND SCIENCES
COMMITTEE FOR THE PRESERVATION OF THE ACROPOLIS MONUMENTS

2ND INTERNATIONAL MEETING FOR THE RESTORATION OF THE ACROPOLIS MONUMENTS

PARTHENON

ATHENS, 12–14 SEPTEMBER 1983

PROCEEDINGS

ATHENS 1985

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Sponsored by his Excellency the President of the Hellenic Republic
Constantine Karamanlis

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INTRODUCTION

The precarious state of preservation of the Acropolis monuments began to become noticeable directly after the Second World War. The monuments gradually deteriorated to such an extent that in 1975 it became essential to take action and the Committee for the Preservation of the Acropolis Monuments was founded; this was done on the initiative of C. Karamanlis, at that time the Prime Minister and now the President of the Hellenic Republic. The Committee is an interdisciplinary organization operating within the framework of the Ministry of Culture and Sciences.

The Committee is made up of specialists in different fields: archaeologists, architects, engineers and chemists, as well as leading members of the Greek Archaeological Service. The Committee's work consists of programming, researching, supervising and carrying out the projects necessary for the preservation and restoration of the Acropolis monuments. The first chairman of the Committee was John Miliades († 1975) followed by Professor Nikolaos Platon from 1975 to 1978, who was succeeded by Professor George Mylonas, member of the Academy of Athens.

The Acropolis Committee had, from the beginning of its operations, a technical office with a staff of architects, civil engineers and chemists, a secretariat and archives for systematically recording the progress of research and work on the buildings.

From 1975-1977 the Acropolis Committee devoted itself mainly to preliminary studies. The problems were recorded, examined in depth and studied. The main problems are as follows: the rusting of the iron clamps used in earlier anastylosis; physical, chemical and biological alterations disfiguring the surface; shifts in distribution of weight in certain parts of the buildings. These problems are complicated by the way in which the rocky slopes of the Acropolis are crumbling, by damage to the rock floor on top, by earthquakes and by aeroplanes flying overhead.

In 1976-77 the efforts of the Committee and its team were concentrated on the Erechtheion which was most in need of attention. This joint effort resulted in the «Study for the Restoration of the Erechtheion» which appeared in August, 1977; it contained a complete analysis of the state of preservation of the building, a description of the various kinds of deterioration classified by type of damage, and proposals for methods of repair.

The Acropolis Committee, taking into account the unique quality of the Acropolis monuments and their preeminent place in the world's cultural heritage, have taken the precaution of adopting internationally established principles and strictly controlled methods; they have also established a triple procedure for vetting proposed anastylosis. The studies for the conservation of the monuments are firstly approved by the Committee; secondly they are submitted for consideration to international meetings of experts; final approval from the Central Archaeological Council, the most authoritative advisory board of the Ministry of Culture and Sciences, opens the way to realizing the projects.

The «International Meeting on the Restoration of the Erechtheion» was held within the framework of this procedure on December 8-10, 1977; around ninety specialists in various fields participated. The «Study for the Restoration of the Erechtheion» was approved at this meeting and was judged to be a model of its kind for future restoration projects.

The work of restoring the Erechtheion, begun in 1979, proceeds at a steady rate and is due to be completed at the end of 1985. Other projects accomplished from 1979-1984 are as follows: minor repairs carried out on the east porch of the Propylaia; walkways for visitors were created at the approach to the Acropolis and between the Propylaia and the Parthenon; the work of consolidating the rock slopes of the Acropolis was started; the project of putting in order and inventorying the architectural blocks scattered far and wide over the Acropolis was begun and continues without a break to the present day. Sections of the Parthenon which became particularly shaky after the earthquake of February 1981 have been temporarily propped up. During all this time the work of systematically measuring, recording and studying the Parthenon architecture went on continuously, leading to the publication in July, 1983 of the «Study for the Restoration of the Parthenon» by the architects M. Korres and Ch. Bouras.

The study includes a complete analysis of the architecture, a concise survey of the Parthenon's history and fortunes throughout the centuries, an account of all of the work of anastylosis undertaken up until 1983, the current proposals for restoring the Parthenon with the goals and principles to be adopted, an analytical presentation of the mechanical equipment to be used. The report has two appendices. One, dealing with the atmospheric pollution and surface corrosion of the Parthenon, was written by Th. Skoulikides, N. Beloyannis, E. Papakonstantinou and D. Charalambous. The second deals with the problem of the monument's resistance against seismic hazards, written by K. Zambas, civil engineer. The proposals have been divided into twelve projects: the east side, northern colonnade, southern colonnade, west side, east porch, east wall, cella cross-wall, north wall, south wall, west porch, opisthodomos and western wall of the Parthenon chamber, ceiling of the west wing, crepidoma and floor. The report contains the full study for the first project and the preliminary studies for the remaining eleven.

The Acropolis Committee then submitted its proposals for consideration by colleagues all over the world by organizing the «Second International Meeting for the Restoration of the Acropolis Monuments: Parthenon». The conference, held on September 12-14th 1983 at the National Research Foundation in Athens, was sponsored by C. Karamanlis, President of the Hellenic Republic. Experts in various fields, archaeologists, architects, specialists in restoration, civil engineers and seismologists, chemical engineers, chemists and specialists in conserving stone were invited to participate in the meeting which attended by interested scholars and representatives of the press.

The President of the Hellenic Republic, C. Karamanlis, inaugurated the meeting. Mrs. M. Merkouri, Minister of Culture and Sciences, and Mr. K. Alavanos, the Secretary General of the Ministry, Mr. Naqvi, the UNESCO representative, Mr. Feilden, the ICCROM representative and other notables attended the opening session.

On the first day of the meeting, Monday September 12th, introductory reports were given on the history and work of the Committee and on the organization and financial aspects of the work by G. Mylonas, Chairman of the Committee, G. Dontas, honorary General Ephor of Antiquities, and E. Touloupa, head of the Acropolis Ephoria. E. Berger, director of the Antikenmuseum Basel, spoke about the Parthenon project carried on in Basel, and archaeologists M. Brouskari, A. Delivorrias and G. Despinis spoke about the recent research on Parthenon sculptures. Prof. Th. Skoulikides presented an introductory report on the problem of atmospheric pollution and the surface damage to the Parthenon. Professor Ch. Bouras spoke about the guiding principles underlying the proposed operations on the Parthenon.

The morning of the second day of the meeting, Tuesday, September 13, Messrs. M. Korres and K. Zambas, the engineers in charge of the work on the Parthenon, presented the twelve projects and the problem of the seismic resistance of the monument. Discussion amongst the participants began during the afternoon session and continued on the morning of the third day of the meeting, Wednesday, September 14th. The conclusions reached by the three groups of participants (archaeologists and architects, civil engineers and seismologists, chemical engineers) were read out at the end of the session. An exhibition entitled «Research, Studies, Work on the Acropolis, 1975-1983» was inaugurated at the National Gallery in the evening.

The exhibition which was held over until the end of October, 1983, presented all the research and technical work accomplished on the Acropolis during the past eight years under the supervision of the Committee. Plans, photographs, models, and original sculpture and architectural members, that had been given treatment for preservation and studied during that time, were on show. The exhibition was rounded out by an audio-visual show on the history of the Acropolis from the Middle Ages to the present, a donation from the National Bank of Greece, and by a film, made by C. Brettakos, dealing with the removal of sculpture from Acropolis buildings, focussing on the removal of the Caryatids from the Erechtheion.

The Parthenon project is scheduled to begin in the fall of 1984, after the technical equipment has been installed. The estimated time for completion of the entire project is about ten years; it will begin with the program for rebuilding the east front which was unanimously approved during the meeting.

The Acropolis Committee being conscious of the Parthenon's worldwide significance aims to circulate its reports and studies as widely as possible among international specialists, thus ensuring the greatest possible objectivity in coming to decisions. With this in mind further international meetings of specialists are planned for the future, in order to examine the other restoration projects in depth and to reach final decisions.

COMMITTEE FOR THE PRESERVATION OF THE ACROPOLIS MONUMENTS

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General Secretary of the Archaeological Society of Athens, Member of the Athens Academy

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Dr., Archaeologist, Ephor of Antiquities Director of the Acropolis Ephoria

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J. TRAVLOS, Dr., Ephoria of Acropolis, Athens, Greece.
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TH. SKOULIKIDIS, Prof., National Technical University, Athens, Greece.
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E. VALLIANTZA, Ministry of Environment, Athens, Greece.
G. VAROUFAKIS, Dr., Athens, Greece.

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ST. PHILLIPS, Journalist, Channel 4 News, London, U.K.
Lady M. POSONBY, Representative of the British Committee for the restitution of the Parthenon marbles, London, U.K.
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N. SKARRIS, Marble technician, Ephoria of Acropolis, Athens Greece.
L. VRANOUSSIS, Dr., Historian, Athens, Greece.

PROGRAM

Monday 12 September

Chairmen: Prof. G.E. Mylonas – Dr. J. Travlos

10.00 - 10.30	Inaugural address by the President of the Hellenic Republic C. KARAMANLIS
10.30 - 11.00	Prof. G.E. MYLONAS, History of the Committee for the Preservation of the Acropolis Monuments.
11.00 - 11.20	G. DONTAS, Travaux sur l'Acropole jusqu' à 1982. Présentation générale des problèmes. Rencontre Internationale pour la restauration de l'Erechthéion en 1977.
11.20 - 11.40	E. TOULOUPA, Travaux sur l'Acropole: organisation et financement.
11.40 - 12.00	E. BERGER, Parthenonausstellung und internationaler Parthenonkongress in Basel.
12.00 - 12.30	Coffee break

Chairmen: Prof. S. Anghelides – Prof. L. Beschi

10.30 - 13.00	M. BRUSKARI – A. DELIVORRIAS – G. DESPINIS, Recent research on the Acropolis sculpture.
13.00 - 13.30	TH. SKOULIKIDES, Pollution atmosphérique et corrosion de la surface du marbre du Parthénon. Observations et propositions.
13.30 - 14.00	CH. BOURAS. The problems of conserving the Parthenon and the possibilities of improving the value of the monument. The principles which will guide the operation.
17.30 - 20.00	Visit to the Acropolis.
21.00	Performance at the Festival of Athens in the Odeion of Herodes Atticus.

Tuesday 13 September

Chairmen: Dr. V. Karageorgis – Dr. L. Linstrum

9.00 - 11.00	M. Korres, Τὰ δώδεκα προγράμματα ἀποκαταστάσεως τοῦ Παρθενῶνος.
11.00 - 11.30	Coffee - break
11.30 - 12.30	C. Zambas, Τὸ πρόβλημα τῆς ἀντισεισμικῆς ἐπάρκειας τοῦ Παρθενῶνος.

Chairmen: Dr. J. Coulton – Prof. G. Schwab

16.00 - 19.00	Discussion
20.00 - 22.00	Cocktails

Wednesday 14 September

Chairmen: Prof. Fr. Brommer – Prof. R. Mainstone

9.00 - 12.00	Discussion Recommendations
18.00	Visit to the exhibition, «Research, Studies, Work on the Acropolis, 1975 - 1983» in the National Gallery-Museum Alexandrou Soutzos.

ADDRESS BY PROF. G. MYLONAS

Chairman of the Committee for the Preservation of the Acropolis Monuments.

Mr. President of the Hellenic Republic,

We welcome you with pride and joy into the circle of distinguished archaeologists, since among your many great services to Greece in the past and in the present is the creation of the Committee of Greek Scientists to whom you have entrusted the priviledge of studying and preserving the immortal monuments of the Acropolis of Athens, the hearth of western culture. Through your efforts resources were obtained which make it possible to realize the envisioned plans and decisions, the progress of which you follow so enthusiastically.

My colleagues and I are especially grateful to you not only for being here with us but also because you have consented to inaugurate the opening of this meeting towards which the world of learning looks with such hope.

This morning we respectfully call on you as President of the Hellenic Republic and father of our country and as the inspirer of the work now being realized on the Acropolis of Athens, to announce the opening of the Second International Meeting to whose care the continuation of this work is entrusted.

Mr. President of the Republic, the Committee gratefully turns the speaker's platform over to you.

We also owe thanks to Mrs. Melina Merkouri, Minister of Culture and Sciences, not only for honouring us with her presence and taking part in our meeting but also for the interest and support that she gives the work of the Committee, for which we express, as always, our gratitude.

ADDRESS BY MRS. M. MERCOURI
Minister of Culture and Sciences

Mr. President of the Hellenic Republic

I welcome you most cordially to the International Meeting for the Acropolis, dedicated to the Parthenon, the monument of beauty and Measure. This monument is not only our heritage, our soul; it is a symbol of world-wide significance being reerected by the Greek state, Greek scientists and Greek technicians. This is a large-scale project of vast significance which we may justifiably take pride in showing to the specialists who are gathered here from all over the world.

Mr. President, your presence amongst us is at once a joy and an honour, a token of the great interest you have always taken in a project which owes its existence to your vision, your initiative, and, if I may be permitted to say so, your ardour for which we warmly thank you.

INAUGURAL ADDRESS BY C. KARAMANLIS
President of the Hellenic Republic

Ladies and gentlemen:

I am very glad to be given the opportunity of addressing leading authorities from Greece and abroad. And to speak for a little while about the great importance of the excellent work that was carried out on the Acropolis in recent years. I myself have had the good fortune of contributing in some ways towards the realization of this project. And I must thank Mrs. Merkouri, Minister of Culture and Sciences, and Mr. Mylonas, member of the Academy of Athens, for making mention of my contribution.

In 1975 I pointed out the necessity of saving the Acropolis monuments and protecting them in a systematic way; working together with the former Minister of Culture and Sciences, Mr. Trypanis, member of the Academy of Athens, I set up a committee of specialists for this purpose. And I then saw to it that the essential needs were provided for, financial support and working procedures, so that the Committee could devote itself uninterruptedly to a task which has attracted the attention of the entire civilized world.

At this point I wish to congratulate the Acropolis Committee and every single person who worked on this unique project, because their devotion, zeal and entusiasm prove that they are fully aware of the responsibilities to which they are committed. I also wish to congratulate the Archaeological Society which has, through its perseverance and sense of responsibility, made a decisive contribution to the prompter and more perfect completion of the project.

Ladies and Gentlemen:

I am not about to deal with the subject which has brought you here together since you know so much more about it than I do. I shall, however, take advantage of the opportunity to set forth some of my thoughts about the profound spiritual significance of the Parthenon in which Lamartine saw «la statue de l'humanité» and Renan «l'idéal christallisé en marbre pentélique». And I say «spiritual significance» because the Parthenon is not merely an example of artistic perfection. It is not only the symbol of the Athenian state at the height of its powers. It is the most perfect expression of the culture of classical Greece. A culture which revealed man's quality as an individual and, by defining the concept of liberty, set the ideal of Measure and established the power of the Reason. It is the supreme expression of the spirit of this culture whose ideas and values were the source for the European enlightenment and the guideline for civilized humanity.

Moreover, art is par excellence the soul of a civilization. No other civilization ever achieved the clarity of form attained by classical Greece. Classical art perfectly mirrors the efforts of its time to attain clarity, purity, measure. To idealize man and to interpret him not as an individual but as a concept, as beauty, as a being of great worth.

The temple of Pallas Athena stands on high at the culmination of this art. The Parthenon is the symbol of Measure. It is the manifestation of Reason and the expression of Beauty. It is the symbol of all humanity because it expresses the spirit of humanism. Its significance is worldwide because it embodies universal values. Its message is not directed to any particular person in any particular culture. It is directed to human consciousness everywhere. Therefore its essence remains immutable, its meaning always timely. Unfortunately our materialistic age seems to be unaware of its significance. Humanity, alienated from the social and cultural models of the Greek spirit, is lost in a sea of excesses and irrationality. Mankind, divided as never before, is in search of new values on which to rely, but is able to determine neither their form nor content. In the midst of our chaotic, one would almost say anarchic, world there is an urgent need to return to the values that Attica brought forth and whose wisdom the centuries attest.

And with these thoughts I now declare the Meeting open and wish that your aims may be crowned with success.

1

INTRODUCTORY SPEECHES

HISTORY
OF THE COMMITTEE FOR THE PRESERVATION OF THE ACROPOLIS MONUMENTS

G.E. MYLONAS

Honored Colleagues, Ladies and Gentlemen,

On behalf of the members of our Acropolis Committee, I welcome you to Athens and thank you for your participation in this, the 2nd International Meeting of Specialists in the field of Architecture and the Preservation of the Acropolis Monuments. Some of you were with us in our First Meeting, in December 1977, others have come for our 2nd Meeting for the first time; all of you are welcome to study with us the problems connected with the restoration and strengthening of the parts of the Parthenon which need preservation and in the way to reach a decision on the process of action. Before this, perhaps, it may be pertinent to give you a brief summary of the recent history of the efforts devoted to the needs of the Acropolis and of its protagonists. Efforts that go back even to the pre-Christian Era and to some scholars old and new, among whom should especially be mentioned the late Nicolaos Balanos and Anastasios Orlandos.

Since Balanos' days, beginning in 1895 and to 1930, scholars rejected the idea that the buildings on the Acropolis ran the danger of being damaged; those in authority refused to allow or undertake proper measures to be taken, while a few archaeologists, faithful guardians of the Acropolis, attempted occasionally small interventions and supports of detached parts. Positive and effective measures were not taken to almost the present time when the danger of deterioration was increased tremendously by the technological progress of our Community. The needs of the Acropolis had been gradually enveloped by inertia. That inertia was dispersed early in 1975 when the then Prime Minister Cons karamanlis and Professor Constantinos Trypanis, then Minister of Culture and Sciences, decided on immediate action that would begin a salvage campaign. On February 22nd 1975, a large commission of Greek archaeologists was convened to exchange thoughts on the matter, to lay the foundations and the guiding lines for the task to be undertaken. Then it was that a working committee was formed and its members and their prerogatives of work were established by law on the 31st of March 1975. Its first Chairman was the late John Miliades; its second Professor N. Platon, who served in that capacity to the end of 1978. In the meantime, the General Secretary of the UNESCO, Dr. Mahtar M' Bow, from the Sacred Rock of the Acropolis called on the Civilized World to a New Crusade to save the Monuments of the Acropolis.

The Committee went to work and decided to concentrate its effort on the Erechtheion which needed help more than any of the other buildings on the Rock. In less than two years' time the Committee completed the study concerning the Erechtheion. In collaboration with the UNESCO, the Greek Government and its Acropolis Committee called the First Meeting at Athens in December 8-10, 1977 for scrutinizing, discussing and adopting a series of measures that had to be taken if the Erechtheion was to be saved. The study and the conclusions reached were accepted by the convention of scholars, and the decision was taken for the work to proceed at once on the guide lines established.

The time had arrived for the plans to be translated into action and this required the securing of the large funds required for the work, not a mean undertaking. The UNESCO generously offered to continue to solicit contributions from the public of the world, an action which had been auspiciously began. The President of the Hellenic Republic Constantinos Karamanlis, having expressed the thanks of the Country to the UNESCO, decided that the task, not only of the scientific part but also of the financial part entailed, should be undertaken by Greece as the owner and guardian of a sacred obligation, of a sacred Greek heritage, which happens at the same time to be the heritage of the World. The President along with the three Governments of the last ten years, i.e. the Ministry of Culture and Sciences and the Ministry of National Economy, succeeded in keeping the necessary funds flowing and the work advanced without interruptions. The sum of 220 million drachmae were secured and contributed to which in September will be added 80 million to cover expenses for 1984; thus 300 million drachmae have been allotted for the work*. Additional sums will be secured as the work will be advanced in the years to follow, until the work is completed. At the decision of the President and the Ministry of Culture and Sciences the administration of the financial and other administrative matters were entrusted to the Archaeological Society of Athens as a full participant in the work, whose General Secretary happens to be the Chairman of the Committee of the Acropolis as well. To the President and the Greek Government involved Greek Science and Heritage are grateful for their deciding help in planning and bringing to a working scheme our work. Gratefully must also be acknowledge the General Grant made by the EEC

* A sum of 30 million dr. was spent through the regular budget of the Ministry of Culture and Sciences as Mrs Touloupa states in her report.

of 500.000 écus to be applied for the work on the Parthenon of which have received already 250.000 or 18.769.945 drachmae. Perhaps I may digress a little and add that to the funds secured for the Acropolis President Karamanlis was able to provide funds for the archaeological work conducted in West Macedonia and Thrace, for farther work of Olympia, Delos and the undersea operations in the Greek areas. He will long be remembered by archaeologists as the patron of Greek Antiquities and protector and inspirer of young scholars.

I may be allowed now to draw your attention to the names of the members of the Committee printed in the Program at hand and to add two names of colleagues who served for a good many years besides Professor Platon, and now have yielded their places to others. These are Professor John Travlos, and Professor S. Anghelides. In addition I wish to draw your attention to the names of the architects and engineers who since the beginning worked on the project and who will present their individual reports to you in the course of our sessions. I must end by adding that Professor Ch. Bouras acted as chairman of the sub-Committee for organization of the conference. His contribution to the studies of the Parthenon will be enjoyed when he will report to you, later.

Ladies and Gentlemen:

Many many years ago Plutarch in discussing Pericles' masterpieces found the few words that characterize their virtues so aptly. He stated «Each one of the buildings in its beauty, was even then and at once antique; but in the freshness of its vigor it is, to the present day, recent and newly wrought. Such is the bloom of perpetual newness, as it were, upon these works of his, which makes them ever to look untouched by time, as though the unfaltering breath of an ageless spirit had been infused into them».

So we hope these buildings will continue to live as described by Plutarch and inspire humanity, when the works on the Acropolis are completed.

TRAVAUX SUR L'ACROPOLE JUSQU' À 1982. PRÉSENTATION GÉNÉRALE DES PROBLÈMES. LA RENCONTRE INTERNATIONALE POUR LA RESTAURATION DE L'ERECHTHEION EN 1977.

G. DONTAS

Mesdames, Messieurs,

En 1975, un décret ministériel créait le Groupe de Travail pour la Conservation des Monuments de l'Acropole. Deux ans plus tard ce Groupe était transformé en Comité dépendant du Ministère de la Culture et des Sciences. On eut alors le sentiment que l'Acropole entrait dans une nouvelle phase de son histoire. Il y avait en effet quelque chose de changé dans l'idée même qu'on se faisait de la restauration de l'Acropole, des buts à atteindre et des méthodes à employer. Les restaurations effectuées par le passé – les dernières avaient été entreprises sitôt après la guerre – étaient exclusivement destinées à rendre aux monuments leur aspect original, dans les limites du possible bien entendu. Ces restaurations avaient été suscitées par un puissant courant classicisant, fortement teinté de nationalisme, qui a marqué le XIXe siècle et les premières années du XXe. C' est ce qui explique que, malgré de grandes difficultés financières – n'oublions pas que la Grèce était alors dans une phase critique de son histoire – d'importantes restaurations ont pu être effectuées dans un laps de temps relativement court, et ceci grâce à la généreuse contribution de l'état et à l'appui moral de l'étranger.

Mais sitôt après la guerre, alors que les travaux étaient encore en cours, on commença à se rendre compte que quelque chose n'allait pas dans les restaurations d'avant-guerre et que les monuments souffraient de maladies. Des fragments se détachaient de plus en plus fréquemment, et il était clair qu'un jour ou l'autre on aurait eu à déplorer, sinon la perte de vies humaines, du moins celle d'importants fragments d'architecture et de sculpture. Les spécialistes alertaient périodiquement l'opinion publique par voie de presse sur les causes de ces dégâts. De leur côté les archéologues s'efforçaient d'aider, dans la mesure de leurs possibilités: ils recollaient, consolidaient ce qui menaçait de se détacher ou de s'écrouler, colmataient les brèches par lesquelles l'eau de pluie pouvait s'infiltrer et saper la résistance du marbre. En un mot ils jouaient le rôle des pompiers devant un incendie qui fait rage. En outre ils ne cessaient d'attirer l'attention des autorités supérieures sur la nécessité de prendre d'urgence des mesures pour sauver les monuments. C'est d'abord hors de Grèce que leur voix fut entendue. En 1968, le Courrier, périodique officiel de l'Unesco, fut le premier à publier un article sur l'état des monuments. Un an plus tard, en 1969, une Commission de l'Unesco visitait la Grèce; elle montrait beaucoup d'intérêt à la question et étudiait les causes du mal qu'elle présentait dans un rapport spécial. En 1971 enfin, l'Institut National Géographique de France procédait à un relevé photogrammétrique des monuments.

Et pourtant les années passaient et aucune mesure radicale n'était prise. Les dangers se faisaient de plus en plus menaçants malgré les opérations du type «pompier» qui se poursuivaient sans relâche, comme celle qui, en 1973, interdit l'entrée du Parthénon pour ne pas user les dallages et les escaliers. Notons que cette mesure a été fortement combattue par le gouvernement d'alors.

C'est en février 1975 enfin que de grandes décisions furent prises. Le Professeur C. Trypanis, savant philologue profondément imprégné de culture classique, alors Ministre de la Culture et des Sciences, se rendit tout de suite compte qu'il fallait prendre d'urgence des mesures systématiques pour faire face aux dangers immédiats et soigner les monuments de façon durable. Il fit appel à des spécialistes de toutes disciplines et constitua un groupe de travail scientifique dont la mission était d'étudier les problèmes et d'émettre des propositions. Il accorda à ce Groupe de Travail des crédits substantiels, prélevés sur le budget des investissements publics. Et cela a été possible grâce à l'intérêt montré dès le début par le Premier Ministre d'alors, Mr. C. Karamanlis, aujourd'hui Président de la République Hellénique. L'intérêt du Président pour cette entreprise est toujours aussi vif; il en a parfaitement saisi l'importance scientifique, mais aussi les dimensions nationales, voire internationales.

Mesdames, Messieurs, je regrette de ne pas avoir le temps d'exposer en détail les travaux effectués par ce Groupe et par le Comité pour la Conservation des Monuments de l'Acropole qui prit le relais en 1977. Mais je vous donnerai, dans le cadre de cette réunion, une idée d'ensemble des tâches accomplies.

Je pense qu'il est également indispensable de souligner à l'avance les deux principes qui ont régi l'oeuvre de notre Comité: le premier a été celui de la collaboration entre diverses professions scientifiques pour mener à bien l'oeuvre de sauvetage. En effet, à part l'archéologie, l'apport de l'architecture et de la science de la construction, de la mécanique, de la physicochimie, de la science des métaux, de la géologie, de la photogrammétrie, de la radiologie, de la biochimie même, a été considéré comme indispensable. Ces différentes disciplines ont été amenées à collaborer de façon permanente avec le Groupe de travail, ou épisodiquement, dans des cas bien particuliers. Le deuxième principe a été de maintenir le fonctionnement – et l'esprit – du Groupe (et celui du Comité par la suite) dans un cadre strictement scientifique. C'est ce qui lui a conféré le poids scientifique et moral nécessaire pour mener l'oeuvre à bien, en dépit des difficultés d'organisation qu'il a eu à affronter, surtout au début.

Les premiers fruits n'ont pas tardé à donner. Première manifestation de l'activité du Groupe: sa participation au Congrès International pour la Protection de la Pierre qui s'est tenu à Athènes en septembre 1976.

Mais c'est surtout la Rencontre Internationale pour la Restauration de l'Erechthéion qu'il avait organisé à Athènes en décembre 1977 qui révéla le Comité. A partir d'une étude importante, aussi minutieuse que détaillée, rédigée par de jeunes collaborateurs, le Comité présenta aux spécialistes grecs et étrangers des propositions à discuter. Conformément à la loi grecque, les décisions prises auraient été soumises au Conseil Archéologique Central du Ministère de la Culture et des Sciences.

Il n'est pas nécessaire d'exposer ici en détail les propositions qui furent discutées ou les décisions qui furent prises, d'ailleurs la plupart d'entre vous étiez présents à ce Colloque. Je me contenterai de mentionner brièvement trois décisions qui me semblent avoir revêtu une importance particulière puisqu'elles sont valables pour toutes les restaurations de l'Acropole.

La première prévoyait le transfert des Caryatides au Musée de l'Acropole afin de stopper le processus de dégradation dû à leur longue exposition en plein air.

Deuxième décision importante: le démontage partiel de l'Erechthéion, d'abord pour enlever les goujons et les crampons métalliques ajoutés par les restaurateurs prédécents et qui ont causé à l'édifice des dommages considérables, et puis pour redonner au monument son équilibre statique, mis à l'épreuve par les vicissitudes qu'il connut au cours des âges, ou bien par l'action même de ces éléments métalliques.

Troisième décision importante enfin: l'adoption du titane comme pièce de liaison entre les plinthes des murs et les autres éléments d'architecture.

Si je mentionne ces décisions c'est qu'elles ont marqué le début de la nouvelle phase de restauration de l'Acropole qui ne se propose plus seulement, comme auparavant, de redonner aux monuments leur aspect d'origine – cette idée n'est quand même pas absente du programme d'ensemble – mais bien plus de les sauver et de les soigner. C'est d'ailleurs cette attitude qui prévaut plus ou moins aujourd'hui dans notre pays en matière d'anastylose: traiter, renforcer, consolider, soigner les monuments et les restaurer si tout cela est possible. On a donc «enrichi» l'idée qu'on se faisait des restaurations – pour ne pas dire qu'on l'a remplacée par une autre. Il va de soi, que cette conception nouvelle est due à l'influence des sciences appliquées et de la technologie. Nous aurons à reparler de ce rôle qui a été le leur.

Passons maintenant aux travaux eux-mêmes. Je dois tout d'abord signaler que, selon la loi grecque, les travaux de restauration sont effectués sous la haute responsabilité du Service des Anastyloses dépendant du Ministère de la Culture et des Sciences et, officiellement, le Comité de l'Acropole n'est chargé que de la rédaction du programme, de la direction et de la supervision des travaux. Mais en pratique l'exécution des travaux constituait si peu de chose par rapport à l'ensemble qu'elle passa, elle aussi, au Comité. C'est ainsi que, nanti de crédits importants – qui sont actuellement versés à la Société Archéologique, institution privée beaucoup plus souple dans les versements –, disposant d'équipes de techniciens et d'une main d'oeuvre abondante, le Comité devint, au moment voulu, le maître des travaux. En assurant la continuité on pouvait espérer un maximum de rendement et toute l'attention voulue.

C'est dans le courant de l'été 1978 que les travaux ont commencé à l'Erechthéion. Des artisans qualifiés ont pris des moulages des Caryatides. Les risques étaient grands, on le devine, car le travail se faisait sur des statues qui, pendant de siècles, avaient été continuellement exposées aux intempéries, et même parfois agressées de façon plus violente. Mais le travail a été mené avec la délicatesse d'une opération chirurgicale et n'a pas occasionné de dégâts supplémentaires. Quant à la deuxième partie de la tâche qui consistait à exécuter des copies, elle s'est révélée longue et laborieuse, et elle n'est pas encore prête d'être terminée, même si elle ne comportait pas les dangers de la première phase. On a cru nécessaire et prudent de faire d'abord, à partir des matrices de plâtre, une série de copies en plâtre, et de prendre sur celles-ci une deuxième série de matrices, en matière synthétique cette fois, qui permettraient de faire des essais pour la confection de copies durables destinées à être exposées en plein air. C'est précisément cette deuxième série de copies qui, aujourd'hui encore, donne à réfléchir.

En même temps qu'on travaillait sur les Caryatides on procédait au démontage du mur Sud du monument pour lui enlever ses crampons métalliques et puis dégager les Caryatides en vue de leur transfert au Musée de l'Acropole. Le démontage et le transfert des Caryatides au Musée furent effectués en automne 1978.

Ensuite on a peu à peu démonté les autres faces du monument. Des ouvriers qualifiés retiraient les goujons ou crampons rouillés et les remplaçaient par du titane, pendant que d'autres restituaient, en marbre, les pièces manquantes, en imitant toujours strictement les formes anciennes. Au fur et à mesure que le traitement avançait on remontait les différentes parties. Tout un côté de l'Erechthéion a déjà été reconstitué. On estime que l'ensemble du programme sera achevé l'année prochaine ou, au plus tard, en 1985. Le British Museum exécute actuellement des copies des fragments architecturaux qu'il possède de façon à les intégrer au monument.

Si le Comité a porté l'essentiel de ses efforts sur l'Erechthéion, il s'est aussi intéressé aux autres monuments de l'Acropole et au rocher lui-même. Je signalerai tout d'abord l'intervention pratiquée en 1981 et en 1982 sur les Propylées. Il s'agissait de retirer une grosse poutre de fer encastrée dans l'architrave Est lors des anastyloses du début du siècle, et qui a causé de gros dégâts. Elle devait être remplacée par une barre de titane. C'est la première opération de sauvetage effectuée sur un monument qui présente les mêmes problèmes que les autres, celui des crampons de fer que l'on rencontre un peu partout. En outre le mur Ouest de la Pinacothèque a légèrement bougé lors de l'explosion de la poudre emmagasinée dans le bâtiment vers le milieu du XVIIe siècle.

Depuis quelques années on a entrepris de consolider les versants du rocher, là où on avait signalé des dangers d'éboulement. Les travaux sont terminés dans l'angle N.-E. de l'Acropole, mais ils se poursuivent encore au S.-E.

Pour ce qui est de la protection de la surface du rocher, qui s'use d'année en année au contact des chaussures de millions de visiteurs, le Comité a décidé d'en recouvrir certains secteurs correspondant approximativement aux voies antiques. Ce revêtement est fait d'un mélange de ciment et de gravier qui imite la terre et la couleur du rocher. Grâce à ces voies les touristes peuvent visiter plus facilement l'Acropole et sont en quelque sorte «canalisés»; ils ne doivent plus parcourir les autres surfaces du rocher qui présentent de nombreuses entailles marquant l'emplacement de monuments, d'ex-voto et d'inscriptions. Dans le cadre de ce projet le Comité a également entrepris de ranger les fragments de marbre éparpillés sur l'ensemble du rocher. Ils sont désormais regroupés de façon homogène, et ce classement a favorisé des découvertes importantes; on a même retrouvé des fragments architecturaux appartenant aux grands monuments.

Le Comité de l'Acropole a encore entrepris le relevé des murs, dans l'intention de les consolider car, par endroits, surtout là où sont conservées les constructions antiques, on a constaté une forte corrosion allant même jusqu'à la désagrégation des pierres de taille.

Il me semble que je ne dépasse pas les limites de mon sujet en ajoutant encore deux travaux en cours depuis des années à l'extérieur de l'Acropole proprement dite, et qui sont effectués, eux aussi, par le Comité. Il s'agit en premier lieu de la reconstitution du Péripatos, cette voie antique qui faisait le tour du rocher. L'opération, lancée il y a plusieurs années, a été poussée assez loin par l'Ephorie de l'Acropole, et cela avant même la formation du Groupe de Travail; celui-ci s'en est chargé par la suite et le travail est aujourd'hui presque achevé.

L'autre projet est celui du relevé architectural et de la restauration du théâtre de Dionysos, programme ambitieux et de longue durée. On a commencé par faire un bon relevé de la cavea et de l'orchestra, et puis on a consolidé et restauré le dallage en marbre de la cavea.

J'ai laissé à dessein pour la fin de mon rapport le projet qui concerne le Parthénon et qui fait l'objet de ce colloque. Vous comprendrez facilement pourquoi. Effectivement tout ce qui s'est fait jusqu'à présent, tout ce qui se fait actuellement ou tout ce qui sera fait – il y a des projets que je n'ai même pas mentionnés car ils sont entièrement du domaine de l'avenir – semble être quelque chose de secondaire – il ne faut toutefois pas en minimiser l'importance – par rapport à l'intervention, colossale tant par son étendue que par son importance, dans laquelle va bientôt s'engager le Comité de l'Acropole, sur le Parthénon. Et c'est précisément le sentiment de la lourde responsabilité qui lui incombe, au moment de prendre, pour l'oeuvre maîtresse de l'architecture antique, des décisions d'une grande portée historique, qui incite le Comité à demander, une fois encore, l'avis des autorités internationales. Il ne s'agit pas seulement de «toucher» une nouvelle fois au monument si cruellement éprouvé dans l'espoir de le guérir en extrayant les fers responsables des maladies, ou d'en démonter les différentes parties pour les remettre à leur place d'origine après qu'elles aient été ébranlées par la grande explosion et les tremblements de terre. Non, le Parthénon pose des dilemmes vraiment tragiques – ce mot n'est pas trop fort pour exprimer la douleur que chacun de nous ressent devant des choix aussi difficiles. En voici un exemple. Après avoir transféré au Musée de l'Acropole les trois sculptures des frontons du Parthénon démontées en 1976 – c'était là une opération relativement facile – on se demande s'il faut aussi détacher la frise agressée par la pollution toujours croissante, même si aujourd'hui elle est moins pernicieuse à cause de la toiture provisoire qui la protège désormais de la pluie.

Peut-on la laisser sur place? Et si oui comment va-t-on la protéger de manière efficace de dégâts éventuels et de la pollution? En outre, si la seule solution est de la démonter, une nouvelle question se pose, angoissante: où va-t-on la transporter et l'exposer? Le problème ne peut pas se résoudre – et c'est là que je voulais en venir – par le Musée actuel dans lequel nous avons réussi tant bien que mal à exposer les sculptures des frontons et les Caryatides de l'Erechthéion.

Ceci pour vous montrer, Mesdames, Messieurs, que si l'on décide de transférer la frise – entreprise qui exigera le démontage d'une bonne partie de la face Ouest de l'édifice, une de celles qui n'ont pas bougé depuis l'antiquité – il est indispensable de créer un grand musée moderne. Tant que le nombre des oeuvres du Musée de l'Acropole restait le même, on n'avait pas à envisager autre chose que le musée actuel, situé sur le rocher même, invisible de l'extérieur, tout près des monuments que la plupart des sculptures qu'il abrite avaient ornés. Tout au plus pouvait-on envisager de l'étendre, toujours en sous-sol, afin de mieux présenter les pièces actuelles et d'en exposer d'autres, choisies dans les réserves. Mais si le musée doit accueillir les sculptures de l'Erechthéion et les sculptures déjà détachées ou à détacher du Parthénon, il ne faut pas songer au musée actuel, même agrandi. Il faut alors chercher une solution en dehors du rocher, mais tout près bien sûr afin de préserver le contact psysique, sinon optique, du visiteur avec l'Acropole. Le terrain choisi dans ce but, il y a quelques années par le Premier Ministre de l'époque, et situé à Makryghianni semble, malgré l'échec de deux adjudications successives, fournir la meilleure solution, à condition toutefois que les immeubles qui le bordent sur trois côtés soient expropriés. Ce qui est fâcheux dans cette histoire, c'est qu'en plus des problèmes financiers que soulève son acquisition, ce terrain est également convoité par d'autres autorités.

Notre Comité ne s'est pas seulement soucié des travaux dont il a la charge, il s'est aussi préoccupé sérieusement du problème de la pollution atmosphérique, et il en a référé aux autorités compétentes, sans beaucoup de résultats malheureusement. Des mesures ont été prises il y a quelques années, mais elles n'ont pas eu de suite. Peut-être qu'à l'époque la crise du pétrole ne permettait pas d'envisager des solutions radicales. Tout le monde a conscience de la gravité du problème en ce qui concerne les monuments, d'autant plus qu'il met aussi en péril la santé de la population athénienne. Il faut avoir le courage de l'avouer et prendre des mesures concrètes et efficaces, quel qu'en doive être leur coût économique ou politique.

Mesdames, Messieurs,

Mon rapport n'a pas touché – il s'en faut – tous les domaines qui ont fait l'objet des soins de notre Comité; il n'a pas non plus épuisé chacun des sujets traités, mais il était destiné à vous donner une idée de son activité, et surtout de celle qu'il a déployée depuis le Colloque de 1977. Et puis il a voulu insister sur le profond changement qui s'est opéré dans la politique d'anastylose et les méthodes employées. Cependant – et je m'adresse ici plus spécialement aux représentants grecs – il s'en faut de peu que ce pas en avant devienne un faux pas. L'introduction des sciences appliquées dans le domaine de la restauration, les utilisations qu'autorisent les conquêtes de la technologie moderne ne doivent nullement nous faire perdre conscience que ces monuments sont avant tout des oeuvres d'art, des fruits du génie humain. Le Parthénon n'est pas une simple application de règles arithmétiques et géométriques. Sa beauté et son éternité doivent beaucoup à ce *παρὰ μικρὸν* que les anciens décelaient même dans les oeuvres du sculpteur Polyclète, pourtant le plus mathématique de tous. Il ne faut pas que les anastyloses traitent le monument comme s'il était un assemblage de chiffres, de plans, de lignes ou de masses. Si la place laissée à ce *παρὰ μικρὸν* semble petite, elle n'en est pas moins considérable, c'est la place du génie, du souffle artistique qui est à l'origine de ces monuments, et il faut donc laisser aux historiens de l'art, aux archéologues, aux poètes de la science qu'est l'archéologie le dernier mot en matière d'anastyloses. C'est un devoir et à la fin un honneur pour eux.

TRAVAUX SUR L'ACROPOLE: ORGANISATION ET FINANCEMENT

E. TOULOUPA

Mesdames, Messieurs,

Une oeuvre aussi considérable, aussi importante que celle du sauvetage des monuments de l'Acropole, exige le maniement et la gestion de grandes sommes d'argent: notamment celles exigées par les achats, l'approvisionnement et le paiement des salaires et traitements. Cette tâche constitue pour les archéologues concernés une source de soucis, de travail et de responsabilité qui s'ajoute aux préoccupations multiples qui forment leur lot quotidien. Cela ne va cependant pas sans quelque compensation telle par exemple la joie d'être au contact direct de ceux qui, sur le terrain, assument la charge des travaux, l'initiation aux techniques actuelles de conservation.

Cette tâche fut celle des directeurs de l'Acropole durant ces dernières années, citons feu Jean Miliades, le Professeur N. Platon et l'éphore général honoraire G. Dontas; cette tâche est et sera celle de leurs successeurs, et ce tant que l'oeuvre de restauration se poursuivra.

Le directeur de l'Acropole est responsable des antiquités préhistoriques et classiques pour le territoire constituant la 1ère Ephorie. Cette Ephorie comporte: le rocher avec ses monuments et son musée, l'agora, y compris le musée de la stoa d'Attale, les monuments de la pente sud de l'Acropole (théâtres, sanctuaire d'Esculape, etc.), les collines de la Pnux, de Philopappos et des Nymphes, une partie du vieux quartier de Plaka avec le Musée Kanellopoulos, l'agora romaine, le monument de Lysicrate, autour duquel d'ailleurs d'intéressantes fouilles sont en cours, et, pour des raisons administratives, l'île de Kéa, une des Cyclades.

Le personnel de l'éphorie comportant deux éphores, quatre épimélètes, trois secrétaires archéologiques, cinq architectes, un ingénieur, trois chimistes, deux sculpteurs, un topographe, deux comptables, un conducteur de travaux, soixante quinze gardiens (auxquels, pendant les mois d'été, s'ajoutent cinquante suppléants temporaires) et cinquante cinq ouvriers spécialisés forme la base sur laquelle l'oeuvre de la restauration a pu s'organiser. Ce *staff* continue avec sa grande expérience scientifique et technique à soutenir les travaux en cours.

En 1982, les dépenses assumées par l'Etat sur son budget ordinaire atteignent:
– pour salaires, traitements et approvisionnements plus de 110.000.000 dr. Vu les exigences nouvelles et les besoins croissants, l'Ephorie ne pouvait assumer seule, et dans son cadre administratif normal, la tâche de sauvegarde et de restauration des monuments en danger. Le Ministre de la Culture et des Sciences chargea de la gestion des 75 millions de dr. annuels d'investissement public, le «Comité pour la conservation des monuments de l'Acropole» créé par lui en 1975.

Depuis 1981 l'argent est versé par le Ministère de Coordination à la Société Archéologique d'Athènes, institution privée, fondée en 1837, dirigée par un conseil de savants et dont le secrétaire général est l'académicien professeur G. Mylonas. Ces dispositions évitent l'entrave des procédures bureaucratiques et lourdes qui forment l'apanage de toute comptabilité publique et permettent un financement plus souple. C'est ainsi qu'il fut possible de recruter 2 ingénieurs, 4 employés de bureau, 60 artisans et 14 ouvriers, de constituer d'importants approvisionnements de matériaux et d'acquérir l'équipement indispensable.

Le Comité qui a la responsabilité des travaux de restauration compte neuf membres renouvelés tous les deux ans. Monsieur l'académicien Mylonas qui préside ce Comité a bien voulu nous confier que Monsieur le Président de la République suivait de très près le progrès des travaux, et qu'il a personnellement veillé à ce que les fonds nécessaires soient toujours disponibles.

Cette année, pour la première fois, des fonds en provenance de l'étranger, ont été versés au compte convertible de la Société Archéologique.

Dans le but d'élargir son activité culturelle, la Commission des Communautés Européennes a, suite à des entretiens entre son secrétaire général Monsieur E. Noël et notre ministre Madame Mercouris, accordé sur son budget ordinaire 500.000 écus (38 millions de dr.) pour l'installation et l'équipement du chantier du Parthénon.

Ceci a permis les investissements suivants:

– 14 millions dr. versés pour l'achat de la grande grue «stiffleg derrick».

– 2 millions dr. versés pour l'achat du pont roulant et pour l'acquisition d'une petite grue qui remplacera le monte-charge.

– 3 millions dr. pour l'achat d'un pantographe à tour de reproduction électrique.

– 4,5 millions dr. pour l'achat d'un échafaudage en duraluminium.

– 2 millions dr. pour l'achat de divers matériaux.

– 3 millions dr. pour l'établissement d'une construction légère devant abriter l'atelier pour les travaux de marbrerie.

A côté des montants versés par la Commission des Communautés Européennes, d'autres sommes ont été versées par différents pays à la suite d'un appel de l'UNESCO. Ces sommes, qui totalisent 35.000.000 dr., ont été versées à la Banque Nationale de Grèce, et c'est le Ministère de la Culture et des Sciences qui en assume l'administration. 13.000.000 dr. ont été depensées pour achat d'apareils et matériaux nécessaires aux chimistes. Ainsi furent consacrés:

– 800.000 dr. pour l'achat de l'appareil Horiba pour l'enregistrement continu de la quantité de dioxide de soufre et l'acide sulfidrique contenus dans l'atmosphère; cet appareil est installé sur l'Acropole.

– 800.000 dr. pour l'acquisition de deux chambres d'accélération de la corrosion due au dioxide de soufre, appareils qui se trouvent provisoirement au Musée National, avec l'argent de UNESCO réuni à l'étranger. 270.000 dollars pour l'acquisition d'un microsonde électronique muni d'un microscope électronique «scanning Jeol.»

Comme il avait, dès le début, été décidé que les fonds provenant de l'UNESCO seraient destinés aux recherches relatives à la conservation des monuments, nous avons le ferme espoir que le projet visant à la fondation d'un Institut pour la pathologie de la pierre se réalisera. Le bâtiment devant abriter cet institut a déjà été trouvé et acquis par voie d'expropriation; il s'agit d'une des plus grandes maisons de style classique d'Athènes. En attendant l'évacuation et la réparation de cet immeuble, les appareils, et notamment ceux déjà acquis et mentionnés ci-dessus, sont et seront placés à l'Ecole Polytechnique où nos chimistes poursuivent leurs recherches sous la direction du professeur Scoulikidis.

Parmi l'énumération de nos revenus, ressources et dons, je tiens à mentionner le don fait par la firme anglaise «Lansing Bagnall» d'un chariot élévateur électrique d'une valeur de 3 millions de dr.

En conclusion, on voit que le financement des travaux est en principe assuré par l'Etat grec mais comporte aussi des apports étrangers.

Il est intéressant de comparer la procédure mise sur pied en vue de la restauration actuelle avec celle qui eut cours pour l'érection, à l'époque classique, du Parthénon et de l'Erechthéion. Cette dernière nous est connue, du moins grosso modo, par les inscriptions anciennes et par les publications de Stevens, Dinsmoor, Stanier, Lauter, Burfold, Coulton, Keramopoulos, Syriopoulos, etc.

Selon ces inscriptions, au temps de Périclès, le financement se fit par la ville-état d'Athènes. Un comité de 5 membres, se renouvelant annuellement et présidé par Périclès, était chargé de l'administration des fonds et de l'inspection des travaux. Nous avons vu ci-dessus que le Comité actuel, composé de 9 membres renouvelables tous les deux ans, est présidé par Monsieur Mylonas et que Monsieur le Président de la République en suit les travaux.

Du temps de Périclès, le comité rendait annuellement les comptes. Les crédits (*λήμματα*) provenaient de sommes transmises par les prédécesseurs, les *épistates*, augmentées de celles provenant de différentes sources: trésor d'Athènes, caisse des alliés, mines de Laurion, versements exceptionnels faits par des autorités ou des particuliers. Le compte des dépenses (*ἀναλώματα*) s'établit d'abord assez rudimentairement et selon le genre de travail exécuté; plus tard cependant, pour l'Erechthéion, l'examen des sorties devint plus détaillé. Ce contrôle assez lâche supposait, soit une confiance absolue de l'Etat dans les administrateurs, soit une grande abondance d'argent. De nos jours, les lois, les moeurs et la dureté des temps exigent une bien plus grande rigueur.

Nous aimerions donner ici et de façon précise les sommes déjà dépensées pour la restauration du seul Erechthéion; cela permettrait de donner une idée, fut-elle approximative, des dépenses futures. Malheureusement cela n'est qu'incomplètement faisable. Bien évidemment il n'était pas possible, au début des travaux, de scinder les dépenses pour chacun des chantiers; nous pouvons cependant indiquer qu'en ce qui concerne le mois de juillet 1983, les dépenses s'établissent, pour le chantier de l'Erechthéion, de la façon suivante:

- Salaires et traitement:
• 2.543.000 drs pour 24 artisans
• 166.000 drs pour l'ingénieur, l'architecte, le dessinateur
• 40.000 drs pour 3 employés dont le 1/4 du temps a été comtabilisé pour l'Erechthéion.
- Dépenses en instruments: outils, coupe de marbre, transport, etc.
• 25.000 drs

Nous voyons donc que le rapport entre les salaires et traitements, et les autres articles du compte de dépenses, est de 10 à 1; approximativement le même rapport fut constaté pour les 7 premiers mois de 1983 puisqu'il fut, pour cette période, de 10 à 1,2;37 millions dr. pour salaires et traitements contre 4.500.000 dr. pour les autres articles.

Relevons en passant, qu'ainsi que l'on peut en conclure de l'inscription de l'Erechthéion, en 433 av. J.C., le tailleur de marbre recevait 1 dr. par jour et l'architecte un peu plus; de nos jours, au contraire, ce que perçoit l'architecte est légèrement inférieur à ce que touche le tailleur de marbre.

Dans l'antiquité, les 2/3 de ceux qui travaillaient sur l'Acropole étaient des Athéniens, le reste étant formé d'étrangers ou d'esclaves. Aujourd'hui, sur les 24 tailleurs de marbre, occupés à la restauration de l'Erechthéion, 20 sont originaires de Tinos. Il semble que cette île des Cyclades possède une tradition artistique dans le travail du marbre remontant au XVIIIe siècle. Ceci est attesté par quelques pierres tombales trouvées dans l'île. Au temps du roi Othon des artisans en provenance de Pyrgos, village de Tinos, vinrent s'établir à Athènes et c'eet à eux que l'on doit le décor de marbre de la Bibliothèque Nationale et de l'Université et plus tard de l'Académie. C'est également a ces artisans de Tinos que des familles riches d'Athènes confièrent l'érection de leurs tombeaux placés dans le 1er cimetière. C'est de ce milieu des artisans de Tinos que proviennent les sculpteurs Halepas, Philippotis, Lytras. Il est heureux qu'une école de tailleurs de marbre subsiste de nos jours à Pyrgos et nous espérons que c'est de là que continueront de venir les artisans dont nous aurons besoin.

Le marbre utilisé pour l'anastylose des monuments de l'Acropole provient du mont Pendeli, *Πεντελέθεν* comme disaient les anciens, et plus précisément de la pente nord de la montagne c'est-à-dire de la carrière de Dionysos, qui abrite encore les principales *λιθοτομίαι.* Ce marbre coûte actuellement de 35 à 45.000 drs selon le volume; la coupe du marbre revient à 1.800 drs le mètre carré. Le transport de la carrière, la *λιθαγωγία* des anciens, au pied de l'Acropole est compris dans le prix d'achat. La montée au niveau de l'Acropole, la *λιθουλκία,* est assurée actuellement par nos ouvriers qui utilisent à cette fin notre vieux monte-charge d'une capacité d'1,5 t.

Notre approvisionnement, les *ὠνήματα,* ne sont pas aussi divers que ceux des anciens. Nous n'utilisons pas une grande quantité de bois, nos échafaudages sont métalliques. (Ceux de l'Erechthéion ont coûté 1.500.000 drs auxquels il convient d'ajouter le coût du pont roulant, 600.000 drs et celui des treuils, 200.000 drs). Bien évidemment nous ne devons plus acquérir ni or, ni ivoire; rappelons que l'habit d'or, le *χρυσοῦν ἕδος* d'Athéna, pesait 1.050 kg. et avait coûté 40 talents, soit 1,5 milliard de nos drs (1 talent valait 6.000 drs du temps). Notons qu'en contrepartie nous achetons un autre métal précieux, le titanium, qui coûte de 2.500 à 5.000 drs le kg. selon le diamètre.

Quant à la méthode de travail, elle diffère peu de celle des anciens. Constatons cependant que le chantier du Parthénon sera plus moderne que celui de l'Erechthéion; disons en passant que ni la grue, ni le pantographe ne constituaient, pour les anciens, des instruments inconnus.

La construction (*οἰκοδομία*) du Parthénon s'étendit sur une période de 15 ans; nous espérons que dans 10 la restauration sera terminée. Nous devons nous faire à l'idée que pendant la durée des travaux l'aspect de l'Acropole sera fort différent de ce que nous connûmes. Les monuments seront partiellement démontés, ce sera un véritable chantier peuplé de machines et d'ouvriers, et pour longtemps interdit aux visiteurs. Notre compensation est de comprendre que toutes ces vicissitudes ont pour seule fin la sauvegarde et la onservation. Nous avons déjà la joie de voir un Erechtéion en grande partie restauré, le mur sud s'élevant de jour en jour.

Le sauvetage des monuments de l'Acropole doit être couplé avec le programme visant à la construction d'un nouveau musée. Le musée actuel du rocher fut fondé en 1865, agrandi en 1888 et rénové, par Jean Miliades, au cours de la période 1948-1954. Ce musée est trop petit. Il ne permet pas l'exposition des pièces de sculpture et d'architecture actuellement emmagasinées dans les réserves. Il ne permet pas d'offrir un abri aux sculptures et inscriptions qui se trouvent actuellement en plein air et exigent protection.

Les Caryatides de l'Erechthéion et le groupe de Cecrops et Callirhoe provenant du fronton ouest du Parthénon ont déjà trouvé refuge au musée, mais peut-être à l'avenir conviendra-t-il d'abriter d'autres reliefs du Parthénon et du Temple d'Athéna-Victoire. Il serait au surplus souhaitable que le musée disposât d'un espace plus vaste, qu'il soit muni des moyens techniques assurant la protection des oeuvres contre la pollution atmosphérique et permette le déploiement de son rôle didactique.

N'oublions pas qu'en 1982 l'Acropole a reçu 1.404.140 visiteurs; à ce nombre il faut encore ajouter celui des visiteurs du dimanche qui entrent gratuitement et donc sans contrôle. Certains jours du mois d'août l'Acropole reçoit 10.000 visiteurs. Agrandir le musée actuel est hors de question. Au contraire il conviendrait de l'éloigner. Ceci permettrait notamment de voir le mur mycénien actuellement visible à partir des seules réserves, et rendrait possible des fouilles qui, éventuellement, mettraient au jour des sculptures archaïques. Il est donc avéré qu'un transfert du musée est indispensable, mais en aucun cas le musée futur ne devra perdre le contact avec le rocher. Par conséquent, il conviendra de l'ériger le plus près possible de celui-ci. Aucune solution n'est idéale et il faudra rechercher la meilleure, compte tenu des possibilités.

Je crois savoir qu'il avait été décidé de construire le nouveau musée sur le terrain de Makryghianni et que le Ministère dont nous dépendons avait organisé deux concours, l'un en 1977, l'autre en 1979, mais sans que ceux-ci aient eu grand succès. En conséquence on se mit à la recherche d'un autre terrain et plusieurs emplacements furent proposés, soit au sud, soit au sud-est de l'Acropole, soit au point sud de la colline de Philopappos où se trouve un théâtre moderne resté inachevé.

Après avoir examiné toutes les propositions, le Comité pour la Conservation de l'Acropole a soumis ses conclusions au Ministère de la Culture et des Sciences. Il considère que le terrain du Régiment Makryghianni, qui grâce à une intervention du Président de la République appartient à l'Etat depuis 1978, est sans conteste le plus grand terrain disponible, non seulement dans le voisinage de l'Acropole, mais encore dans toute le ville d'Athènes. Il a une superficie de 17.000 mètres carrés qui, au surplus, pourrait aisément être portée à 24.000 mètres carrés par la démolition, après expropriation, de quelques maisons. Dans le vaste carré borné par les rues Dionyssiou Aréopagitou, Makryghianni, Hadjichristou et Mitsaion, on pourrait construire un édifice digne de l'Acropole et tracer, au travers du site archéologique qui s'étend de l'autre côté de la rue Dionyssiou Aréopagitou, une nouvelle montée vers l'Acropole. Il va sans dire qu'avant tous ces travaux il conviendrait de fouiller le terrain de façon exhaustive.

Toute solution autre que celle préconisée ci-dessus suppose la destruction partielle de collines boisées qui, en même temps, constituent des sites archéologiques. Qui pourrait admettre que nos services donnent pareil mauvais exemple? Ajoutons que la solution envisagée se trouve être conforme au plan directeur de la Ville d'Athènes tel qu'il est établi par le Ministère de l'Environnement. Constatons enfin que la solution «terrain Makryghianni» a trouvé l'agrément des deux ministères, celui de l'Environnement et celui de la Culture et des Sciences.

Un nouveau concours, qui pourrait être international, devra être organisé en vue de dégager un projet optimum. A notre avis, pareil concours serait assuré du succès, car on peut le circonscrire aux seules salles d'exposition, c'est-à-dire à la partie la plus spectaculaire du musée. Les services administratifs et la section didactique – moulages, modèles, dessins, etc. – pourront être réunis dans le grand bâtiment qui se dresse actuellement sur partie du terrain; cette construction, qui date de 1834, oeuvre de l'ingéneur militaire bavarois Weiler, a servi anciennement d'hôpital.

L'érection de ce nouveau musée exigera sans nul doute des moyens financiers considérables. Notre ministre a bien voulu nous assurer qu'elle avait reçu du Premier Ministre l'assurance que les crédits nécessaires seraient ouverts. Nous espérons d'autre part que d'autres institutions interviendront et que ce vaste projet suscitera de généreuses donations. Nous avons appris qu'une dame d'Athènes, feue Ourania Hadjikyriakou avait disposé, par testament, de 18 appartements avec ordre de les vendre et d'employer les sommes ainsi libérées à l'érection du nouveau musée de l'Acropole.

Pour ce qui concerne l'environnement, nous pouvons dire que d'après le plan directeur et les assurances reçues de Monsieur le Ministre Tritsis, la rue Dionyssiou Aréopagitou est destinée à devenir piétonnière; elle ne serait traversée que par des véhicules électriques à l'usage des visiteurs de l'Acropole. Il est à espérer que le ministère concerné trouvera également une solution acceptable pour la création d'un vaste garage et pour la régulation de la circulation dans l'ensemble du quartier. Lançons nous avec optimisme et sans autre perte de temps dans la réalisation de cette oeuvre importante, et conservons notre foi dans son heureux aboutissement.

PARTHENONAUSSTELLUNG UND INTERNATIONALER PARTHENONKONGRESS IN BASEL

ERNST BERGER

Meine Damen und Herren,

Es ist für mich eine grosse Ehre, Ihnen über das Basler Parthenon-Projekt zu berichten. Unser Unternehmen in Basel ist natürlich im Vergleich zu dem, was in den letzten Jahren in Athen geleistet wurde und was in den kommenden Jahren zu leisten ist, gering und nur als flankierende Massnahme zu verstehen. Umso mehr danke ich der Athener Kongressleitung für die Einladung, unsere Absichten und Ziele auch im Zusammenhang dieses Kongresses kurz zu erläutern.

Die gesamte Bauplastik des Parthenon ist heute in der Basler Skulpturhalle im Abguss vereint, soweit wie möglich rekonstruiert und ausführlich erläutert. Den architektonischen Zusammenhang verdeutlicht ein Modell des Tempels im Masstab 1:20. Dieses Ergebnis – eine Arbeit von mehr als 15 Jahren – wäre ohne die Unterstützung durch die griechischen Kollegen nicht zustande gekommen. Ich kann hier die zahlreichen Beiträge nicht im einzelnen nennen; ich möchte mich aber doch bei einer Person speziell bedanken, die in den vergangenen Jahren die Hauptlast getragen hat, nämlich bei Frau Dr. Maria Bruskari. Ihrem Engagement und ihrer uneigennützigen Hilfe ist es zu verdanken, dass das hochgesteckte Ziel überhaupt realisiert werden konnte.

Die heute in Basel im Abguss überschaubaren Parthenonskulpturen können den zerstreuten Bestand der Originale zwar nicht ersetzen. Der Abhuss hat aber gegenüber dem Original auch einige Vorzüge. Der Erhaltungszustand der originalen Skulpturen ist durch die zufällige witterungsbedingte Verfärbung der Oberfläche oft schwer zu beurteilen. Wir haben darum in Basel die Abgüsse mit einer speziellen Patinierung versehen: Nur die intakt erhaltene Oberfläche ist im Marmorton wiedergegeben, die verwitterten Teile sind durch eine etwas hellere Farbgebung abgehoben, die zerstörten Partien sind weiss gelassen. Die so präsentierten Abgüsse lassen die plastische Struktur oft klarer erkennen als die unter sehr verschiedenen Bedingungen ausgestellten originalen Bestandteile.

Beginnen wir unseren kurzen Rundgang mit den *Metopen.* Von den 92 Metopen des Parthenon sind 57 im Abguss in Basel, nämlich alle erhaltenen: sowohl die 38 Metopen, die sich noch am Bau befinden, als auch die 19 Metopen, die heute in den Museen von London, Athen und Paris aufbewahrt werden. Von den 32 Südmetopen sind einstweilen nur die 18 gut erhaltenen Kentaurenmetopen ausgestellt. Von den mittleren Metopen 11, 13-25 besitzen wir zwar die Fragmente, die aufgrund der Carrey-Zeichnung zugewiesen werden können, doch sind hier noch keine Rekonstruktionsversuche durchgeführt worden. Die Initiative für die Abgüsse der am Bau verbliebenen Metopen ging von Frank Brommer aus – eine höchst verdienstvolle Aktion, für die wir dem um den Parthenon so hochverdienten Gelehrten nicht genug danken können. Die Aufnahmen dieser Reliefs in der Publikation von Brommer wurden unter sehr eingeschränkten Arbeitsbedingungen hergestellt. Wir haben in Basel alle Metopen mit der gleichen Beleuchtung und mit der richtigen Distanz jeweils in 3 Ansichten neu aufgenommen. Der erste, den Metopen gewidmete Band unserer Ausstellung wird im Jahre 1985 erscheinen. – Den Unterlagen zu diesem Kongress ist zu entnehmen, dass man bei der Restaurierung des Parthenon plant, die 1. Südmetope und die 32. Nordmetope durch Abgüsse zu ersetzen. Es wäre meiner Ansicht nach gerechtfertigt, noch weitere am Bau befindliche Metopen zu entfernen: nämlich Ost 1, 4-7, 9, 12 und 14; ferner West 1, 3, 9, 13 und 14 sowie Nord 1, 25, 27, 28 und 29.

Vielleicht der schönste Teil der Basler Ausstellung gilt dem *Parthenonfries.* Es ist ein einzigartiges Vergnügen, den auf vier Museen verteilte Ostfries abschreiten zu können und auch die neuen Fragmente von Despinis im ursprünglichen Zusammenhang zu sehen und mit der darüberliegenden Metopenkomposition direkt zu vergleichen. Für die Rekonstruktion des Westfrieses konnten wir auf die alten Negativformen von Fauvel und Elgin zurückgreifen. Die erschreckend voranschreitende Verwitterung dieser heute noch am Bau befindlichen Platten wird schon durch den Vergleich mit der um 1930 von Balanos (?) veranlassten Abguss-Serie deutlich, von der wir auch einige Proben besitzen. Eine der wichtigsten Aktionen der bevorstehenden Restaurierung in Athen wird die Entfernung dieser und der ersten Südfriesplatten sein. – Die Rekonstruktion der beiden Langfriese von der Nord– und Südseite musste aus Raumgründen im Kellergeschoss aufgebaut werden. Viele der bis heute umstrittenen Fragen betreffend Abfolge der Platten und Zuordnung der Fragmente konnten endgültig gelöst werden. Weitere Probleme lassen sich erst jetzt konkret beurteilen, so auch die für die Deutung so wichtige Frage der Figurenanzahl der einzelnen Abschnitte. Es zeigte sich z.B., dass im Nordfries nicht 12 Apobaten-Gespanne vorhanden waren, sondern merkwürdigerweise nur 11.

Am problematischsten bleibt wohl die Rekonstruktion der *Giebel.* Hier sind wir wegen der grossen Lücken ausnahmsweise von dem sonst befolgten Prinzip abgewichen, nur den originalen Sachverhalt zu dokumentieren. Hier haben wir zur Klärung der Komposition die vorhandenen Torsen in Styropor ergänzt. Mit diesen Rekonstruktionen wollte unser Bildhauer Ludwig Stocker nicht mit Phidias konkurrieren, sondern nur die Proportionsverhältnisse und den Zusammenhang der einzelnen Gruppenelemente klären und veranschaulichen. Aufgrund dieser Maquette ist es jetzt auch leichter möglich, die Zugehörigkeit der zahlreichen kleineren Fragmente systematisch zu überprüfen – eine Arbeit, die noch lange Zeit in Anspruch nehmen wird. Aus den Unterlagen des heutigen Kongresses geht hervor, dass im Zuge der Restaurierung des Parthenon auch die Bestandteile der Randfiguren der beiden Ostgiebelflügel im Britischen Museum im Abguss einbezogen werden sollen, was mir sehr begrüssenswert erscheint. Im Westgiebel dürfte man ausser dem Kephissos und der Kekropsgruppe und den Figuren V und W wohl noch weitere Figurenelemente einbeziehen, deren Standort in engen Grenzen ermittelt werden kann, nämlich die Sitzstatue der Oreithyia (Q) sowie die Amphitrite (O) und wohl auch den Iris-Torso (N), den Jeppesen zu Unrecht wieder dem Ostgiebel zuweisen möchte. Auch die Hermesfigur (H) im linken Flügel und die von Carrey gezeichnete Pferdestütze sind aufgrund der Standspuren eindeutig fixierbar; von der Hermesfigur ist die Basis mit den Füssen im Britischen Museum erhalten und vom rechten Bein fehlt seit der grossartigen Anpassung des Oberschenkels durch Despinis nur noch ein kleiner Abschnitt.

Über den Parthenon-Kongress, der vom 4. bis 8. April 1982 in Basel stattfand, kann ich mich kurz fassen, da die meisten der heute in diesem Saal Anwesenden daran teilnahmen. Die Ausrichtung der 46 Referate auf ein einziges Bauwerk und die Verbindung von Vortrag und Ausstellung haben sich als günstige Voraussetzungen für den Erfolg und das Niveau dieses Kongresses herausgestellt. Folgende fünf Themenkreise kamen zur Sprache: Die historische Stellung und Funktion des Parthenon (5 Beiträge), das Kultbild des Phidias (4 Beiträge), die Bauplastik (20 Beiträge), die nachantike Geschichte und Pflege des Bauwerkes (7 Beiträge). Die Kongressakten werden zusammen mit einem Nachwort des Veranstalters und einer Parthenon-Bibliographie im kommenden Jahr gedruckt vorliegen. Die Querverbindungen zwischen den einzelnen Referaten und zu den wichtigsten Gesichtspunkten der vorausgehenden Literatur werden durch ein ausführliches Register hergestellt.

Wir hoffen zuversichtlich, dass sich die neue Standortbestimmung und die in Basel aufgebaute Ausstellung auch für das bevorstehende Restaurierungswerk als nützlich erweisen wird. Darüber hinaus möchten wir die grosse Hilfe unserer griechischen Kollegen auch konkret vergelten. Wir besitzen in Basel eine Liste sämtlicher Negativformen der Parthenon-Skulpturen. Wir kennen auch die Standorte der alten Negativformen aus dem 19. Jahrhundert, soweit sie noch vorhanden sind. Man wird also vermutlich den Westfries durch die alten Abgüsse ersetzen, die Fauvel und Lord Elgin veranlasst haben. Wir können unsere Hilfeleistung auch für den didaktischen Teil des neuen Parthenonmuseums anbieten, das im Areal von Makriyanni geplant ist und möglichst bald realisiert werden sollte. Denn die beabsichtigten Restaurierungsmassnahmen und die Bewältigung des Tourismus setzen ein neues Akropolismuseum unbedingt voraus.

Darf ich zum Abschluss – auch im Namen aller hier anwesenden Gäste – meinen Dank an die griechischen Kollegen zum Ausdruck bringen. Was in den letzten Jahren hier in aller Stille geleistet wurde und in der heute vorgestellten imponierenden Publikation von M. Korres und Ch. Bouras dokumentiert wird, ist schlechthin bewundernswert. Wir dürfen mit vollem Vertrauen der Restaurierung des Parthenon entgegensehen. Die Arbeit liegt bei unseren griechischen Kollegen in guten Händen. Ich danke Ihnen.

2

REPORTS

RECENT RESEARCH ON THE ACROPOLIS SCULPTURE

M. BROUSKARI, A. DELIVORRIAS, G. DESPINIS

The Committee for the Preservation of the Acropolis Monuments wishes to underline the contribution of classical archaeology in the project presented in the course of this meeting. Especially for the non-archaeologically informed participants it was considered necessary to deliver a paper on the work in process or already accomplished, in connection only with the sculptural adornment of the monuments.

Regarding the small amount of sculptures that have survived, all efforts concentrated on the discovery and recognition of further dispersed fragments, on the completion of existing but mutilated material, on new interpretations of their original content or on proposals concerning their original aspect and, finally, on the composition to which they had once belonged. I must here stress the fact that the scientific work offered by many dedicated foreign scholars, which has helped us, if not to solve, at least to approach the problems, cannot be distinguished from the contribution of Greek scholarship, to whom I must limit this brief presentation.

To start with the Parthenon: during the Roman and the Byzantine period, the most famous of all Athenian classical temples was still standing intact in a more or less good condition. The damages to the monument were not important, with the exception of the central part of the east pediment, which was destroyed at an unknown date, and the reliefs of the metopes on the three sides, which were violently stripped away by the early Christians. The irreparable destruction of the monument and its ornamentation occured in 1687 when the explosion caused by Morosini's bombs destroyed a great part of the existing sculptures, scattering fragments at a great distance. During the following centuries, travellers of different nationalities, while visiting the ruins of ancient Athens, thought themselves more or less bound to take away as souvenirs bits of marbles from the monument. We keep hoping that most of this loot has finally found its way in European museums, where it can at least be more easily traced than if it had remained in private hands. Morosini's ravage was completed in a systematic way, if I may say so, by Lord Elgin, ambassador of Great Britain in Constantinople: between the years 1801 and 1819 he removed most of the sculptures still remaining in their original position.

Recomposing the Parthenon sculptures has been the main effort of classical archaeologists since then. By unearthing unknown material joining fragments together, unveiling the mythological substratum of the representations, reinterpreting the already known pieces, they attempt to rediscover the original aspect of the decoration, at least on paper. But the gaps are still numerous, and the proposed reconstructions depend to a large extent on conjecture. As there are no other ancient sources available on the subject except Pausanias' laconic mention of the myths represented in the two pediments, we are obliged to depend mainly on the sketches done in 1674, a few years before the destruction, by Jacques Carrey on behalf of the Marquis de Nointel, ambassador of France in Constantinople. The original drawings, now at the Bibliothèque Nationale in Paris, apart from the statues of the two pediments, include the reliefs of the inner frieze and the south metopes. In spite of some misinterpretations, due to the distance of the artist from his subject, they provide the main basic information for the decoration of the temple.

Of exceptional inportance, especially for sculptures already lost by Carrey's time, are the new fragments found at various times in different store-rooms, in the area of the Acropolis, or even at a greater distance, which were reused mostly in modern times, as building material in the region of Athens. The future possibility that the entire sculptural adornment of the Parthenon might be, theoretically, reconstructed, was recently put forward in Basel. This was done by regrouping the existing material in plaster casts. The archaeological work has thus been greatly facilitated: the different hypothetical attributions can be checked and further proposals can be easily studied on three-dimensional, fullscale models. We all hope that the example of the Basel Parthenon-Gipssammlung will be repeated sooner or later in Athens, where most of the actual fragmentary material has survived.

I would like to mention now some of the most successful recent additions to the pedimental sculptures of the Parthenon. As regards the figure of Athena on the west front, the right shoulder[1] and a small part of her aegis[2] have been joined to her torso, now in the British Museum;[3] the first was found in the area of the Acropolis, the second in the store-rooms of its museum. Fragments of a pair of feet[4], also from the Acropolis Museum, have been attributed to the same figure, though not fitting any existing part of the almost entirely missing lower body. Other efforts at a still tentative stage, have ascribed an arm and a leg[4a] to the same figure.

More surprising was the successful fitting of the right thigh[5] to the figure of Hermes, whose torso is also in London[6]. The new fragment has been recognised among the piles of marbles in the store-rooms of the Athens National Museum and has endowed the figure with a new plastic value. Another fragment from the back of a head with curly hair[7], found in the store-rooms of the Acropolis Museum has been also attributed to this figure, though not quite fitting the body.

A righ foot[8] from the Acropolis has been ascribed to Poseidon from the same pediment. This has made it necessary to clear up a series of other attributions proposed by various scholars concerning the original aspect of the figure.

Even more surprising were the unexpected results of further researches concerning the lost central groups of the east pediment. I should briefly mention without having projections for showing to you the discovery and exciting interpretation of two badly damaged pieces, confirming the presence of Apollo in the composition of the myth of Athena' Birth, as well as the existence of an unknown female deity holding a torch. But the most striking new evidence has to do with the central figure of Zeus and is due to George Despinis' thorough investigations in the National Museums store-rooms: it is a colossal left hand, holding the thunderbolt[9]. Thanks to this fragment, it has now been proved that the King of the Gods had been portrayed seated on his throne, rather than standing, as some colleagues still seem to believe. But the importance of this new discovery lies elsewhere: it can now be considered absolutely certain, that the fragments of the missing pedimental figures are still to be found among the thousands of scattered marbles surrounding the area of the Acropolis or lying forgotten in the depots of our Museums.

Not less valuable are the fragments which were fitted to some of the mutilated figures of the frieze and the metopes, or which were recognised as belonging to them, although they dont fit any broken surface, because of the still missing intermediate parts. Most impressive was the discovery of a fragment in the Athens National Museum with two entwined female hands[10], which has been attached to the slab showing Artemis and Aphrodite on the east frieze. Another fragment in the same Museum saving the lower part of a figure in chiton and himation[11] completed the slab featuring the peplos-weavers, also on the east frieze[12]. Another interesting fragment was found built into a house in Plaka[13], and was recognised as belonging to the north frieze. It shows horses' legs, and the slab from which it was broken[14] was already not in its original place in Carrey's time. The foot of a rider found in the store-rooms of the Acropolis Museum[15] belongs to a slab now in London[16]. There are several others that have joined fragmentary Parthenon reliefs, among them the head of the rider I am showing you now, which it would take too long to enumerate[17].

Regarding the metopes of the monument, a considerable number of fragments were identified in the Athens National Museum and the Acropolis Museum. The head of a Giant from the store-rooms of the Athens National Museum was recognised as originating from one of the east metopes of the Parthenon[18]. It should be reminded, that this unique piece can be regarded as one of the most valuable; since, apart from the metopes of the south side of the building, all others had been destroyed already by the early Christians, not having left to us but a very few elements to judge their importance. Among the most beautiful recent findings is the upper torso of a nude Lapith[19], probably belonging to the south metope XXIII, as we may suppose in comparing it with Carrey's sketch.

Some further important discoveries concerning the other monuments of the Acropolis as well, should be also mentioned briefly. Among the most significant, for example, were the large fragments[20] belonging to the lower part of the body and part of the head[21] of the sixth Caryatid from the Erechtheion, lost during the Greek War of Independence discovered by Maria Tombropoulou-Brouskari. Two further fragments of Kourotrophoi – seated female figures with children on their laps[22] – have been identified as belonging to the frieze of the Erechtheion[23].

Concerning finally the Temple of the Athena Nike, some small sculptures were identified as part of its pedimental compositions[24], representing battle scenes. I would also like to mention the great number of fragments attributed to the balustrade of the Nike pyrgos. Some of them have served to reconstitute mutilated figures of high reliefs, but most of the others belong to figures that are completely unknown[25].

After all I have said, it should not be supposed that the archaeologist's task is simply to unearth new fragments of the Acropolis monuments or to determine their exact position in their decoration. The archaeologist's task is far more demanding: there is for instance the need to throw more light on the myths that went into the creation of these sculptural compositions, as well as on their social and political associations. Then there is the attempt to discern the unique, individual contribution of each major artistic figure who fashioned these monuments.

These are all part of the activities naturally expected from the archaeologist. But it would be a serious omission not to mention, however briefly, another kind of activity carried out by the archaeologists working on the Acropolis, on behalf of the Archaeological Service. For it was they who had to shoulder the heavy burden of preserving and protecting the monuments, long before the actual work of the Preservation Committe began.

If many fragments were saved at the eleventh hour, if fallen pieces were rescued and put back into place, if the necessary security measures were taken to safeguard marbles in danger of falling, or to protect them from adverse weather conditions, this is entirely due to these people's untiring and selfless devotion. It is also thanks to them that a great deal of scattered material has been rescued in the store-rooms and that the dangers that threatened the Acropolis became more widely known, leading finally to the establishment of the Committee for the Conservation of the Acropolis Monuments.

For these colleagues of ours, the monuments were not simply an object of scientific and scholarly research pertaining to their field, but something far more important: the experience of a lifetime, the fulfilment of a sacred duty.

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POLLUTION ATMOSPHÉRIQUE ET CORROSION DE LA SURFACE DU MARBRE DU PARTHÉNON. OBSERVATIONS ET PROPOSITIONS

TH. SKOULIKIDIS

Je vais vous exposer l'évolution de la pollution, nos observations et les recherches avec mes collaborateurs Mme Papakonstantinou, Mr. Charalambous et Mr. Beloyannis depuis 1977, date de notre dernière réunion, jusqu'à présent.

Voyons d'abord l'évolution de la pollution à la région d'Athènes et de l'Acropole:

La concentration des polluants qui attaquent les marbres comme CO_2, NO_x, O_3, particules en suspension, s'est augmentée, a cause du fait que le nombre et la durée des inversions de la température se sont aussi augmentés. Nous devons noter aussi l'entrée à la circulation de 150.000 nouvelles automobiles. Cette augmentation serait plus grande si le gouvernement depuis 1981 n'appliquait pas des mesures, comme l'abaissement de la production des industries jusqu'à 40% et la circulation de la moitié des automobiles pendant les inversions de la température. Ainsi les polluants n'ont pas dépassé les limites dangereuses pour les gens, mais ces limites sont très hautes pour les marbres. De plus ils se sont appliqués des mesures permanentes comme l'abaissement de la production des industries pendant l'été et la circulation de la moitié des automobiles alternativement entre le 19 septembre et la fin juin. On prépare une loi qui intervient aux sources des polluants, l'industrie, les centrales thermiques, les automobiles et le chauffage central, avec laquelle nous sommes sûrs que dans quelques années la pollution cessera d'augmenter et va même baisser, malgré le fait que dans la région d'Athènes où vit la moitié de la population de la Grèce, il est installé le 60% des industries et circule le 65% des automobiles.

En ce qui concerne l'SO_2 et l'SO_3, qui sont aussi responsables pour l'attaque acide des marbres et la sulfatation, ils se sont abaissés d'une manière surprenante à cause du fait que, depuis 1977 on a interdit l'utilisation des combustibles avec une contenance en soufre plus haute que 1% et depuis 1982 avec une contenance de 0,5% (Fig. 1). On voit au diagramme la concentration de SO_2 en microgramme par mètre cube depuis novembre jusqu'au avril, en 1975-1976 courbe bleu, 1976-1977 courbe rouge et 1977-1978 courbe jaune.

En ce qui concerne la région de l'Acropole nous n'avons pas réussi à remplacer dans la zone, que nous avons précisée par les directions et la vitesse des vents (Fig. 2), le chauffage central par chauffage électrique ou solaire, aussi bien que les automobiles à combustion par des automobiles électriques, à cause des grandes dépenses exigées. Mais on a interdit l'accès des automobiles sur la colline de l'Acropole et on a changé quelques lignes d'autobus, de manière qu'un nombre inférieur circule à la région de l'Acropole. De plus une usine à proximité de l'Acropole s'est éloignée.

En ce qui concerne les problèmes physico-chimiques à envisager pendant la démolition d'une partie du Parthénon et sa restauration, ils sont de même qualité que ceux que nous avons confrontés sur l'Erechthéion, mais comme nous allons voir ils existent quelques différences (Tableau I).

Nous voyons sur le tableau tous les types d'attaque mécaniques, biologiques, chimiques et électrochimiques, comme nous avons précisé la sulfatation. Nous voyons aussi les conséquences de chaque type d'attaque, l'influence de la pollution, la connaissance du mécanisme, les méthodes qu'on utilise pour la protection et les méthodes de restauration.

Le gel ne nous préoccupe pas au cas de l'Acropole. Ce n'est que dans l'hiver dernier après 15 ans que la température à Athènes était pendant deux jours inférieure à zéro.

On peut combattre l'érosion par des particules en suspension dans l'air (une sorte de sablage), qui a comme conséquence des piqûres, des exfoliations et surtout l'élimination de hauts-reliefs des statues et des ornements, par des obstacles d'une grandeur convenable et à une certaine distance des monuments, lorsqu'on connaît la direction et la vitesse des courants d'air. L'application de cette méthode peut pour la première fois faire l'objet des calculs aérodynamiques. Nous ne suggérons pas l'utilisation des couches polymères pour des raisons que nous allons voir. L'érosion s'est augmentée depuis 1977 à cause de l'augmentation des particules en suspension comme est déjà mentionné.

L'érosion des escaliers de Parthénon par les visiteurs s'est retardé à cause du fait que les touristes ne restent pas à Athènes et voyagent aussitôt aux îles, découragés par la pollution. On a en tout cas interdit aux visiteurs l'accès dans le Parthénon. Nous pourrions même les obliger à porter des pantoufles par-dessus de leurs chaussures ou protéger les escaliers par un abri en bois. Nous avons ici le seul cas où on peut utiliser pour la restauration des escaliers un ciment résinique, mais nous préferons le ciment blanc.

La sédimentation des particules colloidales en suspension, qui est augmentée, peut être envisagée de la même manière que l'érosion, soit par

TABLEAU I

Types d'attaque atmosphérique des marbres : conséquences, influence de la pollution, méthodes de protections
(Données connues en 1975)

Types d'attaques	Conséquences	Influence de la pollution	Mécanisme	Méthodes de protection utilisée	Méthodes des restaurations
A. *Attaques mécaniques* I. Congélation de l'eau dans les pores et les fissures	Fissuration supplémentaire due à l'augmentation du volume de l'eau pendant la congélation	Défavorable : elle fait baisser le point de congélation et augmenter la tension superficielle	Connu depuis 1900	Mettre les monuments et les statues à l'abri afin d'éviter le contact immédiat avec l'eau de pluie. Suggestion : appliquer des substances hydrophobes ou tensioactives sur les surfaces	Utilisation de ciment blanc
II. Erosion par les particules en suspension dans l'air	Destruction des couches superficielles et surtout des hauts-reliefs	Favorable : augmentation de l'émission des particules fines par les industries (96 %), les automobiles (3 %) et le chauffage central (1 %) (chiffres valables pour la Grèce)	Connu depuis 1880	Déviation des vents par des obstacles définis sur base de données aérodynamiques	—
III. Erosion due aux visiteurs	Usure et courbure des escaliers en marbre	Défavorable : elle décourage la visite des villes polluées par les touristes	Connu depuis 1600	Pantoufles obligatoires pour les visiteurs, protection des escaliers par un abri en bois ou en terre	Utilisation des ciments résiniques
IV. Sédimentation des particules colloïdales en suspension dans l'air	Coloration des surfaces en noir (carbone), en rouge (Fe_2O_3), etc... Accentuation de l'attaque par les polluants absorbés	Favorable : augmentation de la concentration des particules en suspension dans l'air	Connu depuis 1920	Déviation des vents par des obstacles définis sur base de données aérodynamiques	Lavage à l'eau chaude; laser thermique; substances absorptives
V. Corrosion des goujons et ossatures métalliques, introduits pendant la construction ou les restaurations	Fissuration des marbres	Favorable : le SO_2, le SO_3 et le NO_x augmentent de 30 % la corrosion de l'acier (mesures effectuées dans notre laboratoire et in situ)	Connu depuis 1935, mais aussi depuis l'antiquité	—	Démolition des monuments et (notre suggestion pour l'Acropole) utilisation de titane
B. *Attaques biologiques* Formation de colonies de microorganismes végétaux et animaux	Dissolution des marbres; accélération de la transformation de SO_2 en SO_3	Favorable : les microorganismes se fixent préférentiellement sur les surfaces en gypse, formées par le SO_2	Connu depuis 1960, mais pas tout à fait élucidé	Utilisation d'antibiotiques appropriés	—
C. Attaques chimiques : (contact des surfaces avec l'eau de pluie) I $CaCO_{3(s)} + CO_{2(g)} \overset{aq}{\rightleftharpoons} Ca^{2+}(HCO_3)^{2-}_{2(aq)}$ II $CaCO_{3(s)} + SO_{2(g)} + 0.5\ O_{2(g)} \overset{aq}{\rightleftharpoons} Ca^{2+}\ SO^{2-}_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$ III $CaCO_3 + 3NO_2 \overset{aq}{\rightleftharpoons} Ca^{2+}(NO_3)^{2-}_2 + NO + CO_2$ IV Plusieurs réactions avec les impuretés du marbre	Dissolution des marbres et surtout des hauts-reliefs; détachement des morceaux en marbre. Formation de cavités	Favorable : le CO_2, le SO_2 (50 % industries, 35 % centrales électriques, 6 % chauffage central, 9 % circulation) et les NO_x augmentent	Connu depuis 1945	Appliquer des couches de matériaux organiques ou inorganiques et combattre la pollution	—
D. *Attaque électrochimique*. Caractérisée ainsi par nous-mêmes après élucidation de son mécanisme; (absence de contact de la surface avec l'eau de pluie) : sulfatation, formation du gypse : $CaCO_{3(s)} + SO_{2(g)} + + 0{,}5\ O_{2(g)} + 2H_2O_{(g)} \rightarrow \rightarrow CaSO_4 . 2H_2O_{(s)} + CO_2$	Elimination des couches des surfaces et des détails des statues (nos propres observations)	Favorable : le SO_2 augmente	Inconnu jusqu'à 1975; complètement connu en 1981 (nos propres recherches)	Appliquer des couches de matériaux organiques ou inorganiques et combattre la pollution	—

des obstacles basés sur l'aérodynamique et pas avec des couches plastiques. Ces sédiments colorent en noir ou en rouge les surfaces et accélèrent l'attaque par les polluants à cause de leurs propriétés absorptives, qui ont comme conséquence une très haute concentration des polluants sur les surfaces. Pour éliminer la coloration des colonnes et de la frize de Parthénon nous n'utiliserons pas de l'eau chaude, comme d'habitude, parce que la sédimentation prend lieu sur les surfaces de gypse, formé par la sulfatation, et nous avons constaté que sur les couches de gypse sont préservés les détails des statues et de la frise qui sont déjà éliminés de l'interface gypse marbre. L'eau chaude met en solution les couches de gypse. Nous allons utiliser, soit la méthode Asmus par des lasers thermiques, qui prend beaucoup de temps, soit la méthode d'attapulgite qui absorbe les dépôts; ce sera utilisé en forme de pâte à l'eau froide saturée en $Ca^{2+}SO_4^{2-}$, pour éviter la dissolution des couches de gypse.

Sur la figure suivante (Fig. 3) nous voyons cette sédimentation à la frise en 1976 en comparaison avec les résultats en 1983. On voit que les surfaces avec des dépôts ont augmenté et par conséquent les surfaces des couches de gypse correspondantes.

La corrosion des goujons et ossatures métalliques introduits au Parthénon pendant la construction ou les restaurations, est un problème qui nous a aussi préocupé pendant la restauration d'Erechthéion, à cause de leur gonflement et les fissures qui sont provoquées aux marbres. Voilà quelques exemples au Parthénon (Fig. 4).

Un double T en acier mis pendant une restauration pour consolider le tambour fissuré a causé de nouvelles fissures (à droite en bas) à cause de sa corrosion (Fig. 5).

On voit un autre double T et à la figure suivante (Fig. 6) le détachement d'un morceau de marbre qui a été causé par la corrosion du goujon.

On voit des fissures au marbre causées par la corrosion du goujon (Fig. 7).

Voilà un autre exemple, la partie inférieure est un tambour artificiel en béton armé remplaçant le tambour manquant et introduit pendant une restauration (Fig. 8). La partie inférieure est un tambour original en marbre. Les armatures du béton ont été encastrées dans le tambour authentique. Voilà ce qui s'est passé (Figs. 9,10).

Entre 1952 et 1959 nous avons pris des échantillons des armatures du béton des maisons démolies. Le temps de la construction était connu aussi bien que le poids des armatures par mètre. Nous avons mesuré leur perte de poids et exprimé en Fe_2O_3. Nous avons fait le même sur des échantillons normalisés de béton armé dans le laboratoire pour quelques années. À l'occasion de la démolition d'Erechthéion nous avons mesuré la perte de poids sur des échantillons d'acier incorporés dans du béton et introduits pendant la restauration de Balanos. Nous avons fait le même pour des échantillons d'acier, les deux bouts desquels étaient incorporés dans du plomb et introduit pendant la restauration de Pittakis. Nous voyons que pour toutes les mesures une courbe parabolique selon Wagner est valable pour 142 ans (Fig. 11). Si on sépare les valeurs sur les échantillons pris après 1979, quand la pollution intense avait déjà commencé à cause de l'industrialisation intense de la région d'Athènes, on constate que la courbe est plus précise pour une constante de vitesse de 1,35 et pour les autres valeurs la constante de vitesse est 1,1. Alors la pollution a accéléré la corrosion d'acier de 30%. Par comparaison des photos des Caryatides prises auparavant nous avons constaté que l'accélération de l'attaque atmosphérique a commencé entre 1955 et 1965 (Fig. 12). L'industrialisation intense a commencé en 1956. Pour arrêter la propagation des fissures et la formation des nouvelles, à cause de la corrosion progressive des goujons, on va démolir une partie du Parthénon et remplacer l'acier par du titane, comme nous avons déjà fait pour la première fois à l'Erechthéion. Mais ici il se pose un autre problème: on ne va pas démolir tout le Parthénon et à sa partie inférieure il y a des goujons, qu'on ne peut pas remplacer sans provoquer de graves dégâts aux marbres. On va résoudre ce problème avec une solution ammonifiée d'acide thioglycolique qu'on peut introduire par des fissures ou par un trou très fin pour mettre en solution les oxydes de fer et éliminer les tensions mécaniques exercées aux marbres. Cette solution de fer est rouge, devient jaune par l'influence d'ultraviolet du soleil et blanche par l'influence des ions phosphates. Cette solution a été déjà employée pour la première fois dans quelques cas sur l'Erechthéion.

En ce qui concerne l'attaque biologique, les spécialistes italiens Professeurs Paleni et Curri ont trouvé sur les colonnes et les statues du Parthénon une grande variété de microflore zymotique et mycétique et des thiobaciles oxydants et les ont combattues sur la statue de Cecrops par l'antibiotique chlorure d'isothiazolinone, qui est soluble dans l'acétone. Le même procédé sera employé pour tous les blocs de marbre après leur consolidation: les murs, les colonnes et la frise.

Les trois réactions qui constituent l'attaque acide par CO_2, SO_2, SO_3, NO_x et l'eau de la pluie sont très bien connues du point de vue de leur mécanisme. Elles mettent en solution les surfaces, elles éliminent les hauts reliefs, causent des détachements des marbres et des cavités. (Fig. 13, 14).

Sur les figures sont marquées les surfaces attaquées par ce type de détérioration (Fig. 14).

On utilisait et on utilise plus rarement maintenant les matières suivantes pour la protection des marbres contre l'attaque acide et la sulfatation: des résines epoxy, des ciments résiniques, des dérivés polyvinyliques, polyacryliques, paraffiniques, polyamides, methylcellulose, polyethylène, polyfluorures, silicones, esters siliconiques, acide fluorhydrique, hydroxydes de carcium ou de baryum, ou thionates de baryum. Comme nous allons voir, toutes ces substances, la plupart desquelles n'accomplit pas les conditions de la Charte de Venise, accélèrent la détérioration des marbres. Nous avons fait des expériences avec des solutions aqueuses d'acide sulfurique et nitrique. Après 8 heures pour l'acide sulfurique et immédiatement pour l'HNO_3 les couches de polymère se détruisent (Fig. 15a, 15b).

Pour éviter cette attaque nous avons transporté Cecrops et Kallirhoé dans le musée, comme nous avons fait pour les Caryatides et pour éviter l'attaque par SO_2, qui existe dans le musée, nous avons mis Cecrops dans une caisse transparente avec une circulation d'azote. On a mis à la place de la statue une copie en plastique (Fig. 16).

La frise était mise sous un abri en bois pour éviter le contact immédiat avec l'eau de la pluie. Comme nous avons déjà vu nous avons ainsi évité l'attaque acide mais pas la sulfatation, dont nous allons parler.

La sulfatation, c.à.d. la formation de gypse par l'SO_2, affecte les surfaces des marbres qui dans leur emplacement sont protégées contre la pluie, comme par exemple la partie gauche de la Caryatide de la photo (Fig. 17) (à la partie droite nous avons une attaque acide), les surfaces protégées par exprès, comme nous avons fait pour la frise de Parthénon, les statues placées dans les musées, ou encore en absence de pluie, les surfaces non protégées.

Le mécanisme de la sulfatation n'était pas connu en 1975 et en effet c'est seulement par la connaissance parfaite du mécanisme de cette réaction qu'on peut être sûr des méthodes de protection proposées et prévoir à long terme le futur de cette protection. Malgré cela tout le monde utilisait des couches des polymères ou inorganiques déjà mentionnées pour la protection contre l'attaque acide. C'est pourquoi nous avons entrepris des recherches pour élucider le mécanisme de la sulfatation car nous étions responsables, dans le cadre des activités du Comité pour la Sauvegarde des Monuments de l'Acropole, pour suggérer une méthode de protection et parce que dans bien des cas on avait signalé à l'étranger des détériotations graves de marbres traités de plastiques. Par des analyses chimiques nous avons trouvé que les films de sulfatation contiennent 97% du gypse; le reste est $CaSO_3$ hydraté.

Nous avons mesuré les épaisseurs de ces films par une nouvelle méthode, simple et non destructive, que nous avons appelé «la sonde à épingle» (Fig. 18): On fait entrer normalement dans la couche une épingle à l'aide d'un instrument basé sur le micromètre. Nous avons trouvé des épaisseurs entre 1 et 15 mm sur le dos de Cecrops.

Les observations nous ont aussi permis de constater, pour la première fois, que sur la surface des films de gypse, les détails des statues ont été conservés, alors que ces détails avaient déjà disparu à l'interface marbre-gypse. De fait que les films de gypse se fissurent dès qu'ils atteignent une certaine épaisseur, il faut les consolider afin que les détails, retenus sur leurs surfaces, ne soient pas définitivenent perdus. Dans ce but au lieu d'éliminer les films avec de l'eau comme on faisait jusqu'à présent, nous avons commencé à élaborer des méthodes pour les consolider. En particulier nous avons pu réalisé l'inversion de la sulfatation, c'est à dire transformer le gypse en $CaCO_3$. Hormis notre méthode par CO_2 sous pression et à haute température nous avons une autre méthode maintenant. Nous utilisons pour cette transformation des solutions de K_2CO_3 à la température ambiante. Nous avons révélé son mécanisme en mesurant la vitesse à l'aide d'un spiral de quartz (Fig. 19) et par son énergie d'activation. La réaction est assez rapide, elle peut s'appliquer *in situ* en utilisant un vaporisateur et en augmentant la température des surfaces par des rayons infrarouge. La dureté de nouvelles couches de calcite est cinq fois plus haute que celle du gypse.

Nous avons effectué des essais d'attaque accélérée par SO_2 et air saturé avec de la vapeur d'eau sur des échantillons en marbre traités avec 35 plastiques différents, utilisés dans le but de protection. Dans tous les cas, nous avons trouvé du gypse dans les films en plastique ou/et sur leurs surfaces (Fig. 20). Nous avons aussi constaté des fissurations de ces films, qui ne se produisent pas quand ils ne couvrent pas le marbre.

On voit ci-dessous le réaction en deux stades:

$$[SO_{2(g)} + 0.5\ O_{2(g)} \longrightarrow SO_{3(g)}\ \text{(réaction catalysée rapide)}]$$

$$CaCO_{3(s)} + SO_{3(g)} \xrightarrow{aq} CaSO_4{\cdot}2H_2O_{(s)} + CO_{2(g)}$$

Nous avons suivi toutes les étapes prévues par la cinétique chimique pour révéler le mécanisme de la sulfatation: Nous avons trouvé l'évolution de la sulfatation de poudre de $CaCO_3$ par un spiral de quartz (Fig. 21).

Sur la figure (Fig. 22) on voit les courbes représentant le taux de la sulfatation en fonction du temps. Pour un taux de transformation ~ 11%, qui correspond à une épaisseur de gypse de 300 Å, l'évolution est linéaire. Après cette transformation l'évolution est parabolique. Nous avons vérifié le stade linéaire avec des expériences sur de la poudre de marbre pour lequel la vitesse est plus lente (Fig. 23).

Les points de discontinuité des courbes ont été calculés en combinant les deux equations:

$$\begin{aligned} y_1 &= k_1 t_1 \\ y^2_2 &= k_2(t_2 - t_0) \\ y^2 &- \frac{k_2}{k_1} y + k_2 t_0 = 0 \end{aligned}$$

Les énergies d'activation sont 14 ± 1,5 Kcal/mol pour le stade linéaire et 18 ± 1,5 Kcal/mol pour le stade parabolique. En se basant à la valeur de l'énergie d'activation du deuxième stade nous avons fait l'hypothèse que l'étape déterminante la vitesse est la diffusion en état solide des ions de Ca. Pour que cette diffusion se réalise aussi à la température ambiante une énergie est indispensable, p.e. la formation d'une pile galvanique pareille avec le modèle de Wagner pour la corrosion des métaux (Figs. 24,25).

Si nous calculons le potentiel de cette pile par le changement du potentiel chimique de la réaction on trouve 1500 mV, valeur suffisante pour que les ions Ca^{2+} se déplacent à des sites des désordres réversibles et soient forcés de migrer en état solide à la température ambiante.

Les réactions électrochimiques de la galvanique peuvent être:

$$CO^{2-}_{3(aq)} \quad (CO^{2-}_{3(aq)} \longrightarrow CO_{2(g)} + 0.5O_{2(g)} + 2e)$$

et la notion physique de la constante de la vitesse:

$$y^2 = Kt, \quad \text{où} \quad K = \frac{2E u \mu' + \mu' e V_m}{n e F'}$$

En accord avec cette hypothèse les nouvelles couches de gypse se forment sur la surface extérieure des couches déjà formées c.à.d. vers le milieu corrosif et la couche de gypse ne doit pas être poreuse.

Le modèle de la pile galvanique facilite l'interprétation de la valeur de l'énergie d'activation pour le premier stade linéaire. Elle est une énergie d'activation mixte et correspond à la désorption des ions CO^{2}_{3} (6-8Kcal/mol) et leur diffusion sous l'action du potentiel de la pile (4-6Kcal/mol), si on prend en considération les phénomènes de la relaxation des ions et de l'électrophorèse. Les ions CO^{2}_{3} se décomposent comme ci-dessous:

$$CO^{2-}_{3} \longrightarrow CO_2 + \frac{1}{2} O_2 + 2e$$

Les nouvelles couches de gypse se forment à l'interface $CaCO_3/CaSO_4{\cdot}2H_2O$ (Fig. 26) et elles sont poreuses.

Jusqu'à ce point les seules évidences de la validité du modèle de la pile galvanique sur lesquelles nous sommes basés pour faire l'hypothèse sont:

– la valeur de l'énergie d'activation du deuxième stade,

– l'observation que le gypse se trouve sur et/ou dans les couches polymères sur le marbre et

– l'observation que sur la surface de gypse sont préservés des détails des statues déjà éliminés de la surface du marbre.

Alors l'exposé jusqu'ici manque des preuves. Voilà les preuves:

A. Formation de la pile galvanique $Pt,CaCO_{3(s)}$ /$CaSO_4{\cdot}2H_2O_{(s)}$ /$Pt,SO_{2(g)}$, $O_{2(g)}$,$H_2O_{(l)}$.

Avec une pâte de $Ca(OH)_2$ contenant 50% de $CaCO_3$ (pour agir comme germes de cristallisation) et de l'eau, on a enrobé un fil de platine. Après séchage partiel, le $Ca(OH)_2$ était totalement transformé en $CaCO_3$ par action de CO_2. Le $CaCO_3$ etait partiellement transformé en $CaSO_4{\cdot}2H_2O$ (300µm d'épaisseur environ) par le SO_2 et l'air saturé en vapeur d'eau. Cette électrode a été immergée dans de l'eau distillée, saturée en $Ca^{2+}SO^{2}_{4}$, contenue dans un récipient. Un deuxième fil de platine a été immergé dans un autre récipient avec de l'eau distillée, saturée en SO_2 et en air; un mélange de SO_2 et O_2 barbotait sous le fil. Les deux solutions étaient mises en contact électrique à l'aide d'un pont 10% KCl/agar-agar. Nous avons constaté que, à 25°C:

a) ce système est en effet une pile galvanique;

b) l'électrode Pt, $CaCO_3$ est le pôle négatif de cette pile;

c) le potentiel de la pile varie avec les pressions partielles de SO_2 ou O_2 selon l'équation:

$$E = Eo\ R\ \frac{2{,}3\ RT}{neF'} \log \frac{P_{CO_2}}{P_{SO_2} \cdot P^{0{,}5}_{O_2}}$$

B. Variation de la vitesse de la sulfatation en fonction des pressions partielles P_{SO_2} ou P_{O_2}.

Sous les conditions déjà décrites, on a mesuré la vitesse de la réaction avec des pourcentages différents de SO_2 en gardant constante la teneur en O_2 (31%) et en contrôlant par N_2. La relation entre la constante de vitesse (K) et le logarithme de la pression partielle P_{SO_2} est représentée sur la figure 27.

On a aussi mesuré la vitesse de la réaction avec un pourcentage variable d'O_2, en gardant constante la teneur en SO_2(30%) (Fig. 28).

Il résulte de ces deux diagrammes que la constante de vitesse varie linéairement avec log P_{SO_2} et log P_{O_2}. On constate également que, pour une même augmentation de P_{SO_2} et P_{O_2}, la valeur de K est deux fois plus grande dans le cas de la Figure 27. Cette conclusion est conforme à l'équation de Nernst rappelée ci-dessus, à cause des exponents différents de P_{SO_2} et $P^{0\ 5}_{O_2}$

C. Formation de nouvelles couches de gypse à l'interface marbre-gypse jusqu'à environ 300 Å.

Nous avons indiqué (et illustré par la fig. 26) que, pendant le premier stade linéaire de la formation du gypse (jusqu'à 300 Å d'épaisseur), les nouvelles couches de gypse ne peuvent pas se former qu'à l'interface $CaCO_3/CaSO_4{\cdot}2H_2O$; il s'agit d'une des conséquences du mécanisme proposé.

Nous avons fait les expériences suivantes: on place à 25°C des échantillons de marbre dans une atmosphère constituée de SO_2, d'air et d'humidité pendant un temps tel que l'épaisseur du gypse soit inférieure à 300 Å, c'est à dire que le taux de la sulfatation ne dépasse pas le 6-8% (mesure de l'augmentation de poids). Nous avons ensuite marqué la surface du film formé par un crayon noir et une peinture organique et les échantillons sont replacés dans le milieu corrosif (SO_2+air+humidité) à 25°C. La sulfatation continue comme l'indique l'augmentation de poids de chaque échantillon, mais les marques sont conservées à la surface, parce que les nouvelles couches de gypse se forment à l'interface $CaCO_3/CaSO_4 \cdot 2H_2O$ (Fig. 29a,c).

D. Formation de nouvelles couches de gypse sur les couches précédentes (pour une épaisseur supérieure à 300 Å).

Si l'attaque que nous venons de décrire continue, les marques disparaissent progressivement lorsque l'épaisseur dépasse ~300 Å (11% de sulfatation) (Fig. 29,b,d). Ceci constitue une preuve que, pendant le second stade parabolique de la sulfatation, les nouvelles couches de gypse se forment sur les précédentes.

E. Diffusion des Ca^{2+} en état solide.

a) La formation des couches de gypse à partir de la surface de $CaCO_3$ vers le milieu corrosif a été prouvée en utilisant des lames minces de marbre et en observant son attaque par les SO_2, air et humidité sous le microscope.

b) Des échantillons en marbre ont été couverts avec différents types de films organiques, utilisés pour la protection du marbre, que l'on trouve dans le commerce. Ensuite, ils ont été placés dans un milieu de SO_2, air et humidité (à 25°C). Après un intervalle de temps différent pour chaque échantillon, ceux-ci ont été enrobés dans un matériel de type «polyester». Leurs sections ont été polies, graphitées et analysées par la microsonde électronique (EPMA) pour Ca et S. Quelques résultats sont indiqués sur les figures 30 et 31. Nous avons observé qu'il y a deux catégories de films protecteurs:

1. La première permet la diffusion du SO_2, de l'air et de l'humidité à travers le film et la formation du gypse sur la surface du marbre, et aussi dans le film (Fig. 30a-f); après un laps de temps le gypse arrive à la surface du film (Fig. 30f) et continue à se former vers le milieu corrosif, nourri par la diffusion de Ca^{2+}.

2. La deuxième ne permet pas la diffusion du SO_2, de l'air et de l'humidité. Après une période d'induction, durant laquelle les cations Ca^{2+} diffusent à travers le film, il se forme du gypse sur la surface de celui-ci et non plus à l'intérieur (Fig. 31).

Des films protecteurs appartenant aux deux catégories ont été analysés à la microsonde EPMA en utilisant notre nouvelle technique: on fait des analyses à la section du même échantillon de marbre couvert par un film protecteur, après des expositions successives dans un milieu de SO_2, air et humidité en utilisant les mêmes voies de faisceau d'électrons. A la figure 32 on voit les résultats pour la catégorie 1 des films et à la figure 33 pour la catégorie 2.

Naturellement, la diffusion des Ca^{2+} vers le milieu a également lieu en absence du film; le film révéle simplement la diffusion, il ne la crée pas.

Tous ces résultats donnent une confirmation complète du modèle de la pile galvanique et du mécanisme de la sulfatation de la calcite et du marbre.

Avec les mêmes expériences nous avons vérifié l'évolution parabolique (Fig. 34).

En présence des films protecteurs, le mécanisme est illustré sur la figure 35.

La conséquence finale de ce mécanisme est la destruction des films protecteurs, à cause de la diffusion préférentielle de Ca^{2+}, plus rapide à partir des centres actifs structuraux ou géométriques (y compris les hauts-reliefs). Il conduit à la formation des cavités à l'interface marbre-gypse et à la fissuration des films, puisque la pression des vapeurs dans les cavités est inférieure à la pression atmosphérique extérieure [Fig. 35e (1 et 2)].

La figure 37 est aussi particulièrement intéressante, illustrant la similarité entre la formation de ZnO sur Zn (où le mécanisme de Wagner est valable) (Fig. 36a) et de la formation du $CaSO_4 \cdot 2H_2O$ sur le marbre couvert par un film protecteur (Fig. 36b).

A la suite de ces résultats, nous n'avons pas permis l'application d'aucun film protecteur commercial sur les monuments et les statues de l'Acropole. A la place, nous avons suggéré, et c'est déjà chose faite, le transport des statues dans le musée, dans des caisses transparentes, climatisées, par une circulation d'azote. Ce transport est provisoire. Les statues retrouveront leur place lorsque la pollution atmosphérique aura diminué (on a pris déjà quelques mesures), ou lorsqu'on aura trouvé une méthode de protection convenable. Ce dernier effort est maintenant facilité après l'élucidation du mécanisme et la précision de l'étape déterminant la vitesse de la sulfatation. En effet, nous connaissons maintenant les qualités exigées d'un film protecteur: il doit retarder ou supprimer la diffusion des ions Ca^{2+}. Nous travaillons dans ce but.

Alors nous n'allons pas utiliser des plastiques pour la restauration du Parthénon.

Si la décision des responsables archéologues et architectes est que la frise reste sur place nous suggérons trois méthodes qu'on peut utiliser pour retarder ou supprimer la sulfatation, puisqu'elle sera la seule cause de la détérioration, comme l'attaque acide est annulée par l'abri contre la pluie qui existe déjà:

1. De mettre toutes les surfaces *in situ* dans des caisses transparentes, étanches, conditionnées par circulation d'azote pour éviter l'augmentation de la température, puisque ce système est un piège d'énergie.

2. De souffler de l'azote parallèlement à la surface sur les parties inférieures de la frise pour préserver une couche adhérente permanente d'azote sur sa surface.

3. D'intervenir souvent avec le vaporisateur à solution de carbonate de potassium pour reconvertir le gypse en carbonate de calcium.

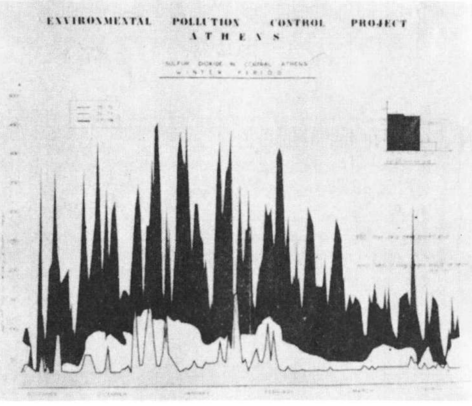


Fig. 1. Diagramme de la concentration de SO_2($\mu g/m^3$) avant (surface noire) et après (surface grise) la suppression de l'usage de mazout à teneur en soufre supérieure à 1% dans le chauffage central des bâtiments.

Fig. 2. Zone autour de l'Acropole, dans les limites de laquelle seulement le chauffage électrique ou solaire sera permis. Dans la zone intérieure l'usage de voitures électriques est recommandée.

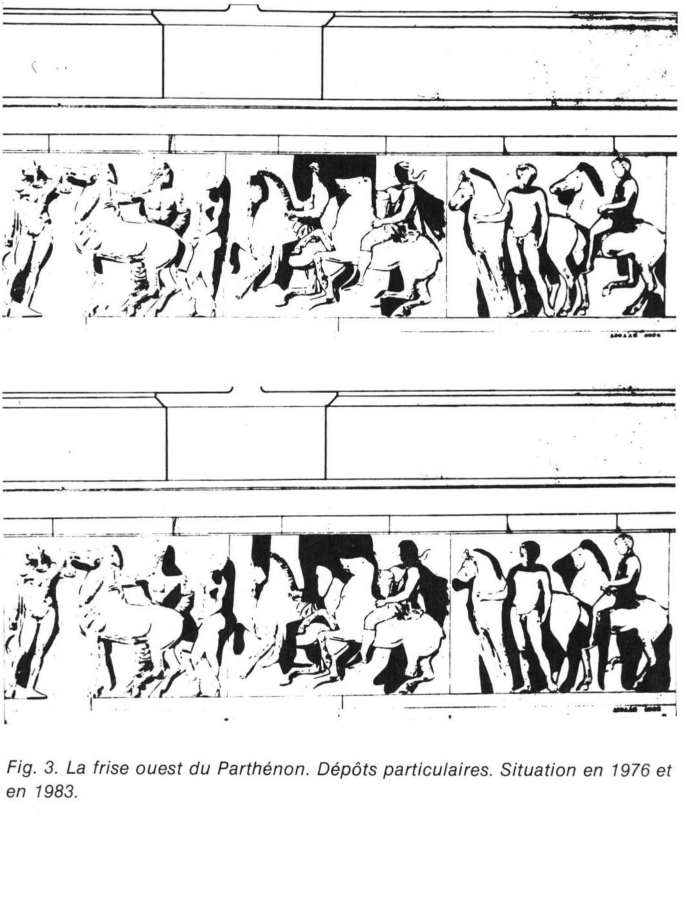
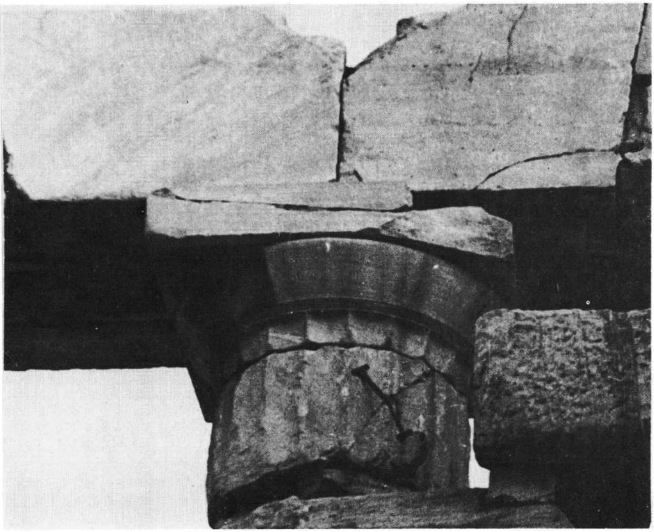


Fig. 3. La frise ouest du Parthénon. Dépôts particulaires. Situation en 1976 et en 1983.



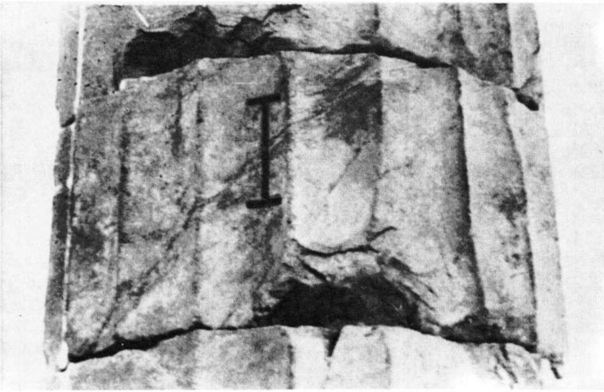
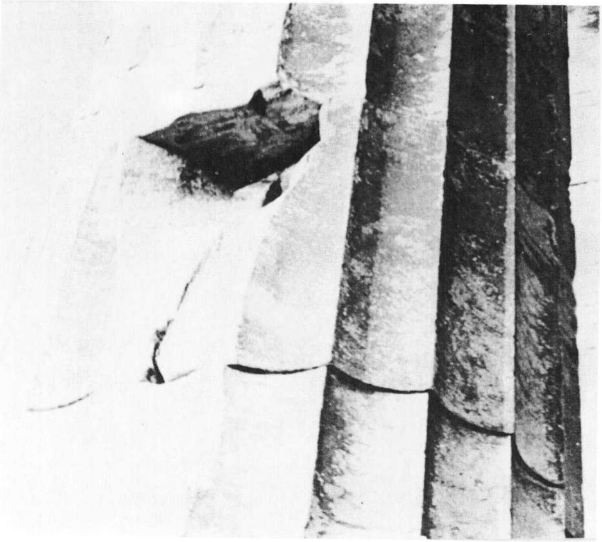


Fig. 4, 5. Fissures et ruptures du marbre provoquées par le gonflement des goujons métalliques.



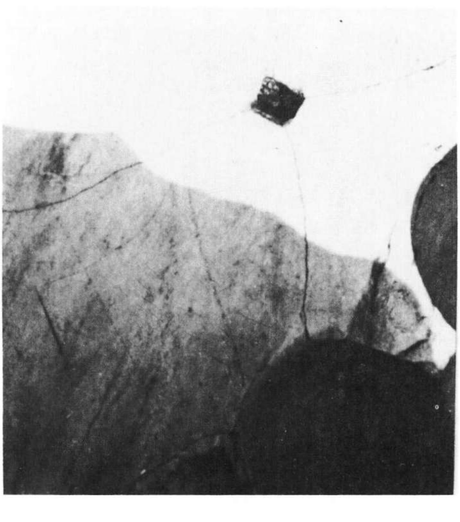
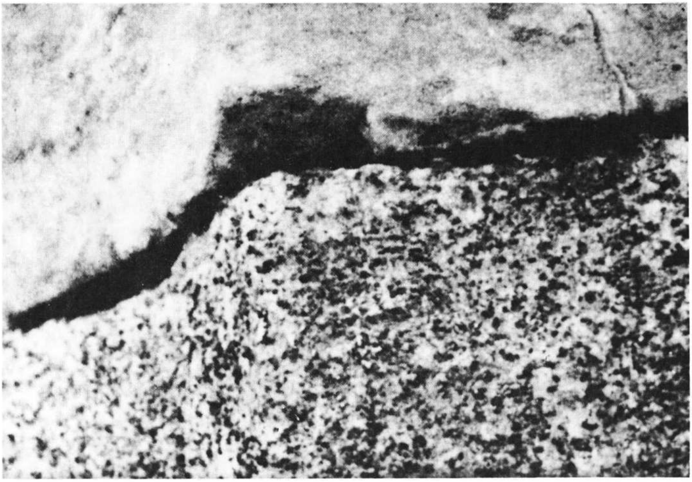


Fig. 6, 7. Fissures et détachements du marbre provoquées par le gonflement des goujons métalliques.



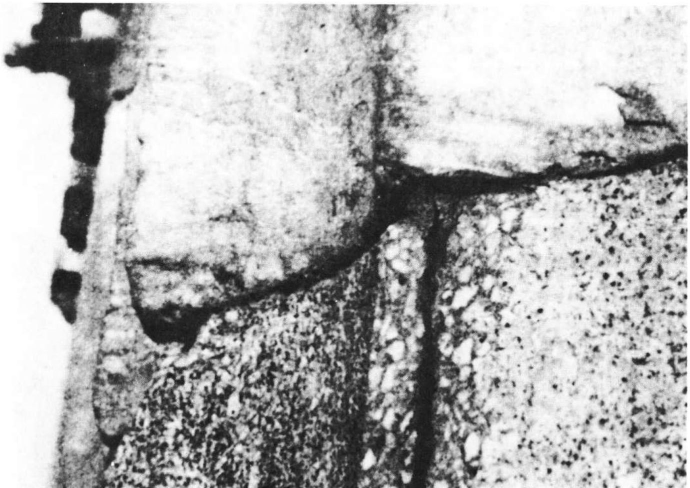


Fig. 8, 9. Phases successives de la corrosion de l'armature du béton en contact avec le marbre original.

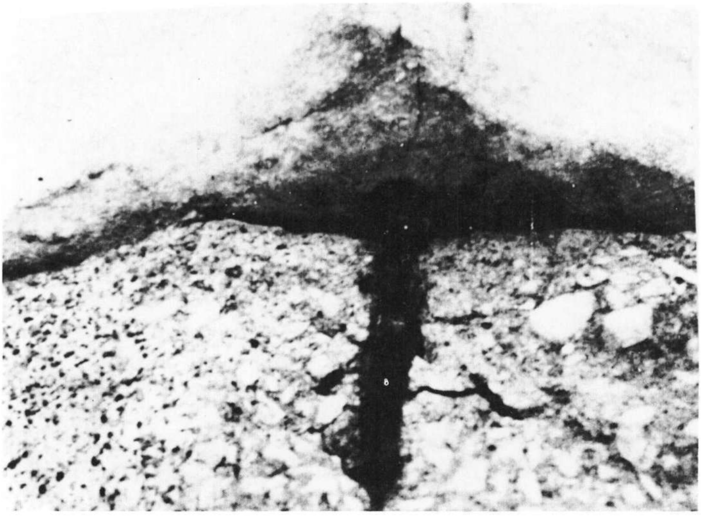


Fig. 10. Phases successives de la corrosion de l'armature du béton en contact avec le marbre original. Ici, la rupture est observée même sur le marbre.

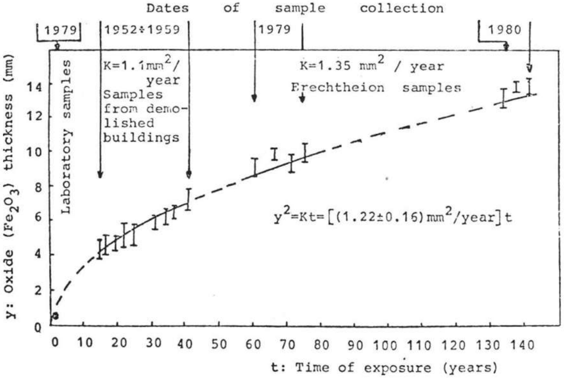


Fig. 11. Perte de poids des armatures du béton exprimée en épaisseur d'oxyde ferrique en fonction du temps d'exposition. 1er groupe: échantillons du laboratoire;2me groupe: échantillons extraits de bâtiments démolis, après un délai d'exposition entre 15 et 42 ans;3me groupe: échantillons extraits de l'Erechthéion en 1979, après un délai d'exposition entre 60 et 75 ans (restauration de Balanos, 1902-1909);4me groupe: échantillons extraits de l'Erechthéion en 1980 après 134 à 142 ans d'exposition (restauration de Pittakis, 1837-1842).

Fig. 12. Comparaison de l'état de détérioration de la même caryatide entre 1955 et 1965.

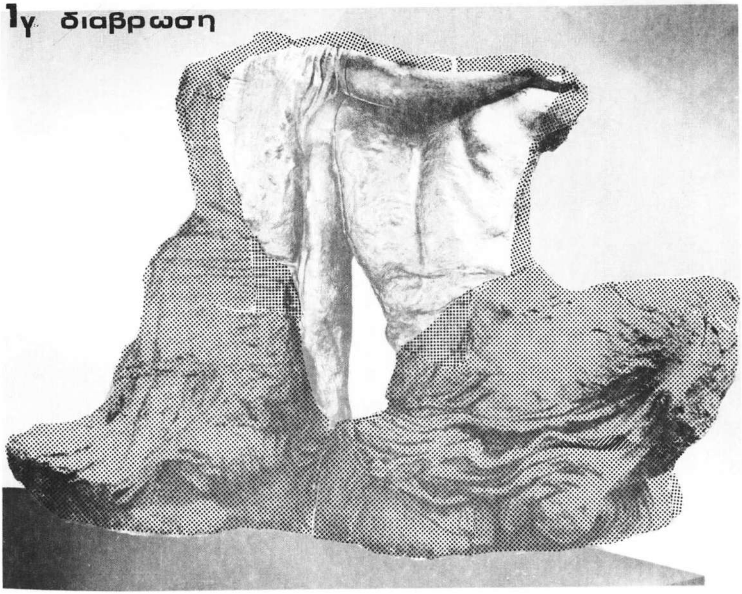


Fig. 13. Action des polluants acides sur les surfaces sculptées.

Fig. 14. Surfaces attaquées (et marquées) par les polluants acides.

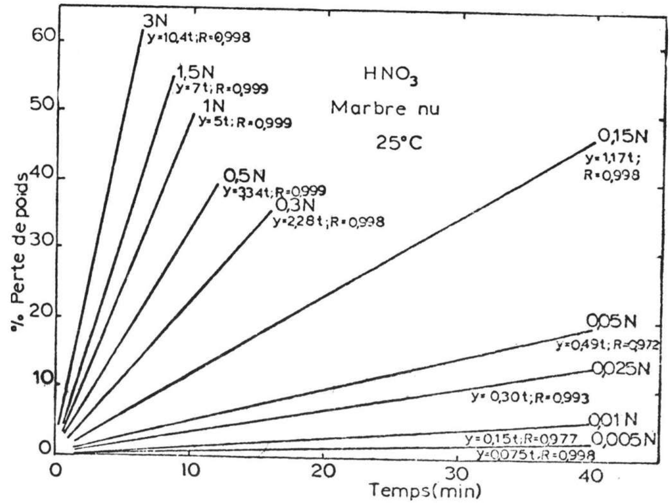


Fig. 15a. % perte de poids des échantillons de marbre nu à la température ambiante dans des solutions de l'acide nitrique de diverses normalités.

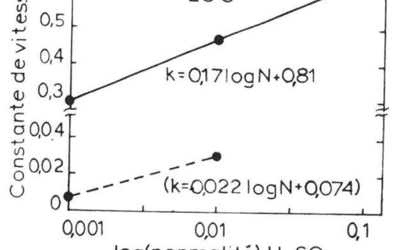


Fig. 15b. Constantes de vitesse en fonction du log des normalités de H_2SO_4 à la température ambiante (——: marbre nu, – – – –: marbre protégé).

Fig. 16. Copies en plastique des statues de Cécrops et Pandrossos.

Fig. 17. Attaque atmosphérique d'une Caryatide. Partie droite de la statue: attaque acide (la surface était en contact avec l'eau de la pluie): dissolution préférentielle des hauts-reliefs; partie gauche de la statue: sulfatation (la surface n'était pas en contact avec l'eau de la pluie): formation d'une couche conservant à sa surface des détails de la statue, déjà éliminés à l'interface marbre-gypse.

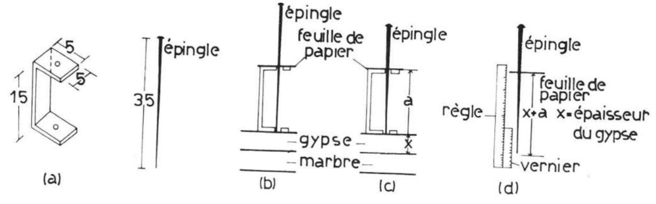


Fig. 18. La nouvelle méthode de «la sonde à épingle» pour mesurer l'épaisseur des films de gypse. (a) L'appareil. (b), (c), (d) Stades successifs du procédé. Nous utilisons maintenant la même méthode sous forme de micromètre à épingle.

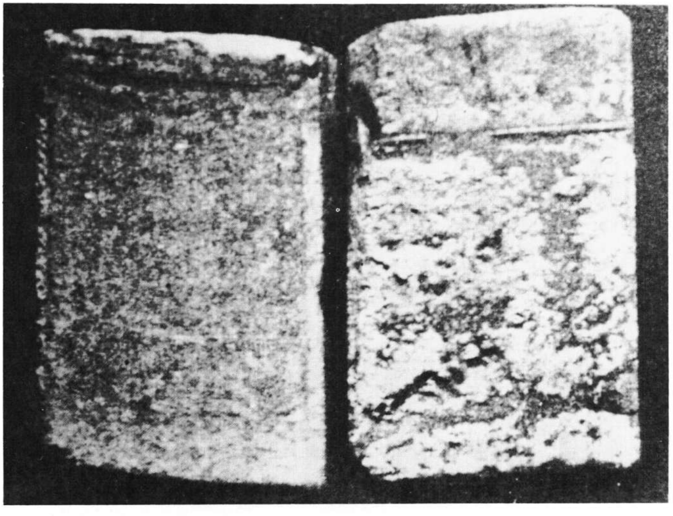


Fig. 20. Eprouvette en marbre traitée avec du plastique; à gauche, avant et à droite après son exposition à une atmosphère artificielle de SO_2 + air + humidité. On observe la formation du gypse dans et sur la couche de plastique.

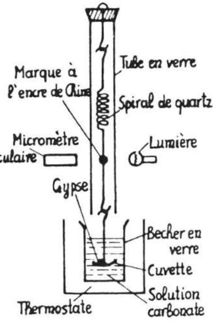


Fig. 19. Schéma de l'appareillage au spiral de quartz.

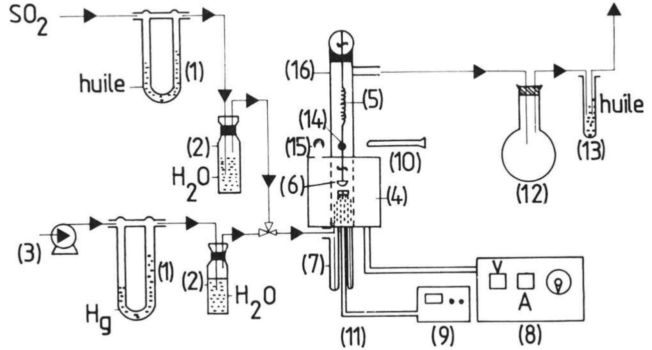


Fig. 21. Représentation schématique de l'appareillage utilisé pour mesurer la vitesse de la sulfatation:

1. Débitmètre, 2. Barboteur, 3. Pompe, 4. Four, 5. Ressort spiralé en quartz, 6. Récipient, 7. Tuyaux capillaires, 8. Stabilisateur en tension, 9. Enregistreur de température, 10. Viseur, 11. Thermocouple, 12. Flacon sphérique, 13. Eprouvette, 14. Tache d'encre de Chine, 15. Lampe, 16. Tuyau en verre.

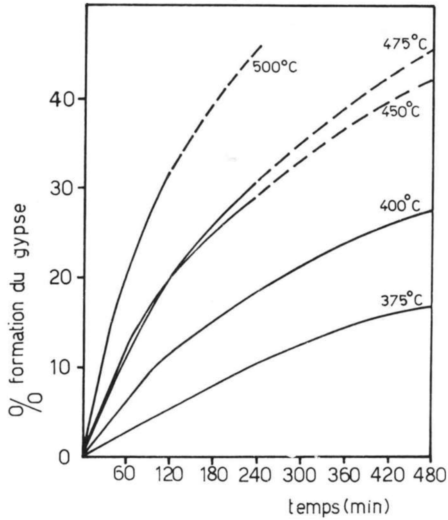


Fig. 22. Taux de sulfatation en fonction du temps (début de la réaction, évolution linéaire).

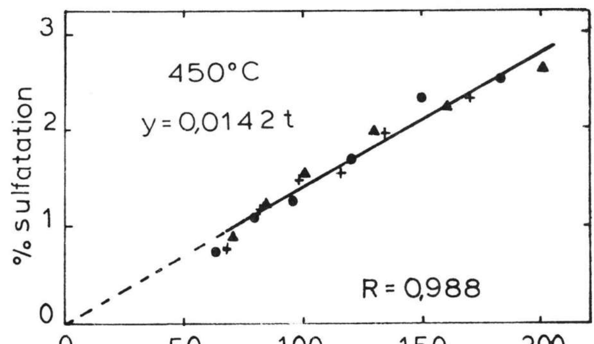


Fig. 23. Taux de sulfatation en fonction du temps à 450°C (poudre de marbre pentélique; 50% SO_2, 10% O_2, 40% N_2 saturé en vapeur d'eau).

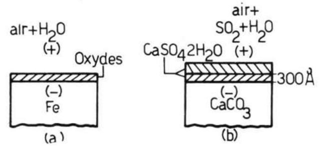


Fig. 24. (a) Modèle de Wagner interprétant le mécanisme de la corrosion des métaux. (b) Modèle de pile galvanique proposé et démontré pour la sulfatation des marbres.

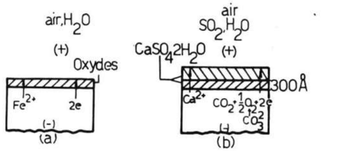


Fig. 25. (a) Modèle de Wagner pour la corrosion des métaux sous forme d'une pile galvanique. (b) Mécanisme analogue, proposé et démontré pour la sulfatation des marbres.

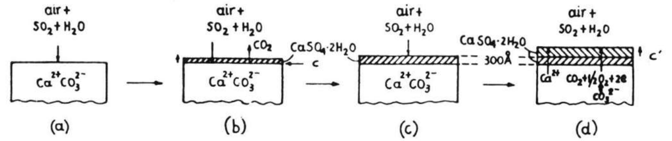


Fig. 26. Evolution de la sulfatation suivant le modèle proposé. (a) Temps zéro; (b) et (c) déclanchement (évolution linéaire: $SO_2(g)$,$O_2(g)$ et $H_2O(g)$ diffusent au long des pores plus rapidement que Ca^{3+} (s); les nouvelles couches de gypse sont formées à l'interface marbre-gypse indiquée par c); (d) Après avoir atteint une épaisseur de = 300Å, la réaction évolue paraboliquement; la couche de gypse n'est plus poreuse et l'étape la plus lente qui impose sa vitesse à la réaction est la diffusion des ions Ca^{2+} en état solide, à travers la couche de gypse indiquée par c′.

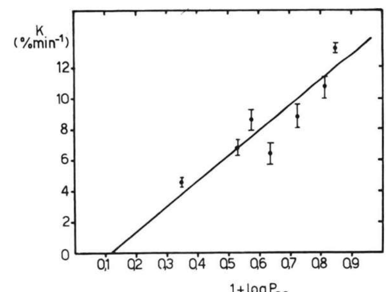


Fig. 27. Constante de la vitesse de la sulfatation en fonction du logarithme de la pression partielle de SO_2.

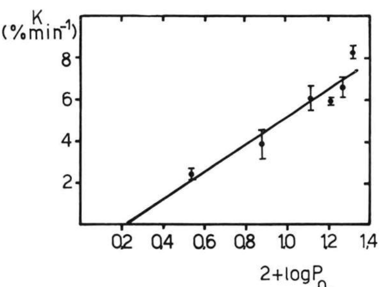


Fig. 28. Constante de la vitesse de la sulfatation en fonction du logarithme de la pression partielle de l'O_2.

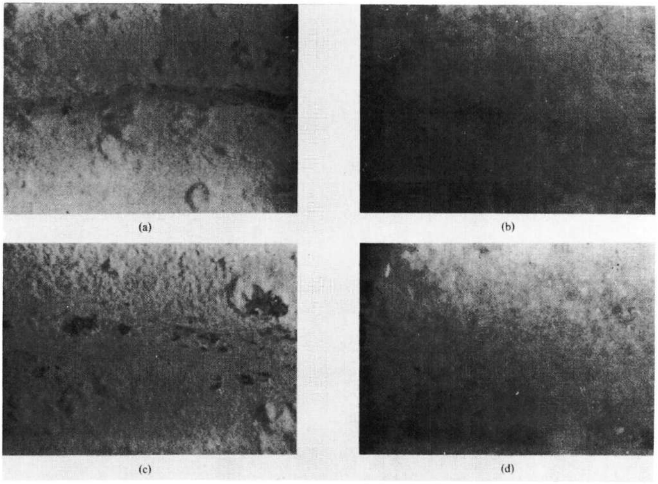


Fig. 29. (a) et (c) Surfaces de films de gypse (épaisseur inférieure à 300 Å) marquées respectivement par un crayon noir et une peinture organique et exposées en conditions de sulfatation à 25°C jusqu'à une épaisseur de gypse restant inférieure à 300Å. (b) et (d) Les mêmes éprouvettes après une sulfatation additionnelle jusqu'à une épaisseur de gypse supérieure à 500Å.

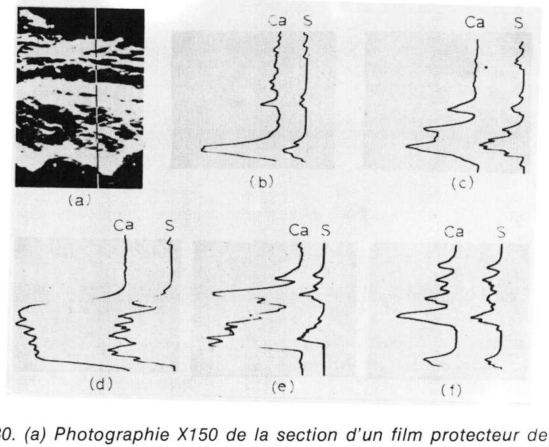


Fig. 30. (a) Photographie X150 de la section d'un film protecteur de 200µm. On voit à la microsonde l'évolution du gypse dans le film protecteur et son arrivée à la surface. (b): 2 jours, (c): 6 jours, (d): 7 jours, (e): 13 jours, (f): 20 jours.

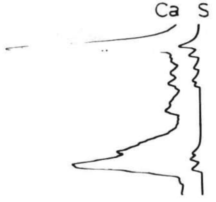


Fig. 31. Formation de gypse sur la surface d'un film protecteur de marbre de 200μm d'épaisseur, indiqué à la microsonde par la concentration des profils de Ca et S.

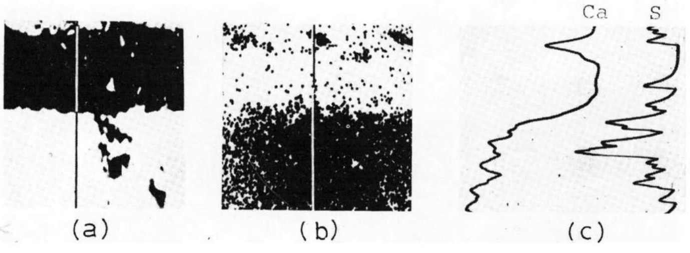


Fig. 32. (a) Micrographie électronique d'une couche protectrice sur le marbre (section). (b) et (c) Micrographie par la microsonde électronique: on constate la présence de calcium et de soufre dans et sur la surface du «film protecteur».

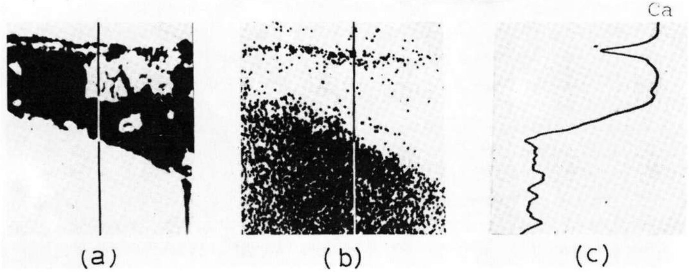


Fig. 33. Micrographies similaires à celles de la figure 32. La «couche protectrice» n'est pas transparente au SO_2, à l'air et à l'humidité. Le gypse se forme à la surface de la couche seulement.

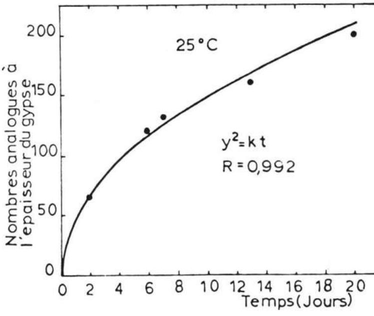


Fig. 34. Epaisseur moyenne du gypse en fonction du temps à la température ambiante dans un milieu 50% SO_2, 50% air saturé en vapeur d'eau sur la surface de marbre couverte du plastique, c.à.d. dans le plastique.

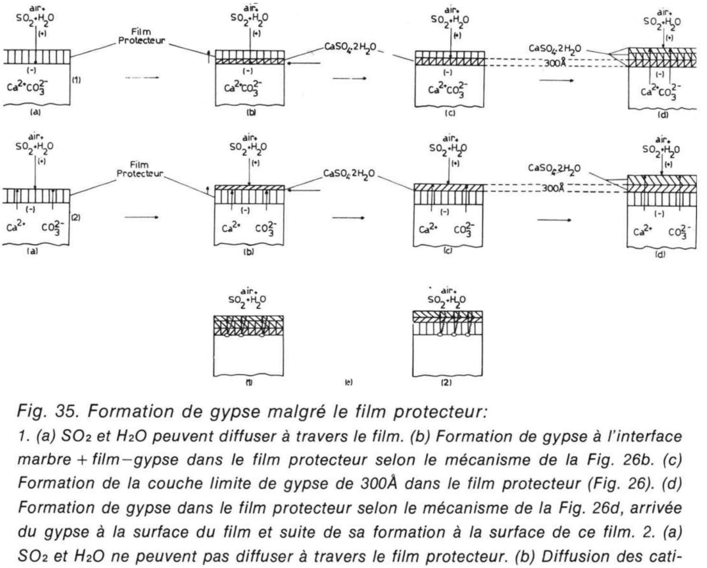


Fig. 35. Formation de gypse malgré le film protecteur:

1. (a) SO_2 et H_2O peuvent diffuser à travers le film. (b) Formation de gypse à l'interface marbre + film—gypse dans le film protecteur selon le mécanisme de la Fig. 26b. (c) Formation de la couche limite de gypse de 300Å dans le film protecteur (Fig. 26). (d) Formation de gypse dans le film protecteur selon le mécanisme de la Fig. 26d, arrivée du gypse à la surface du film et suite de sa formation à la surface de ce film. 2. (a) SO_2 et H_2O ne peuvent pas diffuser à travers le film protecteur. (b) Diffusion des cations de Ca^{2+} à travers le film protecteur et formation de gypse sur sa surface selon le mécanisme des Fig. 26d et 35 1,d. (c) Formation de la couche limite du gypse de 300Å (Fig. 26c et 35 1,c). (d) Suite de la formation de gypse selon le mécanisme des Fig. 26d et 35 1,d. 1,2. (e) A cause de la diffusion des ions Ca^{2+} sélectivement à partir des centres actifs de la surface du marbre, il se forme des cavités; la pression atmosphérique étant plus grande que la tension des vapeurs dans les cavités, le film protecteur et la couche de gypse se fissurent.

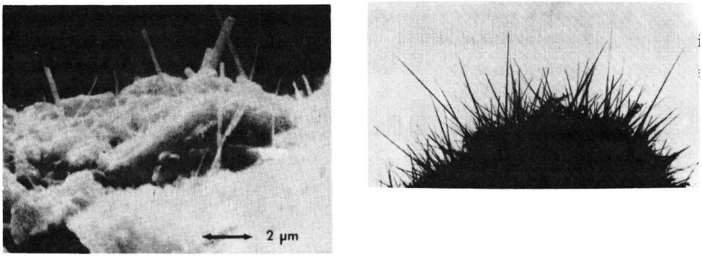


Fig. 36. (a) Formation et croissance des aiguilles de ZnO sur la surface de zinc. (b) Formation et croissance des aiguilles de gypse sur la surface d'une éprouvette en marbre, couverte par une couche en plastique.

THE PROBLEMS OF CONSERVING THE PARTHENON AND THE POSSIBILITIES OF IMPROVING THE VALUE OF THE MONUMENT. THE PRINCIPLES WHICH WILL GUIDE THE OPERATION

CH. BOURAS

A. The aims of the proposed operation on the Parthenon

The initial discussion both of the aims of the work and of the principles that should be paramount in it should take place within a broad framework so as to limit the possibility of adopting an inappropriate theoretical position that might lead to errors or to barren and extensive criticism. The principles involved, in particular, need to be analysed in detail, not only in abstract but also with direct reference to the values that we nowadays attribute to monuments – values which the principles agreed upon should help to reinforce. The purpose of this text is to broaden the framework of the discussion and to ensure that the question is considered from as many angles as possible, so as to arrive at the best solution to each individual problem.

The intervention on the Parthenon is essential and inevitable. The damage caused by the rusting iron components incorporated into the temple during Balanos' restorations is well known and will be discussed in detail in what follows.

The planned programme of work on the Parthenon will be mainly of a rescue nature. And if we are agreed that every change in architectural monuments bears the stamp of its age, the last years of the twentieth century should leave on the monument the stamp of contemporary attitudes towards our cultural heritage. In the text that follows an attempt is made to present this view more clearly, and with detailed documentation.

The planned program of work on the Parthenon aims at:

1) The removal of the causes of the continuing deterioration.
2) The better conservation of the temple after the work is completed.
3) The improvement of the value of the monument.

1. The removal of the causes of the continuing deterioration.

There is a clear similarity between the majority of the causes of damage to the Parthenon and those that have already been studied in the case of the Erechtheion, the effects of which can be detected in the rest of the classical monuments on the Acropolis and in Athens generally: the reason for this is that the same material and methods of construction are used in all these monuments and they all face the same natural conditions. The causes of the damage are:

(a) The oxidation and expansion of the iron supporting and connecting elements that were incorporated in the marble already discussed by Prof. Skoulikidis. This applies to almost all the metal components used in Balanos' restoration (which were inadequately insulated against the surrounding air and against damp), and also to those ancient cramps and dowels that were left in adverse conditions as a result of the Morosini explosion or the later vicissitudes of the temple. This cause of damage affects both the material *in situ* and the marble lying on the ground.

(b) The disintegration and crumbling of the cements used in the Balanos restoration. The effects of the oxidation of the modern iron elements in the Parthenon extend to the reinforcement of the cement covering that forms the visible surface of many of the column drums in the north *peristasis,* causing it to fracture and ultimately to disintegrate completely.

(c) Damage to architectural members when some shift in position causes them to lose their proper seating, with the result that the entire weight is carried on a very small surface.

(d) Erosion of ancient surfaces as a result of sulfation. The problem of erosion by the sulphur oxides in the polluted atmosphere of Athens and the sulfation of the Pentelic marble in the monuments has been discussed by Prof. Skoulikidis.

(e) Wear caused by the feet of visitors. This is mainly wear on the steps of the *krepidoma* and the floors of the *cella* and the *peristasis.* The problem is serious (the curvatures of the stylobates are threatened) but not an urgent one, since visitors have been forbidden to walk upon the monument in recent years.

2. The improved conservation of the temple after the completion of the work.

In addition to the causes of damage that have arisen under modern circumstances, there is also the question of the unavoidable ageing of any structure under natural conditions. The effects of this can be mitigated through conservation.

(a) The free flow of rain water through the superstructure is particularly harmful. Not only does the action of the water cause mechanical wear, but the water itself expands when it freezes, with the familiar damaging effects on the strength and appearance of the stone.

(b) The well known process by which the limestone (and the marble) slowly dissolves under the effect of the carbon dioxide in the atmosphere and re-crystallizes in an adjacent position is quite apparent in a number of parts of the Parthenon.

(c) The earlier fires and explosions have produced vast numbers of cracks and fissures in the superstructure of the Parthenon. The fragments, both large and small, have not fallen from the monument, because they are inter-locked with the stones next to them, and have remained for centuries in a state of unstable equilibrium. Apparently insignificant causes (a storm, vibrations, a strong wind) can cause the flaking away or the collapse of small fragments of marble, and occasionally of larger pieces.

(d) Resistance to the effects of a possible earthquake. The improvement of the static resistance of the temple to horizontal thrusts, more specifically those arising from an earthquake, is also one of the aims in the conservation of the temple.

3. The improvement of the value of the monument.

The work on the Parthenon is essential and inescapable. However, it also affords a major opportunity to improve the condition of the temple; in view of the difficulties involved in the decision-making process on the one hand and the setting up of a large site office on the other, the opportunity might even be called unique. At the same time, the improvement in the condition of the temple depends in part on the proper exploitation of the architectural material lying on the ground, which will in turn save this material from damage or loss.

We are faced, therefore, with additional *anastylosis* (in the internationally accepted sense of the term) and with restoration work: in other words, with the active side of the operation on the monument, which needs to be the subject of particularly careful study, discussion and evaluation. The improvement of the Parthenon means more specifically its improvement as (a) a historical and scientific document, (b) a work of art and (c) a functioning building.

(a) The improvement of the Parthenon as a historical, archaeological and scientific document. Despite its state of advanced deterioration, the Parthenon is nonetheless a source of a wide variety of information, derived both from the building viewed as a whole and from its smallest detail. The architectural material from the Parthenon today scattered around the Acropolis is just as valuable a source of information (if not more valuable) as the material preserved *in situ*. This dispersed material alone would be sufficient to reconstruct the general lines of the temple.

From this point of view, then, the Parthenon is an outstanding monument. Its authenticity ought to be preserved by whatever means possible: even the smallest fragment of it is irreplaceable, given that we cannot know what questions will be asked by future generations, or by what methods.

Briefly, the above survey suggests that three demands must be made if the monument is to be improved as a historical document:

- Interference with the ancient material should be kept to a minimum.
- The sources of the scientific evidence should be collected and correlated: that is, the dispersed material should be incorporated in the monument.
- Earlier errors of restoration should be corrected.

(b) The improvement of the Parthenon as a work of art. The Parthenon represents, both in its architecture and in its sculpture, the finest moment of the art of the ancient world. It is the classical work par excellence throughout the world, with its ideal proportions, perfectly balanced volumes, the aesthetic autonomy of the details and, finally, with its unique sculptural aspect in relation to the natural light. An in depth study of these matters reveals the exceptional sensitivity of the composition, the extent to which its present ruined condition fails to do justice to the monument's beauty, and, worst of all, how the mutilation changes the spirit of the forms and gives the monument a character quite unrelated to that aimed at by its creators. Obviously, only the temple in its original form represented the classical ideal of perfect harmony.

The demand that emerges in the aesthetic sphere is that we should restore the temple as closely as possible to its ancient, complete form. Its improvement as a work of art requires that *anastylosis* should proceed wherever possible.

(c) The improvement of the Parthenon as a functioning building. Once the Parthenon lost its function as a religious building it ceased to be regarded as a living monument, though it continues to be a cultural treasure reknowned throughout the world. Today the temple is an exhibit, an open air museum piece, and a teaching document of interest from many points of view. We may therefore speak of functions in the broader sense of the word and examine ways in which these may be improved. We may also from the point of view of the «users» examine the mechanisms by which, through looking at the monument, they come to appreciate its art and history, and the possibility of communicating with the spirit of classical antiquity.

The demands that arise in the functional sphere if the Parthenon is to be improved are thus clear. It is necessary to improve the conditions under which the monument may be visited and its value for teaching – what may be termed the educational potential of the temple. The «legibility» of the monument must also be improved, as must its clarity and the impressivenes of its forms.

B. Principles that will be observed during the operation on the Parthenon

Today, of course, the restoration of architectural monuments has advanced beyond the era of dogma: the principles form a fairly broad framework, within which the proposals made should respect the particular features of each individual case. The drafters of the Charter of Venice in 1964 provided that «...each country (should be) responsible for applying (the principles) within the framework of its own culture and traditions». This element of relativity in the observation of the principles is especially great in the case of the Parthenon because (a) it is a monument of exceptional importance from every point of view (b) the work on it is not now beginning: even in the theoretical sphere there exists a precedent that cannot be ignored, and (c) our knowledge and interpretation of the Parthenon are unusually well advanced, and any consideration of the problems of the monument correspondingly more complex.

A number of principles will be observed during the proposed work on the Parthenon, in conformity with internationally accepted requirements in the restoring of monuments. The criticism that will undoubtedly be forthcoming will be blunted if the proposals are objective and are set within a framework of generally agreed principles. The foresight exercised in this area in the preliminary study for the restoration of the Erechtheion five years ago had very positive results.

Accordingly, in addition to the internationally agreed principles laid down in the Charter of Venice (which are discussed first below) a further five will be enunciated here, which have general application to all the non-living classical buildings in Greece. These new principles derive indirectly from an interpretation of the precedents, and from the particular experience gained (both good and bad) in Greece as a result of many years of practical efforts to restore monuments, especially those falling within this category.

I will not discuss the articles 1,2,6,11 and 15 at léngth, because of lack of time.

Article 8: «Items of sculpture, painting or decoration which form an integral part of a monument may only be removed from it if this is the sole means of ensuring their preservation».

This principle is of decisive importance for the Parthenon, since its sculptural decoration is unique, not only for its quality but also for its importance as an integral part of the architectural form of the monument. Although the sculptures by Pheidias and his workshop have been admired to the point of excess over the last 200 years, they have been treated in a way that can hardly be described as meeting with general acceptance. The majority of them were removed from the temple during an age of innocence, when the problem of the conservation of monuments had not yet been appreciated. And even today the possibility is discussed of removing the few sculptures that have remained *in situ,* in the light of the emergence of a new serious danger – the pollution of the atmosphere.

Whether or not the principle enshrined in the article is being observed depends basically on an assessment as to how far the removal of the sculptures is «the sole means of ensuring their preservation». And this assessment is related to a changing situation and to actions that may or may not be implemented. Moreover, any course of action that proved to be misguided would not be especially damaging to all the sculptures. Over the last five years, after it was adjudged that the only way to preserve them was to transfer them to the museum, the last sculptures have already been removed from the west pediment. This course of action is readily reversible. The problem is much more acute in the case of the west frieze: it would be extremely difficult both to remove these and to restore them to their original position at some future date. The decision relating to the covering of the west pteron keeping the frieze in situ, or the removal of it is connected on one hand with considerations of the broader policy of the Ministry of Culture and Sciences (the erection of a new Museum to house the frieze, should it removed from the temple) and on the other with a special research of technical nature that has not yet been completed. In the case of this particular programme the question remains an open one, which will be discussed and decided later.

Article 9: «The process of restoration is a highly specialised operation. Its aim is to preserve and reveal the aesthetic and historic value of the monument and is based on respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp. The restoration in any case must be preceded and followed by an archaeological and historical study of the monument».

Respect for the original form of the temple is supported by the knowledge resulting from long research in the past and from modern investigation. In fact, the archaeological study has already taken place and each restoration proposed will accord with its findings. Respect for the authentic features – the architectural members of the temple – is of paramount importance in the case of the Parthenon, and is guaranteed by avoiding as far as possible any new work on them. For the Parthenon, as for the Erechtheion, the ancient cuttings will be used for the necessary modern clamps; wherever any new piece has to be dressed, use will be made of a device for transferring points, so that the break surfaces will remain intact.

The requirement in the Charter that restoration should bear a contemporary stamp clearly refers to work that goes beyond the bounds of certain restoration – that is, to work based on inference and comparative data. No such work is proposed for the Parthenon.

A r t i c l e 10: «Where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation and construction, the efficacy of which has been shown by scientific data and proved by experience».

It has been demonstrated that the traditional technique of using architectural members cut from single blocks and perfectly dressed guarantees, under natural environmental conditions, a very long life to works of Greek classical architecture. The various cements used by Balanos as substitutes for marble (mainly in order to differentiate clearly between the new and the ancient parts) deteriorated in less than half a century. Artificial stone and mortars should accordingly be ruled out, not only because they are in fact cheap materials in themselves, but because they are much less enduring than marble.

In accordance with the principles of article 10 we preclude, as in the case of the Erechtheion, the use of a number of modern materials, such as plastics, polymers and epoxide resins, as professor Scoulikides already said.

A r t i c l e 12: «Replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence».

The harmonious integration of both the ancient marble pieces and the modern replacements that will inevitably have to be set in position on the Parthenon is guaranteed by their morphological and structural fidelity to the original form. In this context, the proportion of new to original material, both in the monument as a whole and in individual sections of it, is a factor of decisive importance. In the proposals set out below, the proportion of new material overall is negligible, and in the individual sections of the monuments it is invariably low. No part of the temple will give the impression that it has been rebuilt.

The need to distinguish between original and replacement parts laid down by article 12 poses a particular problem for the Parthenon. A deliberate distinction in terms of form or colour would disturb the superb harmony of the temple. The fact that the new parts, and the additional restoration work, will show no signs of deterioration will differentiate them clearly enough and cover the requirements of the Charter adequately in the short term. The solution adopted by Balanos, and now being applied to the Erechtheion, which was to carve inscriptions on those surfaces of the new parts that are not visible, is perhaps the most suitable for the Parthenon.

A r t i c l e 16: «In all works of preservation, and restoration there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report should be published».

An extensive general documentation of the Parthenon has already been published, including descriptions, drawings and photographs, and also special measurements for the analysis of specific problems. The second part of chapter one of the present study included a system of codification by means of which the documentation was set on a unified basis. New drawings will be made methodically both of those parts of the temple that will be dismantled and of the dispersed architectural material. In the case of the former the drawings for each of the twelve programs will record the details in the precise spirit of the Charter, and in a manner similar to that deployed in the Erechtheion.

C. Principles deriving indirectly from the Charter of Venice relating to Greek classical architecture.

Article 1. Reversibility: it should be ensured that it is possible to return the monument to its present state, before the operation.

This principle stems from the view that a monument is a source of scientific evidence and from the premise that mistakes may occur during the preliminary study or the execution of the work. It takes as its starting point, that is, the intention to preserve the monument as a source of evidence after the work is completed and also to ensure that any mistake is rectifiable.

This principle is now being carefully observed in the restoration of the Erechtheion. It is guaranteed by two safeguards: the reduction to a minimum of interference with ancient material, and exhaustive documentation before any change is made.

Article 2. Preservation of the autonomy of architectural members and their static function.

The above derives from an interpretation and extrapolation of the provisions of article 9 of the Charter of Venice particularly in connection with Greek classical monuments. The structure of the «non-living» ancient monuments of Greece is exceptionally simple: they are trabeated buildings, in which there are no lateral thrusts or horizontal stresses, and they have carefully dressed seatings. They are characterised by a total absence of binding agents (mortars), by the structural and morphological autonomy of the individual stone members, and by the fact that they achieve static equilibrium through their own weight. Corbels, eccentric loadings, and «dynamic states» in general, are avoided. These properties should be respected during the operation on the Parthenon.

Article 3. The operation should be restricted to those parts of the monument that have already been restored.

The dismantling and reassembling of parts of the temple that have remained undisturbed since antiquity is acceptable only exceptionally.

Article 4. The ruin should be made self-conserving.

The ancient parts themselves, when restored (with either ancient or modern additions), will make it possible to conserve the monument properly and afford the building the required degree of protection.

Article 5. The changes in the appearance of the monument should be kept to a minimum.

This last principle derives from the fact that the most important Greek temples have acquired the value of symbols for modern society. During the last fifty years, the Parthenon has remained completely unchanged, and has been visited by more people than at any previous period. The image it now presents has become familiar throughout the entire world.

All this should make us very careful when planning changes.

TWELVE PROGRAMS FOR THE RESTORATION OF THE PARTHENON

M. KORRES

The following text only approximately reproduces my presentation on September 13, 1983 because the main part of my talk was accompanied by a sequence of slides. The speaker commented on the slides, using them as a visual aid in order to transmit information more easily and to save time. The short freely delivered verbal comments either by themselves or accompanied by photographs would be neither satisfactory nor adequate as a printed text. All the more so since for practical reasons the many illustrations have been dispensed with here because virtually all of them are to be found in Study for the Restoration of the Parthenon *by M. Korres and Ch. Bouras, Athens, 1983 (henceforth cited as: Study). Thus we have chosen to present a revised version of the talk with some rearrangement of the subject matter and, in place of the slides, references to illustrations in the* Study *and in the book by N. Balanos,* Les Monuments de l'Acropole, relèvement et conservation, *3 vols., Paris, 1938 (henceforth cited as: Balanos). In addition my reports on the architectural and sculptural character of the building, written during the development of the 4th restoration program, are appended here as a self-contained unit.*

The varied character of the spoken presentation is, however, preserved and reports on questions of preservation or of anastylosis are interspersed with brief or longer interpolations on historical and archaeological evidence and problems.

Yesterday, inside the Parthenon, most of those present received a preliminary introduction to the subject and to the twelve programs. In order to save time we shall attempt to describe several programs together, just as we did yesterday, insofar as similarities in structure and problems allow. Thus program 3 for the south colonnade and program 4 for the north colonnade are discussed together (*Study,* p. 720). In the same way the south wall and the north wall are jointly treated (*Study,* p. 723, programs 8 and 7). Let us begin with program 1 on the east façade of the temple. Since the project will begin with this program it will receive more extensive treatment here.

Program 1. East side. Documentation.

The east side of the temple is preserved in its original form nearly to the floor of the pediment. Most of the pediment was destroyed by violence after the Roman period. The sculpture groups in the wings survived until the 19th century, but they too were removed from the temple (Lord Elgin) and are exhibited today in the British Museum. In Early Christian times the metope reliefs were destroyed by hammering; they were not, however, completely obliterated. In most cases the outlines of the figures are preserved and also parts of the carved relief. The middle columns are in good condition and almost in their original position, whereas the corner columns have undergone many structural changes (*Study,* p. 477,9). A corner is missing off, five capitals and the epistyles are cracking especially at the corners (*Study,* p. 437; *Balanos,* folding plan 10). The corner epistyles have fractures right through the blocks which drastically diminishes the stability of the corners of the temple (*Study,* pp. 460-461, 467, 489). The same holds true for the corner geison blocks (*Study,* pp. 475, 340). The projecting parts of some other geison blocks have broken off. In 1911 a repair was done on the NE corner (*Balanos,* pls. 80,81) because the geison block and the acroterion base had shifted outwards in a way which was statically risky and also aesthetically displeasing (*Balanos,* pls. 50, 80 a). The dislocation was partly corrected and parts of the tympanon and its backers were filled out with new blocks (*Balanos,* folding plans 10,11). In 1930-1931 the following work was carried out: a column capital was restored with new marble; a fragment was glued on to a horizontal geison; and the SE triglyph was restored with new marble (*Balanos,* folding plans 10,12 no. 3). The SE geison block was taken down, repaired with new marble and put back in place (*Balanos,* pls. 102, 103; *Study* p. 496). Six raking geison blocks and two sima blocks were put back on the building (*Balanos,* folding plans 10-11). Casts of Helios, the two outer horses of Helios' team, Dionysos (*Study* p. 493) and one of the horses of Selene were set up in the east pediment.

The stones were glued together with cement; bonding was done with iron clamps and the repair work was reinforced by means of ten iron rods and iron I-beams up to almost three metres long. In order to prevent the corner geison blocks from toppling over they were anchored to the corner triglyph blocks by means of strong bars. The clamps were sheathed in lead; the rods and beams were concealed with various types of mortar. Restorations of the back of two horizontal and three raking geison blocks were restored in reinforced concrete.

Today almost all of the iron elements mentioned above are in an advanced state of rusting and swelling which has caused the marble to split wherever ron has been used (*Study,* p. 301). The corrosion on the east side is about the same as elsewhere on the building; but there is a remarkable difference between the corrosion on the upper and lower sections of the triglyph-metope-frieze. This discrepancy is due to the shadow cast by the geison (*Study,* pp. 321-323).

Investigation of the structural changes in all parts of the building allows us to pinpoint the cause for each kind of deterioration individually. The three main causes are: 1) earthquakes; 2) the explosion of 1687; 3) pressure exerted by expansion of iron clamps.

The dislocations on the east side are caused almost exclusively by earthquakes.

We have found out something of particular importance for the history of the monument, namely that the greatest dislocation of all is due to the first and conclusively bigger earthquake to which the Parthenon was subjected, the earthquake of 426 B.C. described by Thucydides (*Study,* pp. 329, 678). Replacement of a geison block and the addition of extra clamps are two of the repairs carried out after the earthquake in the area of the NE corner (*Study,* pp. 115, 463).

The earthquake of February 24, 1981 (6.7 on the Richter scale, 6.4 five hours later) was the most severe earthquake in Athens during the past two hundred years. Earlier earthquakes had caused the corners of the temple to shift outward, as can be seen from the way the epistyle joints opened up (*Study,* pp. 331-332, 336, 467, 469). At the NE corner the displacements were more than tripled, 3 1/2 cm. at the epistyle, 10 cm. at the geison! (*Study,* pp. 460-461) and a piece of the geison together with the sima and lion head would most probably have crashed to the ground if the work of consolidation carried out in 1930 had not still held in good condition and if the temporary framework of supports around the lion head had not been constructed in 1979 (*Study,* p. 460). The deformation of the NE corner is created not only by simple shifts in the position of the blocks but also by something far more serious, pronounced changes in the inclination with the result that the blocks are no longer seated as they were originally. The whole NE column is seated only on one edge and this holds true of the epistyle and all of the blocks above. This situation caused the stylobate and the lowest column drum to fracture, thus diminishing the stability of the corner to the danger point (*Study,* p. 479).

After the earthquake similar phenomena were observed in the area of the SE corner, but they were on a smaller scale and with no significant loss of stability.

Program 1: East side. P r o p o s a l s

Because almost all the damage and potential danger is limited here to the NE and SE corners of the entablature and pediment, that is to say, two parts of the building which are mirror images of each other, the first program is subdivided into two sections, one for the NE and one for the SE corner, with the same type of work carried out in each.

The work to be carried out at each corner is as follows:

a) The blocks of the raking geison are to be taken down; at the NE corner the sima blocks with the lion head and acroterion base will also be taken down.

b) The tympanum slabs and their backers are to be taken down.

c) The corner geison block and the five adjoining blocks of the horizontal geison are to be taken down.

d) The corner architraves and the triglyph-metope frieze blocks above are to be taken down.

All of the blocks to be taken down will be treated for conservation (all of the iron fastenings will be replaced), attached, reinforced, restored, replaced on the building and attached by means of clamps made of titanium.

– The NE corner column is to be restored to its original form and position, insofar as this is possible without taking it down.

– Original sculpture still remaining on the pediment is to be removed to the museum (two of Helios' horses and two of Selene's).

– Copies of the surviving pediment sculpture to be set on the pediment.

(The surviving sculpture all comes from groups in the pediment wings, above the 1st and 2nd, 6th and 7th interaxials. In 1930 copies of the following sculptures were placed on the pediment: Helios, two of his horses, Dionysos, one of Selene's horses. Casts still need to be made of the Demeter and Kore group, Iris, the three goddesses and Selene).

– It may prove necessary to set up part of the tympanum behind the casts of the sculpture.

Further work needed is as follows:

– Restoration of the lowest drum in column 1.
– Restoration of the lowest drum in column 5.
– Restoration of the 11th (top) drum in column 7.
– Conservation work on column capitals 2,3,6 and 7.
– The SE column capital will probably be restored.
– Conservation work on geison block 15.
– Fragments of the entablature, above interaxials 2-6, that either fell down or fell apart are to be mended up.
– Possibly the 2 metope reliefs at the E. end of the N. and S. sides will be removed to the museum and copies put up in their stead.

Program 4. West side. Documentation.

More of the west side of the temple is preserved in its original form than the east side, but the state of preservation is not as good. Here too are the scars inflicted by violence. Morosini's cannon, shelling the Acropolis from the Hill of the Muses, scarred the columns deeply in hundreds of places (*Study,* pp. 385 right and 439 above). In certain places concentrated shelling dug deeply into the marble, producing star-like fractures. Very large pieces have broken off of seven drums, largely as a result of the bombardment. This has drastic consequences for the strength and the appearance of the structure.

Due to the expansion of dowels in the epistyle and to the bombardment, large pieces have broken off all but one of the column capitals (*Balanos,* pl. 83a; *Study,* p. 305).

In the same way virtually all of the epistyle blocks have pieces missing from their corners, show fractures and heavy damage to the surface. The metope reliefs were systematically chiselled off by the early Christians and the metope-triglyph frieze has also suffered other damage, such as pieces broken off from metope 6 and triglyph 11. The projecting parts of 4 horizontal geison blocks have also broken away. Only a little of the pediment sculpture has remained in place until our time. Only two of the ten large tympanum slabs are not in place; a part of one of them has been reset, while a still larger fragment is preserved on the ground. The raking geisa have been partly reset (*Balanos,* pl. 79γ); the geisa blocks towards the corners were consolidated in 1900-1902 (*Balanos,* pl. 68). Restoration was carried out on the west side as it was on the east side. Four column capitals (1,4,5 and 7) have been restored with very large pieces of new marble (*Balanos* pl. 83 and folding plan 6). In order to facilitate the work of restoring capitals 4 and 5 the epistyle block overhead was temporarily pulled out (*Balanos,* pl. 77) and so were metopes 7 and 8 just above. A great many different types of iron fastenings were used to attach and consolidate the various blocks. New fastenings were installed inside the column capitals (*Balanos,* pl. 78) and also on the outsides of column drums, column capitals, architrave blocks, geison blocks, the tympanum and the raking geison. Huge bars and beams were used on the corner geison blocks (*Balanos,* pl. 79γ, pl. 7 and pl. 104α). The wall in back of the tympanum was consolidated with many bars and attached to the tympanum with new fastenings.

Today most of the iron fastenings installed in 1900-1902 have rusted and expanded, causing the marble to crack.

The earthquake of 1981 appears to have rocked the whole west side, but the damage and remaining deformations are not serious by comparison with those at the corners of the east side (*Study,* pp. 269-272).

Program 4 West side. Proposals.

a) The following are to be taken down, given conservation treatment and reset:

– Two corner geison blocks and two adjoining geison blocks, four in all.

– The corner blocks of the pediment (in one piece with the sima and false water spout).

– All raking geison blocks.

– All of the sima blocks.

– The two acroterion bases.

b) Restoration of the two central tympanum slabs.

c) Horizontal geison block 13 to be removed, conserved, and reset.

d) All of the large external iron fastenings on the epistyle to be replaced by titanium fastenings.

e) Architrave block 4 to be pulled out, so that the column capitals 4 and 5 can receive new fastenings in place of the old ones and be treated for conservation; the architrave block to be put back in place.

f) The west side of capitals 1 and 7 to be restored. The recently installed external clamps on the capitals to be replaced.

All of the work listed above involves the repairs carried out in 1900 and aims at undoing the damage and removing the causes of injury linked to the earlier interventions.

The following interventions involve parts of the building which have not been worked on before:

a) The south central slab of the tympanum to be restored, using the large ancient fragment and new marble.

b) The second tympanum slab S. of the centre is the only one entirely missing; it will be restored in marble so as to complete the tympanum.

c) Five raking geison blocks (2 ancient and 3 new ones of marble) are to be set in place in order to fill the gaps.

d) Restoration of deeply shattered column drums (2nd drum of column 4, 2nd drum of column 5, 6th drum in column 6).

e) The SW column will possibly be restored.

f) Restoration of the S. corner pediment block in new marble and incorporating fragments of the lion head spout now in the museum.

Note: The north corner pediment block may eventually be replaced with a marble copy so that the original lion head and painted ornament may be better preserved inside the museum.

g) Casts of two sculptures, Kephisos (now in the British Museum) and Figure V to be added to the pediment.

Programs 2 and 3. North and south sides. Documentation

The columns and flank entablatures had been preserved in well-nigh excellent condition up until the moment of the explosion in 1687 when the north, east and south sides of the cella collapsed and also eight columns on the north side and six columns on the south side with the entablatures above (*Study,* pp. 240, 244).

All of the metope reliefs on the north side were mutilated in the same manner as those on the east and west, with the exception of the corner metope relief at the west (*Study,* p. 240); eleven metopes are preserved. The metopes of the south side were not subject to mutilation, but half of them were victims of the explosion in 1687. In 1801-1802 Elgin's agents completed the wreckage of the south side. They were not content merely to remove fifteen more metopes (they left the corner metope relief at the west in place, *Study,* p. 244 below). In order to facilitate removal of the metopes they hurled down all of the geison blocks (*Study,* p. 392, right); around twenty blocks weighing three tons each were flung down on the crepidoma from a height of fourteen to fifteen metres! In addition they also destroyed the edges of the triglyph blocks (*Study,* pp. 390, 399 right). The north side in its present form (*Study,* p. 453 above) is the result of extensive restoration carried out in 1902 and 1922-1930, in the course of which earlier restorations done in 1842-1844 were dismantled (*Balanos,* foldouts 8-9, pls. 95-100). The present form of the south side is due to restoration done on a fairly small scale in 1933 (*Study,* p. 455 above; *Balanos,* foldout 13). In 1842-1844 only three drums of column 8 had been restored. The reerection of the columns and entablature of the north and south sides was effected with 85% of the original material on the north side and 95% on the south. Peiraeus limestone was used for restoring column drums or for making entire drums of new material; the limestone was sheathed in reinforced concrete in which the flutes were carved or moulded (*Balanos,* pl. 85-87). The broken column drum fragments were fastened together with iron clamps embedded mainly in the horizontal surfaces of the drums (*Balanos,* pls. 88γ, 90α,β). The restorations of the column capitals and the copy of the capital in the British Museum were carried out in marble. Epistyle 3-4 of the north side and the backer were both restored in marble.

The epistyle blocks made up of fragments were consolidated by means of large iron beams bedded in the hidden sides of the blocks (*Balanos,* pl. 93). In the case of epistyle 6-7 of the north side the consolidation was not yet accomplished by means of iron beams embedded in the block, but by placing the beams above the block and suspending the fragments from the iron beams by means of braces. Because of thermic fractures (for this phenomenon see below) and after the explosion of 1687 the backs of all the geison blocks, particularly those on the flanks, broke up into a great many fragments which were easy to remove for reuse as they lay on the ground. So it happens that all of the reerected geison blocks are made up of well-preserved fragments in front but have huge restorations in reinforced concrete in back (*Balanos,* pl. 94). The ancient fragments are attached to the restored sections by means of external fastenings, hidden bars and iron beams at the sides. All of the iron fastenings reported above are embedded in the marble in large cuttings and concealed sometimes with stucco, sometimes with lead. The 5th column from the east on the south side poses a special problem in regard to stability: it tilts south of its axis by about .20.

(*Study,* pp. 386 above, 387, 388, 487). The tilting was caused by the explosion of 1687 and was considerably increased by the most recent strong earthquake in 1981 (*Study,* p. 258 below). The rusting iron fastenings are continually inflicting damage on the flanks, particularly on the north side (*Study,* pp. 303 left, 304). Extensive fractures have been noted not only in the ancient marble blocks but also in the reinforced concrete.

The earlier work in restoring the building suffers from serious omissions, e.g. the large gap in the cornice above metope 1, and there is reason to suspect that many blocks have been put back in the wrong places for practical reasons.

Program 2: North colonnade. Proposals

The entablature and the eight columns that were restored by Balanos to be dismantled.

Replacing all of the iron attachments in the section restored by Balanos: beams, suspended braces used for epistyle 6, clamps and dowels.

The column drums that were restored in concrete by Balanos to be replaced by new marble drums.

The metope relief at the west end of the north side to be transferred to the museum and a cast put up in its place.

Some metopes may eventually be restored in the form of plain plaques. Geison blocks now lying on the ground to be restored and put back into place (wherever the entablature and columns below have never been moved).

Waterproof covering above.

Program 3: South colonnade. Proposals

Six columns restored by Balanos and the architrave above the columns (3 + 2 epistyles) are to be taken down.

All the metal attachments in the restored section to be removed. The column drums that were restored in concrete by Balanos to be replaced by new drums of Pentelic marble.

An ancient triglyph block, now lying on the ground, to be added. The metope relief at the west end of the south side to be transferred to the museum and a cast set up in its place.

Copies of 7 or 8 metopes, now in museums, to be set up. Thirty-three geison blocks to be added, of which 15 to 20 can be largely mended up from the original fragments.

Waterproof protection for the entablature.

Drum 1 of column 5 to be restored in place of extemporized masonry installed by Pittakis.

Column 5 and the entablature above to be put back in place.

Programs 5,6,7,8,9,10. General analysis of structural problems in regard to the walls and columns

The present state of preservation of the inner building is as follows:

- The entire opisthodomos: 6 large columns, 2 antae, the epistyles and the major part of the frieze in place (*Study*, pp. 237-238).
- The west wall to virtually its full height (*Study*, pp. 242 below, 243 below).
- The western fourth of the flank walls, partly rebuilt.
- The orthostates of the east wall and a few of the blocks in the next course (*Study*, pp. 73,74, 352 right).
- All of column 6 in the pronaos (*Study*, p. 353) and the other columns to a height of 1-3 m. (*Study*, p. 352).
- Insignificant remains of the wall dividing the cella from the western chamber.

A great quantity of the marble stones belonging to the inner building is on the ground around the temple and is even to be found outside the Acropolis; most of the blocks have badly damaged surfaces caused by deliberate smashing (*Study*, p. 399 above).

If we add up the material still in place together with what is lying around on the ground the amounts preserved, expressed in approximate percentages, is as follows (plus or minus to be understood after each): flank walls, 55%; east wall, 20%; pronaos columns, 70%; southeast anta, 95%; pronaos entablature, 85%. Historical depredations, not physical deterioration, largely account for what was preserved and in what condition. The explosion of 1687 was the main cause of the disaster for the colonnade but it was only a secondary cause of damage to the interior where the damage was caused first and foremost by the conflagration at the end of the Roman period.

Today much of the marble is lost to a great depth on the inside of the walls and columns of the pronaos and opisthodomos.

It was formerly believed that the fire had reduced the marble to lime to the depth of the marble surfaces now preserved and that subsequently the lime wore off or weathered away chiefly by the action of rain. Today we know that the missing pieces of marble were never reduced to lime; they were subjected to thermal fracture during the fire (*Study*, pp. 295, 348, 350 below) and broke off from time to time as a result of vibrations, earthquakes, technical interventions and principally the explosion of 1687.

Blocks that have reduced thickness occur most often in the rebuilt sections; the reason for this phenomenon is thermal fracture. That is, the blocks that had to be reerected are the very ones which came loose from the original construction and suffered the shock of falling (*Study*, p. 349). The whole inside of the building including the floor has suffered essentially the same injuries but they go unnoticed behind the extraordinarily well preserved surfaces. The preservation of these surfaces is due to the fact that the pieces of marble affected by thermal fractures hold together and adhere both to each other and to the inner, firmer marble from which they have separated but not broken away. (For a detailed account of thermal fracture, see *Study,* pp. 285-292-295, 344-353.) After the fire extensive work was done on the Parthenon: clearing up, demolition and repairs. For reasons of economy the new roof covered only the main body of the building; the damaged marble ceilings of the colonnade were removed. From that time on the entablature of the colonnade remained exposed to the weather and so did the floor of the colonnade in which various channels were cut in order to drain off the rain water (*Study,* p. 236 plan by Orlandos). The new roof was supported on the new cella two-tiered colonnades and epistyles obtained by systematically dismantling a large stoa in the town (*Study,* 398 below). (This stoa also provided the columns with which the East Stoa in the Asklepieion was rebuilt).

The doors of the temple received new thresholds, new jambs and lower lintels and they were no longer as large as the original doors (*Study* pp. 138 a above, 362 right, 364, 245). The walls, antae and floor were, in many places, sheathed with marble plaques after the ruined original surfaces had been cut down to the thicyness of the plaques (*Study,* pp. 353 right, 363). The column capitals and epistyle blocks of the pronaos and opisthodomos were repaired in stucco held in place by means of iron pins (*Balanos,* pl. 55β, 65, plans by Durm). When Christianity finally triumphed the temple was converted into a church, probably in the time of Justinian. Most of the east wall was demolished and a large apse was constructed (*Study,* p. 138 a below, plan by Knowles). The western chamber, now the narthex, communicated with the main chamber by means of three newly constructed doors. Two new doors gave access to the narthex from the side colonnades (*Balanos* pl. 57 b). The SW corner of the narthex was remodelled as a baptisterion. Other noteworthy alterations include: taking down the central epistyle of the pronaos and cutting it for reuse as the base for the big double window of the apse (*Study,* p. 398 below); removing the central column in the lower colonnade at the back of the cella in order to create a large arched opening leading to the nave; walling up the intercolumnations of the outer colonnade. The late Roman roof over the pronaos was abolished; a much larger part of the roof over the main church was remodelled; three windows were opened up on the sides of the main chamber at the height of the frieze and the cross beams. Later alterations worth noting are the spiral staircase in the south part of the opisthodomos which was made higher and made over into a minaret during the Turkish period (*Study,* pp. 239, 364) and two large cisterns on either side of the apse. During the collapse in 1687 the thermally fractured marble broke off; 20% of the headers were affected, 40% of the inner stretchers and 50% of the blocks in the dividing wall between cella and Parthenon chamber. These quantitative differences in damage account for the differences in state of preservation and also explain why almost nothing is left of the blocks of the dividing wall. The two central columns of the opisthodomos suffered multiple fractures in the fire and were badly shaken by the explosion and by the later earthquakes (*Study,* pp. 209, 210 no. 3, 211; *Balanos* pl. 70). After the Venetians had withdrawn, the Turks built a new mosque (12.5 × 16.5 m., 13 m. high) in the middle of the ruin, this time with the orientation towards Mecca. In 1801-1802 Elgin's seizure of the sculpture also had ill effects on the inner building. Scores of frieze blocks were removed and many were sawed in two longwise in order to reduce the weight to be transported (*Study,* p. 398 above, the fragment in back of the geison block).

After the Acropolis had been liberated and rated as an invaluable archaeological area, a beginning was made of clearing the ruins. In 1844 the crumbling mosque was demolished, the floor was cleared and a considerable portion of the side walls was rebuilt. Some extraneous material was used in rebuilding the walls, including remains of frieze blocks (*Study,* p. 394). Wall blocks were laid in wrong positions and the inside was restored with brickwork (*Study,* p. 348γ 1,2; 349γ, 302 right). The side doors of the church were also walled up with brickwork (*Balanos,* pl. 134 above). In 1859 the last remains of the church apse were removed.

In 1872 a shallow brick arch was installed in order to support the ruinous lintel over the west doorway (*Balanos,* pls. 139-141, *Study* p. 245) and clumsy cuttings were made in the epistyle blocks in order to insert rectangular braces for the west frieze (*Study,* p. 268 above, 393 left; *Balanos,* foldout 5 fig. 3, pl. 66 above).

In 1898 the spiral stair was repaired and the work of restoration started.

In 1900-1902 momentous restorations were carried out. Three column capitals were restored in marble and two marble slabs replaced the two frieze blocks that had been removed by Elgin. The wall crown was restored with two marble blocks. Furthermore, new marble blocks were also used to replace original members which, although still in place, were thought to be ruinous and insecure (*Balanos,* pls. 76, 71-74; *Study,* p. 393 left). Six epistyle blocks and seven frieze backers. In all of the above-mentioned restorations iron was extensively used in vast quantities (*Balanos,* foldout 5). Large new cuttings were made on the upper surface of the wall crown and clamps of galvanised Swiss iron sheathed in lead were installed (*Study,* p. 248 above). In 1913 some blocks of the west wall were restored in marble (*Study,* p. 243 below, restored blocks indicated by dotting) and in 1926 a major intervention was carried out on the west door: the arch of 1872 was demolished and virtually the entire Late Roman repair was removed (*Balanos,* pls. 138, 142). The four preserved fragments of the two central backers of the ancient lintel were taken down and left on the floor of the temple where they are still lying today (*Study,* p. 247, 4 large marbles near the wall). All of the backers were replaced in reinforced concrete; the outer block of the lintel was reinforced with large iron beams and filled out with mortar (*Balanos,* pls. 142-145, *Study* 242 below, 243 below). At the same time errors of the earlier restoration in 1844 were corrected, the bricks were removed from the inner faces of the rebuilt walls and the side doors of the church were opened up (*Balanos,* pl. 134 below). In 1931 the preserved columns of the pronaos were dismantled and reset (*Balanos,* pls. 129, 132-133). The drums of column 6 that were fractured were reinforced chiefly with internal iron clamps, but also with bronze clamps (*Balanos,* pls. 130-131). Similarly the southeast anta was partly dismantled and reset. At the beginning of the 1960's many inner orthostates of the south wall were replaced with new marble (*Study,* pp. 246, 247, 392 left, 394 above); the church doors were blocked up again, this time with marble blocks copying the original masonry.

The problems of conserving the inner building are acute. The iron used in restorations, reported above, produces continuous damage, the frieze blocks *in situ* are deteriorating and are exposed to the vicissitudes of the weather (since 1977 a temporary wooden roofing protects the frieze). The condition of the central columns of the opisthodomos gives rise to serious misgivings as to their ability to support additional loads in the event that the ceiling of the west porch were to be restored in order to protect the frieze *in situ,* if in the end the decision is taken not to transfer the frieze to the museum.

Programs 5,6,7,8,9,10. Proposals

Program 5: The pronaos

Column 6 (counting from the north) to be taken down, its iron fastenings replaced, and reerected.

Conservation and restoration of the south anta.

Reerection of the other columns; 70% of the material has been located and five out of the six capitals are at hand.

Restoration of all of the epistyle blocks; 80% of the material exists.

Copies of the whole east frieze to be set in place (the originals are now in the British Museum and the Acropolis Museum).

Reerection of the cornice above the frieze, at least above the side interaxials and above the 1st and 5th interaxials in front including the corner blocks.

Four ceiling beams to be set in place, two ancient and two new ones.

Program 6: East cella wall. Pronaos, Inner dividing wall

The following work is to be done on the east wall of the cella and the east doorway:

The existing orthostates to be restored and reset and new orthostates to be made.

Restoration, conservation and resetting of the surviving wall blocks and of the anta.

Restoration of the doorwall with ancient blocks lying around and with new blocks.

Partial restoration of the south jamb of the doorway.
Waterproof covering above.
Partial restoration of the Late Roman threshold blocks.
The plan of the early Christian church apse to be indicated on the pronaos pavement.
The dividing wall. Some of the orthostates to be restored in new material for purely educational reasons. Two blocks of the first course to be set in place for the same reasons.

Program 7: North wall

Everything put up by Pittakis in 1844 to be taken down and all metal fastenings to be replaced by titanium.
The wrongly placed orthostates to be removed.
Four modern orthostates, the back halves of frieze blocks sawed off by Elgin's agents, to be replaced with new orthostates.
One hundred and sixty-four wall blocks are to be set back in place after they have been systematically reconstituted from fragments, mended up and treated for conservation.
Some of the wall cornice and ceiling beams to be set back in place.

Program 8: South wall

Everything that was reerected in 1844 to be dismantled. All metal fastenings to be replaced with new ones of titanium.
All blocks reset in the wrong places to be removed.
The orthostate blocks to be restored.
A number of wall blocks, now scattered here and there, to be reset after they have been treated for conservation and restored (up to 281 pieces could be reset, i.e. up to the eleventh course).
Waterproof coating above.

Program 9: Opisthodomos

(This work will be carried out after the ceiling beams have been removed as specified in programs 10 and 11).
A) Taking down, conservation, replacing metal fastenings and resetting:
– The cornice blocks above the frieze (2 corner blocks, 27 headers on the west and 6 on the south side).
– The ten frieze backers of new marble.
– Frieze blocks 1 and 2 (new marble).
– The new epistyle blocks: 3 above the first intercolumniation and 1 east of the fourth intercolumniation.
– Intervention on column capitals 1,2,3,4,5.
– Intervention on the top drum of column 5.
All of the work listed above involves only the area of the intervention car-

ried out in 1900 and aims to repair the damage and to eliminate risks engendered by the earlier repairs.

Further plans:

B) Two slabs of the west frieze that had previously been restored with new plain slabs to be replaced with casts of the originals in the British Museum.

C) Copies of frieze blocks from the north side (in the British Museum) to be added.

D) Modern cornice block 1 to be replaced by the ancient stone*.

E) Ancient frieze backers to replace the first two modern backers*.

F) Ancient epistyle blocks to replace the three epistyle blocks over the first interaxial*.

G) The missing part of capital 6 (at the southwest) to be restored in order to provide seating for the epistyle backers above.

H) The cuttings in the west front of the architrave (made in 1872 in order to brace the frieze) are to be filled up with new marble. At least one ancient fragment with the regula to be set back in place (it fell down before 1872) and the details of the mouldings to be carved on the modern restorations.

I) Original frieze blocks still in place may be transferred to the museum and casts set up in their place. This problem has to be studied separately.

– Weakened column drums mainly from the two central columns may have to be repaired in order to improve the stability of the portico.

The number of drums and the type of treatment (restoring the missing parts, reinforcement or replacement) are still questions being studied and correlated with Program 11.

Program 10: Opisthodomos and west wall

Two frieze blocks to be temporarily removed from the west wall.

Fifteen headers to be removed temporarily from the west wall.

The westernmost of the four great lintel beams to be treated for conservation.

The two inner lintel beams to be mended up from fragments and the missing parts restored.

The first inner lintel beam to be made of new marble.

Metal fastenings in the southernmost beam to be replaced.

For orthostates, wall blocks and wall crown blocks: treatment for conservation, metal fastenings removed and replaced, missing parts restored.

For the spiral stair of the early Christian church: conservation work; removal of blocks that do not belong to the monument.

* Conservation and consolidation of these blocks, now lying west of the Parthenon, is planned as part of the program.

The material from the Late Roman repair of the jambs of the doorway, now partly in place and partly lying around in some quantity, is to be suitably dealt with.

The broken edges of the classical jambs to be restored in order to show the evidence for the original wooden construction of the doorway.

Program 11. Ceiling over the west colonnade. Documentation

Important parts of the original ceiling are preserved in the west colonnade: complete ceiling beams, a fragment of the central beam, six complete interbeams, and a fragment of an interbeam (*Study,* p. 248 above; *Balanos,* pl. 60 B). Above the opisthodomos entablature four blocks continuing the ceiling beam course are preserved. In 1900-1902 the southernmost ceiling beam 7 was taken down and replaced with a modern marble copy because its poor condition had aroused doubts about its stability. This ceiling beam is still lying west of the Parthenon and carries a number of recent cuttings which had evidently been made with the idea of consolidating the block by means of clamps which were, however, never utilized (*Study,* pp. 248, 393 right). At the same time (invisible) iron dowels were set inside the beam (*Balanos,* pl. 75a). The colonnade ceiling also has two new interbeams of marble. The new ceiling beam and interbeams have dowels and clamps sheathed in lead. At the end of the 1950's three new marble ceiling beams were prepared: beams 1,4 and 6. These beams were left over from an earlier operation and had received preliminary cuttings in Balanos' time as old photographs show (cf. *Study,* p. 158 note 131). Other new blocks which had also been prepared are as follows: 2 interbeams, 18 coffer slabs, 3 wall crown blocks to complete the wall crown below the west side of the ceiling (*Study,* p. 248 below). None of the newly made blocks mentioned above was ever set in place, because of uncertainty as to whether the opisthodomos columns would hold up. Marble ceilings elsewhere in the temple are preserved as follows: from the opisthodomos, the two end beams and two interbeams *in situ;* from the pronaos, seven fragments of the two side beams on the ground; from the east colonnade, one beam in five fragments on the ground and another beam also fragmentary; 26 beams which rested on walls, complete or fragmentary; 11 beams which rested on entablatures (*Study,* p. 84); many fragments of the ceiling coffer slabs enabling scholars to reconstruct the coffers (Penrose, Orlandos). A recent study of the ceiling beams and other ceiling stones, both on the building and on the ground, has made it possible to assign blocks to their original positions in the top course and led to the following interesting conclusions:

A) The roof of the temple was not supported on walls as had been thought but on stout piers (*Study,* pp. 16β, 85).

B) Although the east and west colonnades have different dimensions, their ceilings have the same dimensions; the same holds true for the pronaos and opisthodomos. But the ceiling of the pronaos was somewhat lighter, conforming to the more slender columns of the pronaos.

C) Both the original and the Late Roman systems of ceiling support are preserved and distinguishable.

D) Cuttings in ceiling beams that rest on walls provide evidence for the locations of the side windows made in the church period. The destruction of the west colonnade ceiling was contemporary with the destruction of all the other ceilings of the temple and the fact that a good part of the west colonnade ceiling was preserved *in situ* should not tempt us to think otherwise. Study of the material on the ground shows that the following ceiling beams were preserved *in situ* until the building collapsed in 1687: from the east colonnade at least two ceiling beams; from the pronaos at least the southernmost beam, if not also the northernmost of which, as mentioned above, all the fragments have been recovered (*Study,* p. 451). Fragments of ceiling coffers were found in a Late Roman wall in the ancient Agora together with fragments of the original cella columns; this evidence, taken together with the evidence of thermal damage to the geison blocks and the evidence provided by the locations of the channels for draining off rainwater in the floor of the colonnade, leads to the conclusion that the ceiling coffers were removed either because they were about to collapse or because they had already partly collapsed as a result of thermal fracture. During the subsequent repair much of the pronaos ceiling, which had been more badly destroyed than the other parts of the building, was rebuilt. But in the ceilings of the colonnade only those beams which had not been touched by the fire (because they were protected by the coffers) remained. When the Parthenon was remodelled as a church the Late Roman ceiling of the Pronaos was removed except for the two end beams. They must also have removed the rest of the ceiling in the east colonnade, at least above the central intercolumniation.

The iron dowels and clamps were pried out of the ceiling beams when they were taken down. Thus most of the beams were spared the breaks caused by chopping out the iron. Some of the beams are more badly cracked, probably as the result of some very strong earthquake. In the big earthquake of February 1981 the beams of the west colonnade shifted toward the east by 2-3 cm. (*Study,* pp. 259, 334, 335).

Program 11: Ceiling over the west colonnade. Proposals

The modern ceiling beam to be replaced by the ancient one.

Ceiling beam 1, counting from the north, to be restored with the original fragments which have now been found.

Metal clamps in interbeams etc. to be replaced.

Interbeams to be restored with both ancient and new pieces and reset in place.

Both ancient and modern beams may eventually be reinforced with titanium supports.

The carving of the ceiling coffers prepared for Orlandos' restoration (circa 1958-1962) to be rectified and completed.

Waterproof coating for the ceiling and entablature. Drainage system for the rainwater.

(Program 11 needs both intensive theoretical research on the method of covering the spaces between the beams and the solution to specific static problems: a) how the columns that have been subjected to fire will stand up under pressure and b) how the whole ceiling system would behave in an earthquake after being loaded with the new marble beams and coffers. The program is contingent upon prior decisions concerning the preservation of the frieze *in situ;* see program 9).

Program 12: Crepidomas and floors. Documentation

The crepidomas are preserved virtually throughout. The only outstanding damage is along the east edge of the toichobate on the north side.

The floors of the colonnade are preserved almost complete; only three slabs are missing at the northeast corner and four near the southwest corner (*Study,* p. 236, plan by Orlandos). The floors of the pronaos and opisthodomos are preserved nearly complete.

About 15% of the cella floor and 50% of the west chamber are missing. In 1960-1963 most of the gaps in the floor were filled in with new marble paving (*Study,* p. 237). Part of the floor was left open on the south side of the cella so that the Ionic anta base from the Older Parthenon, which had been built into the floor foundations, would remain visible. During the same period blocks missing along the east and south sides of the upper two foundation courses were replaced with new blocks of Peiraeus limestone (*Study,* p. 240 below); the new material amounts to 23% of the 21st course, 51% of the 22nd course which comes to 15% of the entire south side of the stereobate. The step blocks in the middle of the east crepidoma were restored in new marble.

As was the case with the other parts of the monument, the crepidoma and the floors preserve the traces of repairs and small or large-scale alterations made in each historical period. These traces provide precious historical evidence, even if, from an architect's point of view, they also comprise damage or causes of damage. We may summarize our report as follows: in ancient times a great number of bases were placed in front of and between the columns. Not one of them has survived. But contact between the base and the monument has brought about concentrated corrosion of the marble (*Study,* pp. 312, 315 above, 317 left). The big fire in ancient times was responsible for catastrophic damage to the paving. The upper surface of many blocks was destroyed to a considerable depth because of extensive thermal fractures. Still a greater number of blocks, seemingly intact, have fractures hidden from view (*Study,* p. 354). The fire apparently ruined many of the blocks right away; this is the only way of explaining the extended shallow irregular cuttings (*Study,* p. 363), especially on the flooring of the western chamber: they must have been done in order to patch the floor with thin plaques cemented with stucco, traces of which are preserved in some of the cuttings and on plaques found both inside and outside of the temple. (The same method was used to repair the walls). After the ceilings of the colonnades were done away with the rainwater ran off the new roof onto the floor of the colonnade. The channels for collecting and draining off rain water must have been carved at this time. These channels were carved according to a far from simple system, the study of which is especially interesting. The main drainage channel is at the west end of the south side where a large settling basin has also been carved to the detriment of the crepidoma. On the floors inside the walls, especially in the cella, are a great number of markings, cuttings for dowels and other structural elements. Some of them are for ancient dedications, especially in the Roman period; others have to do with the interior arrangements and with the remodelling for the early Christian church. The building has been seriously disfigured by the many steps hacked into the crepidoma at eight points around the outer colonnade and four places around the inner building (*Study,* pp. 317 right, 361 below). The remarkable dislocations and damage at the northeast corner of the cella crepidoma resulted from the explosion of 1687 (*Study,* p. 386 below). The deep hollows on the second step of the east and south sides of the crepidoma were made by rainwater dripping from the cornice and by wear (*Study,* p. 386 above). Wear on the floor has caused serious damage. In certain places the floor has been worn away to a depth of more than two centimetres. Estimates as to the amount of damage inflicted in earlier times, particularly during the church phase, are in many cases reliable. But the greatest amount of wear has certainly been caused by visitors who, until recently, were permitted to go inside the building. The deterioration described above has dire consequences for the future of the building, mainly because it has created and continues to produce conditions in which rain water collects on the floor and crepidoma in great quantities amounting to many cubic metres. Now that the original watertight construction has ceased to exist in so many places, the water seeps down through the floor into the joints and pores of the foundation blocks. In the colonnade this process has been going on and getting worse for sixteen centuries and inside the building for three centuries. The paving has settled in one place on the north side of the cella; according to one theory this happened because rain water seeping through the floor disintegrated the soft limestone of the foundations (*Study,* p. 257). The settling, however, has occurred in one place only, a fact which strongly supports the older explanation that the foundations are not continuous at this particular spot. But here, too, water seeping down has obviously played a role in the settling process. It is not easy to estimate the amount of deterioration to the foundations caused by the phenomenon described above. In the past the settling seemed so alarming that even the curvature of the floor was attributed to settling. Josef's Durm's reaction is characteristic: he proposed installing manholes and drains below the floor in spite of the detrimental effect they would have on the temple.

Program 12: Crepidomas and floors. Proposals

Cleaning.

Conservation and restoration for the crepidoma blocks and paving of the colonnade.

Resetting blocks of the inner crepidoma, especially the eastern third of the north side.

The paving slabs inside the walls to be treated for conservation and missing sections to be restored either in marble (for the large pieces) or with a suitable type of cement (for the small gaps). The toichobate of the Older Parthenon and the cutting for the central wooden mast for the Athena Parthenos and other places in the floor are to remain open to view for teaching purposes; they will be covered with a transparent substance.

In certain places the floor will receive a protective coating.

Disiecta membra of the Parthenon

(*Study*, pp. 370-374, 378-384, 397-399)

The fallen marbles are now scattered arownd the temple helter-skelter (not in the places where they fell) and all over the Acropolis from the Propylaia to the Belvedere. The total area they occupy is larger by far than the area of the Parthenon.

But the area covered by these disiecta membra is not neutral territory. They lie on the sites of other prominent Acropolis monuments such as the Brauronion, the Chalkotheke, the site of Athena Promachos, the sanctuary of Zeus, the precinct of Pandion, the temple of Rome and Augustus, to name but the most important. The superstructures of these monuments are not preserved *in situ*. But the ground plans are preserved in foundations and in rock-cuttings of greatest scientific and aesthetic value. Architectural members are also preserved. Rock-cuttings for the bases of a great many votive offerings are also preserved. There are also rock-cuttings and foundations from the earlier historic phases of the Acropolis, from Mycenaean to archaic times.

It follows that the Acropolis rock floor itself is a monument of universal historic significance. Thus the thousands of tons of Parthenon marble lying around on the ground does not only mean that the building lacks the material belonging to it. They also create confusion and are literally stumbling blocks, preventing us from appreciating the archaeological, historical and aesthetic character of the rock itself. If the many great masses of marbl e rro themple were somewhere else the visitor would experience far less difficulty in understanding the area, the ground plans and the material from all of the other monuments and all of the other historical periods, including recent ones, such as cisterns and remains of walls. The results would be most beneficial, not least from the point of view of the Parthenon itself, (its surroundings vastly improved). But that «somewhere else» is not to be found anywhere on the Acropolis. There are remains of monuments everywhere except for one area south of the Parthenon but it is already overcrowded with marble from the temple. Unfortunately this state of affairs does not only harm the monuments and the rock. It is equally harmful to the marble blocks from the temple which deteriorate on the ground where they are exposed to the weather and to visitors. After close study we have found that there is no better solution to the problem than anastylosis, in spite of the fact that it is the hardest way. Fortunately, intensive study and theoretical preparation enables us to identify the blocks, so that they may be reset in their proper places.

After the most pressing phases of the various programs are completed, the preliminary work of putting the disiecta membra in order will be started, to be done in such a way that the blocks will be exposed to strain and deterioration as little as possible and may be easily examined. The material from the Older Parthenon will be one group, the material from the Hellenistic stoa reused in the repair another group, the material used for the church still another and so on. Depending on how much space is available south of the temple it may be possible to present samples of restored architecture «Architekturproben» with obvious practical and didactic aims (*Study,* p. 399). Eventually some of these may be transferred to suitable exhibition spaces in the (new) museum.

The work site

After the nature and extent of the operations essential to the project had been determined, the many different ways of organizing the work site were analyzed. Because of the great weights to be hoisted and transported (marble blocks up to 11 tons), the choice of lifting devices was the decisive factor in organizing the work site as a whole (*Study,* pp. 512, 514, 515). In carrying out a detailed comparative analysis of various possible types of equipment, we applied special criteria such as a high degree of safety and stability (avoiding unstable oscillations). We also kept in mind the desirability of not obscuring the building with huge pieces of equipment while work is in progress (*Study,* pp. 531, 532, 533). In order to determine how the Parthenon would look we compared photomontages in which the various kinds of lifting equipment, scaffolding, portal cranes of various types are shown in and around the building (*Study,* pp. 535, 537, 539, 541, 543).

Analysis of the technical and aesthetic aspects indicated that an electrically operated crane of the stiffleg derrick type would be most suitable; it will run on tracks inside the temple and will be able to reach all sections of the operation (*Study,* pp. 565, 566, 567). When the crane is not in action the boom will be lowered so that the presence of the crane will be barely noticeable. The entire work site will be on the south side and only on that side (*Study,* pp. 517, 518, 519). A low portal crane of ten tons allows the area ($80 \times 10 \times 2^1/_2$ m.) where the marbles are collected to be used to the best advantage (*Study,* p. 570). The roofed workshops are sited in the eastern half of the work site and are served by one extension of the portal crane (*Study,* p. 580). Special attention has been devoted to the design, material and colour of the roofed workshops so that they will be as inconspicuous as possible. An electrically operated fork lift truck for rough terrain, capacity $2^1/_2$ tons, will be used for horizontal transport outside the work site and in certain cases a hand-operated chain hoist will be used (*Study,* pp. 514, 570). Iron tracks connect the work site to the southeast corner of the Akropolis where there will be a collapsible crane (chosen for aesthetic reasons), capacity ten tons, with which it will be possible to hoist large loads (such as marble blocks, machinery, sections of the crane) from below up to the Acropolis (*Study,* p. 568). An automatic electrical-hydraulic device will take care of the more routine operations in producing copies, thus allowing the marble workers to spend their time in a more creative way. The equipment for marble working will include all of the traditional tools and also electrical devices. Also hydraulic and mechanical jacks, marble tongs, wagons etc. (*Study,* p. 569). Access to the upper parts of the building will be effected by means of towers consisting of aluminium tube scaffolding with intermediate levels, ladders, supports, rollers etc. (*Study,* p. 518). The crane is able to move the towers from one point to another with great speed increasing the efficiency of the towers to such a degree that only three to six towers will be required to handle several programs simultaneously (*Study,* p. 567). For the duration of the entire project the floor of the temple will be covered with a protective layer. The various components of the protective layer, the rails and the parts of the crane will be conveyed to the interior of the temple by means of a temporary tube scaffolding placed in the middle of the south side (*Study,* p. 578).

APPENDIX

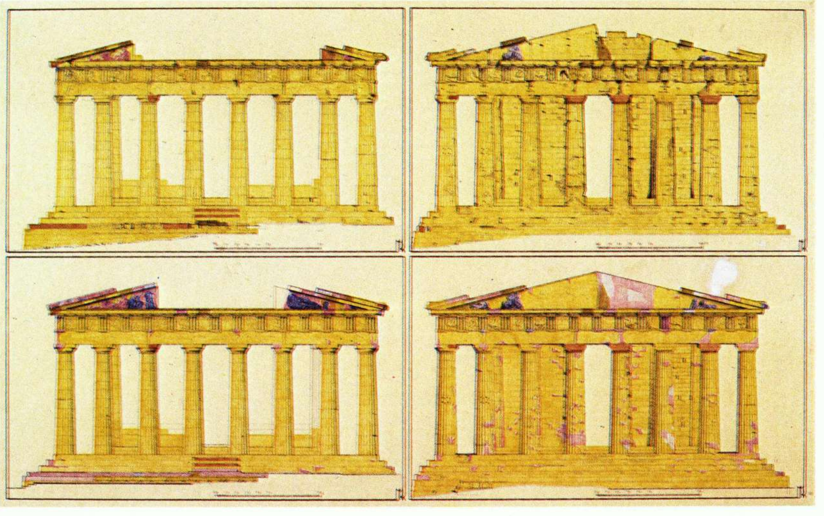
A consideration of the tectonic and plastic character of the Parthenon as in a half-finished state, as completed, as a ruin and as restored.

The perfection of the carving of the stones of the temple surpasses even its legendary fame; to understand this one has only to be in a position to observe details which, at a superficial first glance, are not revealed. The perfect jointing, called *ἁρμονία* by the ancients, is an essential value of the architecture. Essential, because many architectural forms as, for example, the columns or the cornice, are traditionally considered to be indivisible units and therefore monolithic, at least in concept. Because of their huge size they were put together out of more than one blocks, but only under the condition that art would provide a substitute for the ideal monoliths by means of matchless *ἁρμονία,* that is to say with jointing so perfect that one does not see it. The columns and other units of the building did not receive their final forms and surfaces until after they were in place in the building. Thus the carving of these architectural units is in every way comparable to the carving of a piece of sculpture, with the result that they have a closed compact, fully three-dimensional form by virtue of artistic self-sufficiency; they also have the quality of plasticity both because of the general form and because of the unbroken continuity afforded by the jointing. This is the famous and much-admired plastic quality of Doric architecture and in particular of Doric columns. Painting the columns, walls etc. only so as to conceal the joints would have been unnecessary, but using several pieces of marble to assemble a single unit inevitably involved uneven colouring and the final dressing of the stone gave it its blindingly white glare that was visually undesirable. Therefore painting the completed building is definitely not incompatible with the magnificence of the marble; apart from the influence of the tradition of polychrome poros limestone architecture, painting the architecture is fully justified on its own as a desirable creative finishing touch. The final product is nothing else than the result of a *μεταμόρφωσις*. The individual blocks composing the architectural units are set in their final positions before the last stage of carving is completed. When the blocks are set in place on the building they all still have an extra layer of thickness, a protective mantle, allowing leeway for the final carving and smoothing. Furthermore, the protective mantle is itself protected by another outer layer. The ancients called these two extra layers purposely left on the blocks *ἄπεργον*. The German equivalent is *Werkzoll*. As there is no equivalent English term we will borrow the Greek word and speak of *ἄπεργον*. On two of the four edges of the front surface of the block the *ἄπεργον* was bevelled in order to avoid breaking the edges when setting the blocks into place. After the blocks were in place the bevelled edges had the following aesthetic effect: the horizontal and vertical joints were outlined in shadow so that each block stood out separately. In addition there were other strong accents as follows: the penultimate *ἄπεργον* over the final *ἄπεργον* on the columns and the orthostates of the walls; the bosses, one or two on each block, setting up a rhythm of their own; the special dressing of the face of each stone with the point to produce a pattern of shadow and neutralize the white glare and with margins because the point was not allowed to come within a certain distance of the easily broken edges. The joints followed a special system, that of the structural composition of the building. The system of emphasized joints together with the margins, the apergon, the bosses, the various tool marks etc. all served to set off the individual blocks as component lines of the building, thus creating the other much admired quality, the tectonic character of the building.

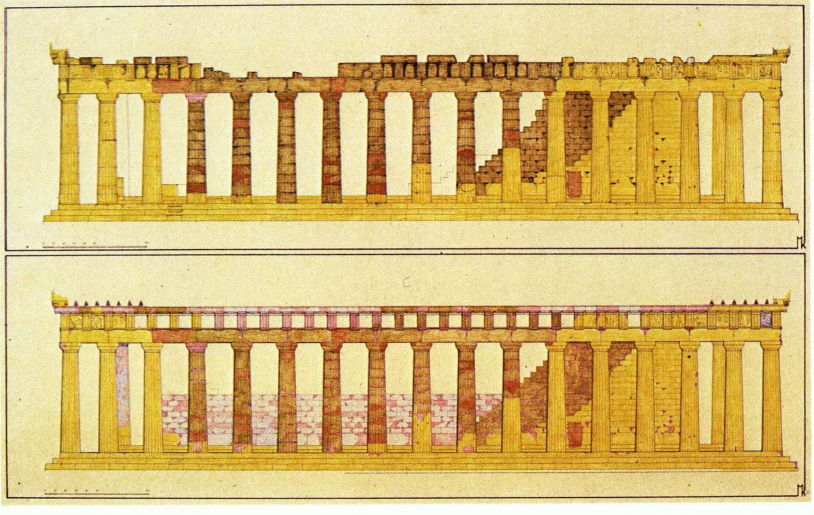
With the completion of the building the plastic quality took over without, however, entirely displacing the tectonic quality, which continued to be expressed in the general relations of unit to unit: epistyle to column, triglyph to epistyle etc.

Another aspect of the tectonic character, the jointing system, was no longer to be seen after the building was completed insofar as the joints withstood the onslaught of time, but in the course of centuries they gradually reappeared as natural and other forces attacked the building, causing the joints to open up, simultaneously destroying the paint and revealing the natural texture of the individual blocks: one more metamorphosis in the series of metamorphoses, lasting a long time and not a work of art but rather a product of the environment. Today all of the blocks may be separately distinguished because of corrosion, damage and the opening up of the joints. The original tectonic character of the building has reappeared and competes violently with its plastic quality. The logic of the structure emerges much more strongly than was originally intended, along with the ideas of form and rhythm. If we accept that the deterioration of the jointing and the plastic quality are in some way inevitable, then we are obliged to admit that the reappearance of the tectonic quality is a very rewarding compensation. It is clear, however, that the balance must not be changed beyond certain limits. If the factors creating the plastic values are further diminished and if the numbers of widening joints and worn off edges and uneveness in colour were to increase as a result of new material or atmospheric deposits, the consequences for the Parthenon as a work of art would be dire. It is clear that whereas on the one hand the joints and the increasing uneveness in colour affect both aspects of the building in a way that, to a certain degree, balances out, on the other hand certain anomalies in form and the many injuries to the marble have a catastrophic effect on both aspects, but still worse on the plastic quality of the building.

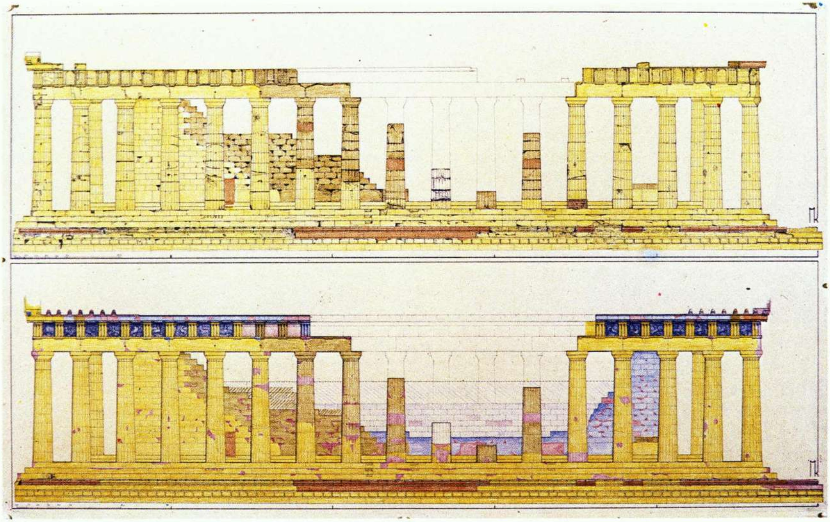
The form of the reerected columns and the reerected sections of wall are a general example of damage to the jointing. The form resembles the original form only in the main lines, dimensions and proportions, but it lacks the basic property of continuity that is decisive for the plastic quality. Many blocks and column drums have rounded horizontal edges, an intrusive feature characteristic of other kinds of architecture in other periods. Penrose warned about this deficiency many years before Balanos' restoration; at that time the columns reerected by von Klenze and Pittakis served as examples. We recognize this deficiency today and we are particularly concerned with both the theoretical and practical side of the problem as it relates to anastylosis. We think that the value of the plastic character requires greater care in restoring continuity than was shown in earlier restorations and therefore we recommend completing injured blocks first by using original fragments as much as possible, insofar as they are preserved and identified, and secondly by using new material. This work is necessary in the case of large gaps for static reasons. In the case of the smaller gaps it is optional and will proceed with due caution. The injuries to the west façade were caused mainly by the bombardment of 1687, and what we have said above about the large and small gaps holds good. Healing these wounds with any means at our disposal does not, in any event, endanger the tectonic character of the building, because in its present state it is so far removed from the original jointing system and from its original plastic character.



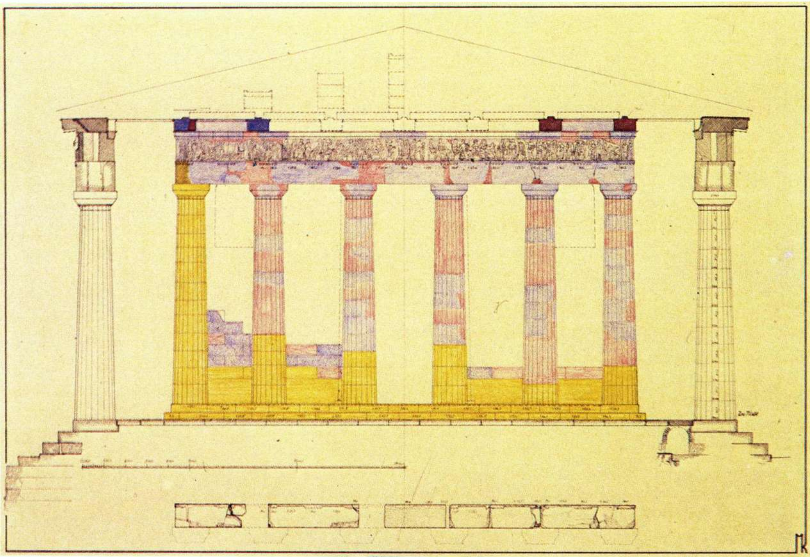
1. Parthenon: East facade: actual state of preservation (above) and proposed restoration (down). West facade: actual state of preservation (above) and proposed restoration (down). (see index of colours p. 126)



2. North colonnade: actual state of preservation (above) and proposed restoration (down). (see index of colours p. 126)



3. South colonnade: actual state of preservation (above) and proposed restoration (down). *(see index of colours p. 126)*



4. The Pronaos: proposed anastylosis. (see index of colours p. 126)

INDEX OF COLOURS

Parts in situ (parts of limited dimensions which during previous restorations have been dismantled and immediately put back to place on the monument are not differentiated).

Original material in previous restorations.

New material added in previous restorations.

Copies of the sculptural decoration of the monument and of architectural members now in the British Museum.

Original material to be reintegrated in the proposed restoration.

New material proposed for the completion either of the architectural members (in situ or previously restored) or of the more extended parts of the monument.

Copies for the substitution of the sculpture which is proposed to be provisorily removed or of the sculpture actually in the British Museum.

THE PROBLEM OF THE PARTHENON'S EARTHQUAKE RESISTANCE

TESTING THE EXISTING SITUATION AND THE RESTORATION PROPOSALS IN A STAGE OF PREPARATORY STUDY

C. ZAMBAS

1. Introduction

The extent and the seriousness of Parthenon's structural damages that make an intervention inevitable have been discussed in detail in the main part of this study. In the following text and the accompanying calculations an attempt is made to set the problem of Parthenon's earthquake resistance within the framework of the introductory study about the restoration of the monument. The partial subjects that have to be considered are the following:

a) The possibility of the monument in its existing state, to safely withstand the loading caused by a design earthquake, probabilistically derived from the seismological data of the region and with respect, at the same time, to the unique importance of the monument.

b) The consequences to Parthenon's earthquake resistance of the interventions suggested for other reasons, such as replacement of the dispersed material aiming to the monument's rehabilitation.

c) The formulation of proposals for possible interventions that do not stem from the architectural-archaeological part of the study, but whose necessity is exhibited by the earthquake resistant inspection and which should by all means respect the principles demonstrated in chapter Δ of the *Study for the Restoration of the Parthenon.*

In relation to these aspects of the problem, the following general remark should be made: while for the inspection of a modern structure the seismic history of the region is the basic criterion for the determination of the expected seismic actions, in the case of a monument 25 centuries old its uptodate behavior under seismic actions is a source of information about the seismic history of the region. By the end of the last and the beginning of this century, seismology has utilized observations on monument behavior for the derivation of seismological conclusions[1-3], while recent research in earthquake engineering[4] using probabilistic analysis methods has arrived at more reliable estimates of seismic intensities by making use of such observations. Of course, Parthenon's satisfactory behavior under seismic actions for 25 centuries, even if no considerable changes of the seismicity of the region have occured, may not by itself be considered as a safe criterion of a satisfactory behavior today. During the various phases of the monument's history, radical alterations have occured concerning the general geometric configuration, the interconnection of the structural members and the state of the materials, which all impose the use of analytical and experimental methods for the determination of its earthquake resistant capacity.

The importance of the monument's behavior under seismic actions during its various phases is greater for decision making with respect to points b and c mentioned above. While the history of the monument pleads for the restoration of parts of the temple, in a structural sense (members strength restoration, connections strength restoration, replacement of architectural members, etc.), it makes us very cautious over possible serious interventions for the strengthening of the ruins. Interventions of such a nature could be considered only after a very exact analysis of the monument, always from the point of view of the good restoration practice and of the generally accepted principles.

However, in the case of Parthenon, as with the rest classical monuments having similar structural characteristics, an exact dynamic response analysis is exceptionally difficult, as it will be shown later. Since no such a method of analysis is available at present, the linear method with equivalent static loads will be employed. This method, as it will be seen later, provides useful conclusions, compatible with the symptomatology of the monument's damages and is a first measure for the evaluation of the restoration proposals. The static method is a first indispensable step that should necessarily be followed by others as is diagrammatically suggested in the last part of this text.

2. Earthquake response characteristics

2.1. Characteristics of the structural system

The bearing structure of Parthenon is composed of bulky structural members of Pentelic marble. The visible surfaces and the surfaces of support of the members are most carefully hewn, assuring a continuous contact across the horizontal joints and along the edges of the vertical joints. On the vertical bearing members, columns are composed of freely supported drums and walls are composed of stoneblocks in courses, interconnected within a course through iron clamps and connected to stoneblocks of neighboring courses through iron dowels. The horizontal structural members of the entablature and of the ceilings, as a rule, are also connected among them and to the vertical members of the load bearing structure, with clamps and dowels. The clamps and the dowels are surrounded by a layer of cast lead. An analytic description of the monument's structural characteristics along with valuable data for the structural analysis of the monument are to be found in the main part of the *Study for the Restoration of the Parthenon.*

The most important characteristic of the structural system that distinguishes it from the usual contemporary or traditional structures in regard of response to dynamic loadings, is the free support of the partial architectural members. In particular, between the column drums the only existing constraint is friction liaison. As a result, when horizontal loads are exerted between the column drums no tensile stress can develop and the maximum shearing force that can be sustained is friction. In Fig. 2.1 the simple case of a freely supported column under the action of horizontal loads of various magnitudes and the relevant stress regimes at various levels are depicted.

For horizontal forces of small magnitude, the normal stress σ distribution over the joint surfaces is trapezoidal and the shearing stress τ distribution is parabolic. If the relation $\tau \leqq \mu\sigma$ holds true everywhere, μ being the friction coefficient, the column behaves elastically and the relation between horizontal load-deformation is linear everywhere. For horizontal forces of larger magnitude, equilibrium of the column can be attained only with the assumption of a neutral region with respect to normal stresses. For an elastic behavior of the material, the boundary of this neutral region is assumed to be linear. The relation $\tau \leqq \mu\sigma$ holds true in this case, too.

When the overturning moment exerted on the column exceeds the restoring moment, overturning occurs. In the case of static loads exerted, the column will collapse. However, when a dynamic loading, such as an earthquake, is exerted, restoration of the column to its original position followed by overturning towards the opposite direction and so on, is possible. It is also possible that sliding restitution and so on might occur. The «overturning – restitution» oscillation of a freely supported body was first theoretically studied in the beginning of the 60's[5-6].

The basic conclusions of those first investigations[5] are the following:

(a) The equation of motion of a freely oscillating, freely supported absolutely rigid body, seated on an absolutely rigid base is:

$$\ddot{\varphi} - p\varphi = p^2\alpha, \text{ having solution the } \varphi = \alpha - (\alpha - \varphi_o)\cosh pt \qquad (1)$$

where $p = \sqrt{\dfrac{Gl}{\Theta}}$

Θ is moment of inertia about A and

φ_o is maximum deflection from vertical (Fig. 2.2)

(b) The period of oscillation depends on the maximum deflection from the vertical and is given by:

$$T = \frac{4}{R}\cosh^{-1}\frac{1}{1-\dfrac{\varphi_o}{a}} \qquad (2)$$

(c) During the oscillation and after each pounding, there is an energy dissipation depending on the restitution coefficient which, in the case of slender bodies, is given by:

$$e = \frac{\varphi i+1}{\varphi i} = 1 - \frac{ml^2}{\Theta}(1 - \cos 2\alpha) \qquad (3)$$

(d) For forced oscillations of slender bodies, due to earthquake which is represented by a sequence of pulses and by employing an energy method[5], it is found that the condition for collapse to occur with a 50% probability, is

$$r = s_v \sqrt{\frac{H}{g}} \qquad (4)$$

where S_v is the value of the seismic velocity response spectrum.

(e) The required width of support to have a probability of collapse less than 50%, for a given S_v, does not increase linearly with height as would result from a static loading, but it is affected much less. Consequently, the stability of slender bodies of great height is larger than others, regarding bodies of less height but with the same height over support width ratio.

In Figs 2.3 and 2.4 the forms of the T-φ_0 graph and of the free oscillation as a function of time are given.

To the present, during the development of the relevant research, the equation of motion of a free supported body using the accelerogram of an earthquake as a dynamic input has been formulated and solved and the results have been compared with experimental ones derived from experiments on a shaking table[7]. Moreover, a convenient approximating technique for the estimation of the maximum deflection has been proposed. This technique involves the use of a tripartite response spectrum and simulation of the free supported body by a single-degree-of-freedom elastic system[8]. Finally, the motion has been fully studied for all of its possible forms (sliding, rotation, sliding and rotation, horizontal translation with a jump, rotation with a jump) and by introducing the conception of the tangential restitution coefficient, that is the dissipated energy during the tangential pounding[9].

A basic conclusion of the analytical and experimental research is that the motion of a freely supported body is intensively non-linear and extremely sensitive to variations of the restitution coefficient, which obviously depends on the material when we overstep the assumption of an absolutely rigid body, and of the supporting conditions where slight irregularities may alter the image of the motion. The analysis is even more complicated when we consider the scheme overturning-restitution as a partial case of the phase during which a region of the supporting section is neutral[10,11]. The relevant analysis has been conducted assuming an elastic base but a rigid supporting plate of the overlying structure.

All researches above regard the study of the oscillations of an isolated body of rectangular cross-section, moving on a single plane. It is obvious that the analysis is manifoldly difficult when we encounter an assemblage of freely supported bodies interconnected through other overlying members, as is the Parthenon's case. A recent publication[12] expands to the study of two or more monolithical piers of rectangular cross-section, connected with overlying beams, when a free oscillation or a forced motion due to earthquake is taking place in the plane of the structure. The beams are considered independent of one another (Fig. 2.5). In this study an analytical solution is given and experiments on a shaking table with a sinusoidal relation between displacement – time as a dynamic input, follow. The friction response on the supporting surface is also considered.

In the case of Parthenon, the system peristyle -entablature is a space frame. A linear analysis is valid to the degree that no neutral regions appear at any place (column joints, column-entablature joints, entablature joints). For instance, on the column joints, there are 3 moments and 3 forces T, My, M_z and N, Qy, Q_z applied (Fig. 2.6). The condition for no neutral region to exist is

$$c = \frac{\sqrt{My^2 + Mz^2}}{N} \leqslant 0{,}25\ r \qquad (5)$$

The shearing stresses developing on the joint due to Qy, Q_z, T, should be withstood by the friction liaison. That is,

$$T_Q + T_T \leq \mu\sigma \qquad (6)$$

If one of the relations (5) or (6) is not true, then a neutral region with respect to normal or shearing stresses appears, not necessarily with respect to both. For instance, a neutral region of shearing stresses may appear, not simultaneously being a neutral region of normal stresses. The significance of the presence of joints on the columns and their effect on the column stiffness is illustrated in the example of section 6.1.

For static lateral loading, if the peristyle is considered as a space frame, the columns stiffness is affected by the external loading (appearence of a neutral region or not) and the columns stiffness in turn, affects the distribution of the internal forces over the members of the structure. That is, even though we consider an elastic behavior of the material, the behavior of the structure is not linear.

For a dynamic loading, the changing stiffness of the structure affects the external loading as well. A relevant study regarding the behavior of a rigid body on elastic base with six degrees of freedom and utilizing a finite elements partition of the circular supporting plate for the determination of neutral regions of normal and shearing stresses, is reported in 13.

In case overturning occurs at some places, we can make the assumption of an absolutely rigid bodies assemblage, whose oscillation is governed by the laws of motion of a freely supported body. This assumption is very close to reality since elastic deformations are very small compared to the geometric displacements. In Fig. 2.7 the vibration mode of a column when shearing deformation is dominant (e.g. motion of a portion of the peristyle along the longitudinal direction), is illustrated. The system has 36 degrees of freedom for a planar motion.

2.2. *Initial and present state*

The previous discussion regards the response characteristics that result from the structural system. However, the characteristics of materials and its present state compared to the initial state are of great importance for the analysis of the monument.

The initial state of the monument is characterized by the perfect quality of construction, as it is presented in detail in the main part of the *Study.* Of course, the quality of construction is of decisive importance for the strength of the structure and it is possible to simulate it exactly utilizing an analysis model, to the degree that no malworkmanships, inhomogeneities etc., exist. A basic problem, even for the initial structure, is the inhomogeneity of the main building material, the marble. In addition to the geological stratification of the material, there are locations with serious discontinuities, not always easy to detect, and which are locations of reduced strength. A possible failure in such a location may affect significantly the seismic response of the whole structure.

The clamps and the dowels are made of iron and even though experimental results on their mechanical properties are not to the present available, it is reasonable to assume-regarding the technology of that era- a considerable variance of their values. What is of major importance for the connections of the architectural members is the use of cast lead as a filling material in the gap between the clamp or the dowel and the cutting on the marble. Lead has an extended plastic region in the σ-ε graph, allowing the plastic deformation of the connection before its failure. In other words, lead offers to the connection ductility, a very useful property for the good seismic behavior of the structure.

The general form of the bearing structure in its initial state is composed of a stiff core – the secos – connected through a strong coupling structure and marble ceiling to the six columns of the pronaos and the opisthonaos respectively, to the 46 columns of the peristyle which are arranged in parallel to the secos sides and are linked together with a strong coupling structure of the temple's interior. The arrangement of the vertical bearing members is symmetric about the major axis of the temple and approximately symmetric about the transverse axis. Obviously this arrangement conforms to the current provisions for an aseismic arrangement of the bearing members. The diaphragmatic connection of the peristyle columns to the secos-pronaos-opisthonaos system is assured by the marble ceiling of the porticos, composed of transverse marble beams and coffer slabs as well as of the timber roof of the temple. The diaphragmatic performance is partial, since the horizontal members are not anchored in the vertical ones but they cooperate through friction.

The temple is excellently founded on solid rock and the foundation is composed of successive courses of stoneblocks with well hewn support surfaces. Geologic research[14] and the absence of deformation on the stereobate as well, show that the superstructure's foundation conditions are excellent. This fact is a considerable advantage in terms of the earthquake – resistant behavior of the temple, as much in its initial state as in the present state.

The present state of the bearing structure and of the structural members is radically different from the initial state. The existing 42 columns of the peristyle are interconnected with parts of the entablature of differing sufficiency and connected to the preserved east portion of the secos and of the east porch with only 4 beams. The structural members bear a number of cracks, the joint-gaps of the superstructure have opened, the ties have rusted to the extend that not only do they fail to fulfil their connective purpose, but they also cause dangerous cracking to the neighboring marble members. In addition, during the Balanos restoration, column drums of different material have been used. The locations, the type and the reasons of the damages are described in detail in the main part of the study.

2.3. Conclusions from the damages record of the Monument

Damages of decisive importance to the Parthenon were caused by the great fire and the explosion of Sep. 26, 1687. It is therefore extremely difficult to distinguish those deformations that are probably due to strong earthquakes that have eventually struck the monument until now. To separate the damages due to earthquakes requires a combined archaeological, historical and structural research. From this aspect, the remark referred to in chapter Γ.5 of the *Study* for the NE corner of the entablature is of major importance. Beyond the great disasters that have been historically confirmed as due to the 1687 explosion, we consider as characteristic damages, induced by major lateral forces, without being able to figure out whether they are also due to the explosion or previous causes, the following:

a) Rupture of all four corner architraves of the temple.

b) Rupture of the projecting parts of the column caps of the peristyle's four corner columns as well as of some other columns. These characteristic damages show the particular sensitivity of the peristyle's corners. This same effect was confirmed after the great tremors of February 24 and 25, 1981.

The epicenter of the above earthquakes lay on the Alcyonides islands (38.14°N, 23.00° E), 65 km away from Athens. The main shock of Feb. 24, 1981 was of magnitude Ms = 6.7 and the main aftershock was of magnitude Ms =6.4[15]. The most important consequences of the earthquake on Parthenon are illustrated in Fig. 2.8 which has been prepared on the basis of measurements and observations by the architect M. Korres and by the speaker. In brief, the consequences of the earthquake are as follows:

a) On the entablature:

Opening of the joint gaps along E-W direction of the north and south parts of the entablature, near the four corners. At the NE corner, the joint between the NE architrave and the first architrave of the N. side which already had an opening of 12.5 mm width below and 20.5 mm above, attained an additional opening of 21 mm below and 36 mm above. At the SE corner the corresponding joint opened by a magnitude of 10 mm (M. Korres' measurements). It must be mentioned that in both places the architraves are not interconnected since the ancient clamps are destroyed.

In the regions near the NW and SW corners the entablature's rupture showed up on the joints between the first and second architraves above the columns next to the two corner columns. In both cases the joints have a gap of 6 mm width (Fig. 2.8). In the region located by the NW corner it was observed that the bronze tie placed there after the Balanos restoration to fix in place the frieze, had broken approximately at midlength. It is noted that this is the first time, at least during the recent time period of systematic studies on the Acropolis Monuments, that a tie has been observed to have broken as a result of purely mechanical strain, and this effect is characteristic of the intensity of the stress regime developed in that region.

Finally, a southward rotation of the 4th from the East, span of the south side with its center on the east joint, was observed.

b) On the peristyle's columns, the following were observed:

A clockwise rotation of the two first column drums of the SE column with its center at the south edge of the supporting surface. On the second from the SE corner, column of the east side, westwards displacement of a previously cut-off piece of the 10th drum. On the 4th column of the east side, an anti-clockwise rotation at the lowest supporting surface, with its center lying near the north edge of the supporting surface. The NE column exhibited a south-westward displacement and a rotation on the vertical plane. The NW column exhibited a clockwise rotation with its center on the N. edge of the supporting surface. The first drum of the SW column exhibited a NE-ward displacement and the first drums of the two neighboring columns of the west side exhibited an eastward displacement.

c) At the beams of the ceiling of the west wing, eastward displacements of magnitudes about 35 mm and 25 mm appeared (measurements by M. Korres).

From the above description it becomes apparent that the four columns of the Parthenon were particularly strained. In this regard, we consider that the deformation magnitude depends on the local conditions at each place, such as the non-existence or connection at the NE corner and the locally reduced entablature's stiffness, in addition to the dependence on the general lay out of the structure.

The effect of overturning did not seem to have occured anywhere but only in the case of the NE column. A piece had been cut off the lowest drum due to stress concentration on the outer region of the drum's supporting surface. The surface of rupture coincides with the surface of a flaw inside the drum.

3. Linear static analysis for lateral loads

3.1. Assumptions – structure's modelling – results

As previously mentioned, the behavior of the monument under the action of large seismic loads is intensively non-linear. Since there is no directly applicable analytical method for a non-linear analysis, we thought that it would be useful in a preparatory study to proceed with a static linear method of analysis in such a way that its application conditions would not be violated. The monument is analysed in its present state and in the state which will result after the implementation of the restoration proposals and its completion with the dispersed architectural members and with the members of new marble. The consideration of the consequences of the restoration proposal is necessary because, beyond the restoration of the existing architectural members on the monument, and of the members supporting and connecting conditions, this proposal provides also for the addition of new members that apparently alter the behavior of the structure. The monument is also analysed for the case of having the peristyle completed by restoring the four columns of the S. side and the corresponding part of the entablature since a relevant proposal[16] has been stated in order to increase the monument's stability.

In all three cases the peristyle was studied, independently of the opisthodomos part to which it is connected through the four remaining beams of the west wing's ceiling. At the places these four beams are supported on the entablature, we assumed that vertical forces of half the beams' weight and horizontal forces equal to the vertical multiplied by the friction coefficient are exerted on the entablature. This assumption corresponds to reality since, as previously mentioned, the west porch's stiffness is considerably greater than the stiffness of the peristyle, so that a slight transverse displacement of the peristyle results in sliding of the four beams of the ceiling.

The peristyle was studied as a space frame. For the determination of the overall dimensions and of the members' sections of the bearing structure, the drawings and relevant measurements from *The Architecture of the Parthenon,* by A. Orlandos, were used. To attain a simpler description of the structure, the following simplifications were made:

a) The columns were assumed vertical, of uniform base diameter 1.85 m and with a diameter of 1.39 m at the hypotrachelion supporting surface, with the exception of the four corner columns which were considered as having diameters of 1.89 m and 1.42 m respectively. That is, an average meiosis was taken into account for the columns and not the entasis. The echinus was considered as truncated cone with its large base inscribed in the abacus, which was assumed to have average dimensions 2.03 × 2.03 m for the inner columns and 2.06 × 2.06 for the corner columns.

b) The stylobate was assumed horizontal and the height of columns uniform. The average distance between columns was assumed 4.30 m for the intermediate spans and 3.70 for the corner spans.

c) The cross-section of the architraves (1.77 × 1.35 m) was assumed as the effective cross-section of the entablature for the long sides, since the overlying members are not sufficiently fixed together to be considered contributing to the stiffness.

d) The complex cross-section composed of the architrave, the frieze and the cornice was taken into account for the small sides and the W. end of the N. side. It was also assumed that the members of the west side's pediment do not contribute to the transverse stiffness of the entablature since they are located at the center of the section and they are poorly connected. These members were assumed as overlying dead loads approximately uniformly distributed along the east part of the entablature (Fig. 6.2). The beam-column panels were assumed completely rigid, which is a necessary assumption in the case of a complex cross-section.

e) The elements of the structure were assumed as being composed of discrete members simply supported or interconnected with clamps and dowels but the knitting of the members was assumed undisturbed. That is, the openings of the joints, the irregularities of supports, the local ruptures of the members and the rest disturbances of the bearing structure were not accounted for.

The lay-out of the idealized bearing structure is shown in Fig. 3.1. and the method of modelling the structure is shown in Fig. 3.2. Of the previous assumptions-simplifications, we consider that only the last one is a serious modification of the present real state of the structure. Therefore, while the idealized form of the structure corresponds to the present general geometry of the structure, it also corresponds to a stage where the local disturbances of the members connections have been restored.

For the idealization of the structure in the stage after the restoration proposal and for the case of the peristyle being completed (Fig. 3.3), respective assumptions were made. The restoration proposal, beyond the removal of the damage causes, the restoration of the integrity of the members and the completion of various members with new marble, provides also for the restoration of the entablature, hence and of its integral cross-section and stiffness, by using the dispersed material as well as members of new marble.

A basic prerequisite for the linear analysis method to hold is that the stress regime at each joint, as it results from solving the structure for a given load, will not produce a neutral region with respect to normal stresses and that the friction liaison will be capable of bearing the shearing stress developing on the joint. Naturally, this condition holds only within a certain scale of lateral loading. From first trials it was found out that this condition is approximately satisfied for horizontal loads uniformly distributed over the mass of the structure and equal to 4% of the dead loads at every place. This load is the design seismic load imposed by the present Greek Earthquake Resistant Code to check structures in the vicinity of Attica and for good foundation conditions. Of course, this load as well as its specific manner of distribution do not correspond to the loading produced by a real design earthquake resulting from the region's design spectra[17] and allowing for the unique importance of the monument. However, it has been used in a stage of preparatory study, since the purpose of the analysis is a first approximation of the stress regime induced on the monument by lateral loading, in the phase of linear behavior of the structure's members.

To resolve the structure (present state, restoration proposal, peristyle's completion), the STATIC computer program (Institut für Informatik ETH Zürich) was used. The solution was made for dead loads and for four combinations of the structure's weight with lateral loads ($\varepsilon = 0.04$) along directions $\pm$ x and $\pm$ y (Fig. 6.4). By using a subprogram of this program, the sectorial properties were computed in advance of each solution. Especially for the determination of the sectorial properties of the entablature's complex cross-section, a finite elements program under the title SASA (Sectorial Properties Stress Analysis), (Fig. 3.4), was employed. The marble was considered homogeneous material (density $p = 2.71$ Mpm^{-3}, modulus of elasticity 4.3×10^6 Mpm^{-2} and Poisson coefficient $\mu = 0{,}20$).

Following, the distribution of the most characteristic sectorial properties over the members of the structure is given, in a diagrammatic form. In each diagram the distribution of these properties is shown for all three cases (Existing state, Restoration Proposal and Completion of Peristyle), so that comparison be possible.

The distribution of the eccentricity of the normal force exerted on the supporting surface (base) of the columns is given in form of diagrams. The eccentricity is calculated by the formula $c = \dfrac{\sqrt{M_y^2 + M_z^2}}{N}$ and is everywhere compared with the limit value $C_{cr} = \dfrac{r}{4}$ beyond which a neutral region of normal stresses appears. The representation of the eccentricity variation was preferred rather than the representation of the forces and moments variation since, as it can be seen in Sect. 6.1, even for a large eccentricity the developing compressive stress due to N, My, Mz is relatively small. On the contrary, the eccentricity is needed to check the assumptions of the calculation and is an indication for the places where a neutral region first appears and, probably but not necessarily, overturning is exhibited for larger loadings.

The distribution of the eccentricity of the normal force exerted on the hypotrachelion supporting surface is also presented in a diagrammatic form. The eccentricity on the columns, which deform according to the shearing pattern, is at this location greater as compared to the eccentricity at the base, because while the bending moment is large, the normal force is reduced by the weight of the column.

Next, the twisting moment distribution diagrams for the peristyle's columns are presented. Twisting moment combined with N, My, Mz and Qy, Qz results to the horizontal rotation of the columns. It is noted here that even if no neutral region is present regarding the normal stresses, a shearing stresses neutral region may exist and due to this fact the torsional stiffness, therefore the stress distribution over the structure, too, may be affected.

Finally, the diagrams concerning bending moments My and Mz and the twisting moment on the entablature are presented for three different cases with respect to the structure and for four cases of loading.

On the basis of the above results inspections of the following critical locations have been performed: base (lowest supporting surface) of columns, hypotrachelion and entablature supporting surfaces. At the base and the hypotrachelion of the columns the assumption of linear behavior was checked as well as the sufficiency of the friction and the maximum compressive stress. At the beam-column joints which are subject to triaxial stress, especially near the corners, the assumption of the analysis, the sufficiency of friction and of the entablature's member connections were also checked.

Because the sharp peaks of the diagrams at the support positions do not correspond to the actual stress regime of the beam-column joints, cross-sections of the entsablature at both sides of the column capital and at the boundary between the column capital and the entablature were considered and the internal forces at these locations were computed. Following, for the case of the entablature's complex cross-section, the internal forces were distributed over the discrete parts of the entablature and from the equilibrium of each part, the stress regime on the joints and the forces withstood by the connections were deduced. The resolution of the beam-column joint is illustrated in Fig. 3.5.

For the analysis of the stress regime on the partial elements of the complex cross-section, the simplified theory of bending was used to deal with bending moments and the finite elements program SASA to deal with shearing forces and twisting moments. Based on the shearing stresses distribution over the parts of the cross-section, the internal forces N, Qy, Qz, T, My, Mz were determined for each part. The determination of the forces sustained by the connections was derived from the six forces developing on the member joints, with the assumption, that the cross-sections remain plane.

3.2. Conclusions

From the normal force eccentricity diagrams it is concluded that the assumption of linear behavior under the given loading is not in general violated in all three considered cases. In the case of a restored monument, while the moments at the critical locations under consideration (base and hypotrachelion) appear to increase, the normal force also increases resulting thus in a small, as a rule, change of the eccentricity.

The inspection of stresses on the surfaces shows that the normal stresses are very small and that the shearing stresses are safely withstood by friction. The conservation of stresses within restricted limits is due to the very low average compressive stress developing when the structure bears the vertical dead loads only.

The value C_{cr} is noticeably exceeded at the hypotrachelion of the west side columns in case of an + x direction earthquake, with a maximum of 0.33 m. The neutral axis lies in this case within the circular supporting surface at a distance of 0.475 m from the outer tangent and the moment of inertia of the circular sector is 60% less than the moment of inertia of the whole circle. (Sect. 6.5). According to the example of 6.1 we consider that the change of the column's stiffness at these places and for these eccentricities may be regarded negligible, therefore its influence on the interesal forces developing may be also regarded negligible.

A large eccentricity of the normal force also appears on the south side columns at the place where the peristyle's continuity is interrupted. A characteristic case is that of the column with code no 32, where the eccentricity at the hypotrachelion amounts 0.48 m and the respective neutral axis lies at a distance of 0.89 m from the outer tangent to the circle. It should be noted that during the February 24 and 25, 1981 earthquakes, a rotation of the architraves was observed at this place. In any case, this rotation was influenced by the unstable support of this column which after the 1687 explosion greatly deflects from the axis of the colonnade and whose first drum is partially composed of masonry.

Finally, from the eccentricity diagrams it is found out that the alteration which would occur after a possible completion of the peristyle is limited within the neighborhood of the missing part.

From the bending moment diagrams an important increase of these moments is observed at the corner columns and the neighboring ones. This fact is consistent with the exhibition of rotation of the drums at these places. However, for the assumed scale of lateral forces, the shearing stresses due to torsion are sufficiently sustained by friction. The presence of a shearing stress neutral region at the locations where a normal stress neutral region also exists is of minor importance as far as the distribution of stresses over the structure is concerned.

For an earthquake along ± x no noticeable change of torsion on the columns is observed. However, for an earthquake along ± y a considerable increase is exhibited, amounting almost to a moment twice as much exerted on the columns next to the corner column and on the column no. 5. But even after this increase, the moments still remain small and the developing shearing stresses are safely withstood because of the normal force increase, as inspection show.

From the entablature moment diagrams the existence of a considerable strain at the regions near the corners, where a triaxial strain exists, is deduced. Worthy to be noted is the great magnitude of My at the corner architraves (e.g. beam no 167, + x diagram) which explains the rupture of architraves (outer stone) of all four corners in much earlier times (a past earthquake? the explosion in 1687?). From the inspection of the connections in the present state, a very intense strain on the joints nos. 142 and 157 near the east side corners was deduced, an effect quite consistent with the connections failure realized at these locations during the Alcyonidae Islands earthquake (see 2.3, Fig. 3.1). The connections inspection showed in general that considerable forces are sustained, even though the columns condition is far from being critical for the assumed loading. By comparing the diagrams of the existing state and of the restoration proposal, it is derived that the moments increase at the long side corners and at the points of discontinuity (the place where four columns are missing – south side –) of the peristyle after completion of the entablature for an ± x directed earthquake and that they increase over the whole length of the long sides and at the short sides corners for an ± y earthquake. However, although the addition of dead loads increases the internal forces at certain locations, the enhancement of the sections stiffness caused by the addition of cornices, results in a reduction of the connections strain and of the stresses on the entablature's joints.

In these diagrams too, the forces almost coincide for the case of the restoration-completion proposal and for the case of peristyle completion. We believe that this fact which has been also noted in other diagrams is explained by the absence of diaphragmatic action among the vertical members of the bearing structure, which allows an increased independence regarding the behavior of the various parts of the peristyle.

The general conclusion of the linear static analysis is that under horizontal loading, there is an intense stress regime, especially on the entablature. Even though the analysis assumptions cease to be valid from the moment that neutral regions begin to appear in the joints or small displacements and rotations of the members are exhibited, the distribution of the internal forces is compatible with the damage symptomatology of the February 24 and 25, 1981 earthquakes as well as of previous impacts. The significance of the connections which has resulted from the entablature's joints analysis supports the necessity for an intervention regarding the removal of the rusted connections and their substitution with titanium connections such as to offer the required strenth and ductility. The entablature completion proposals, while they cause an increase of the force magnitudes, they do not cause an increase of the members' strain, since the entablature's stiffness is accordingly raised. Finally, the completion of the peristyle favors the columns and the entablature parts located in the close neighborhood of the four missing columns. This subject could be posed to the degree that the architectural study will provide evidence justifying this proposal from the aspect of good restoring practice. (e.g. possible detection of drums which were used during the Balanos restoration in the south side, while they actually belong to the north side).

4. The problem of completing the roof of the West Wing

On the west wing's ceiling presently exist four marble beams spanning between the entablature and the frieze of the opisthodomos porch. The problem of completing the ceiling by putting in place the rest three beams and the coffer slabs spanning between the beams, is set forth in order to increase the educational value of the monument as well as to protect the frieze from rainwater. The question rising is whether roofing the west wing is desirable or not, from the structural point of view. The problem is particularly complicated because of the west porch columns' condition, since they bear numerous cracks throughout.

Eventual roofing of the wing will, structurally, induce two consequences: the increase of the vertical forces exerted on the columns due to additional dead loads and the exertion of additional horizontal forces on the level of the ceiling beams' support, in case of earthquake. The increase of the vertical forces is almost 12% of the forces now transmitted on the base of each column. The additional horizontal force expected in case of earthquake is at most equal to the additional load of the ceiling multiplied by the friction coefficient (horizontal force approximately 7 Mp exerted at the level of the ceiling's support). We consider that the horizontal forces, caused by the partial co-performance of the peristyle-porch, generate the most crucial question about the porch columns bearing capacity.

The consideration of the problem might be in an analytical or an experimental manner. For the resolution of the secos wall-porch system, the geometry of the rupture surfaces of the column drums should be known, which is extremely complicated, as a rule. A work on the determination of the magnitude, the depth and the geometry of the cracks has been conducted for the west wing's beams[18]. With this technique, but with devices of greater capacity, it is theoretically possible to determine the crack characteristics. However, we believe that the already exceptionally complicated form of the structure's seismic response will become even more complicated, should the drums' cracks also be included in the analysis and, therefore, we are very cautious about the practical results of such an analysis. In addition, experimental methods currently in use for ordinary structures (test loadings, for example) is senseless to be employed for a unique monument.

We believe that should other reasons impose the roofing of the wing, two requirements must be assured. The minimization of the additional dead loads (for instance, by cutting large cavities in the new marble members, by reducing the thickness of the coffer slabs, etc.) and the achievement of independence between the peristyle and the porch by introducing rollers between the new members and the frieze. The check of the columns behavior under the additional vertical loads may be carried out by installing strain-gauges on the crack locations and by increasingly exerting the corresponding vertical trial loads.

5. *Proposals for the definitive study and the required research*

Parthenon's major importance calls for the implementation of the most advanced analytical methods in the stage of the definitive study as well as the exploitation of the current technological potential regarding the experimental techniques, to check the reliability of the analysis. Of the existing ready-to-be- used by the designer methods which are costly as a rule, none corresponds to the peculiarities of Parthenon. Therefore, a certain adaptation of these methods is needed.

As previously mentioned, the monument's bearing structure starts behaving non-linearly for a level of horizontal loading far from being critical. The analysis of the non-linear phase of the structure's behavior is possible, under the condition of elastic behavior of each distinguished member, with a non-linear method of ultimate strength analysis. The force-deformation graph for a column for which only one possible deformation pattern is accepted (e.g. shearing deformation for columns of one side when load is exerted parallel to the longitudinal axis of this side), can be used to describe the column behavior with the assumption of a constant vertical load, independent of the horizontal loading. With this varying stiffness of the vertical members, the distribution of the internal forces along the vertical members for every loading level is possible. The members of the entablature may be simulated by means of spatial finite elements. The validity of the method ranges up to the point that relative displacements or rotations of the members appear, such that a dynamic analysis would be necessary for their utilization in the monument behavior study.

A non-linear dynamic analysis of the structure considered as a space frame is exceptionally difficult and an original theoretical approach would be required for the adaptation of the in-use methods to the specific characteristics of the structure. Selection of simulated accelerograms, corresponding to the dynamic characteristics of the Acropolis rock, would also be required. For the determination of the rock characteristics – as well as of the stereobates' – pertinent research is needed.

We believe that along with the implementation of analytical methods, experimental testing of the monument's response to dynamic loading on a scale model would be valuable. But, since a significant non-linear scale effect on the response of free supported structures exists, as mentioned in sec. 2.1, the stress and strain properties as measured on the model cannot be reduced to the real structure. However, what is possible, is to test the analytical method which is independent of scale. Also, a model built according to the real structure's building pattern may provide us with the sequence of the failure mechanisms about which no relevant experience exists as for modern structures.

A broad research program such as the one described above is surely costly and, certainly, does not regard a structural problem of great economic importance and breadth. The pertaining research, beyond some inferences about modern structures it can produce, concerns a limited number of monuments of the Classical Greek and Roman Antiquity, saved up to-date. However, the inestimable cultural value of these unique monuments, and of Parthenon in particular, justifies the economic burden that accompanies such a program for the accomplishment of which international co-operation of scientists and research centers is imperative.

6. *Calculation books*

The calculation books available to every interested party can be found in the archives of the Committee for the Preservation of the Acropolis Monuments and regard the following items:

6.1. Determination of the influence of joints on the stiffness of a free column.
6.2. Determination of loads for the linear static analysis of the Parthenon.
6.3. Analysis of the entablature's complex cross-section.
6.4. Linear static analysis of the existing state, of the restoration proposal and, after completing the peristyle, for a loading consisting of the dead loads and uniformly distributed horizontal loads, with $\varepsilon = 0.04$, along $\pm$ x and $\pm$ y.
6.5. Check of the peristyle's column joints.
6.6. Analysis of the entablature's beam-column joints.
6.7. Check of stresses on the entablature connections.

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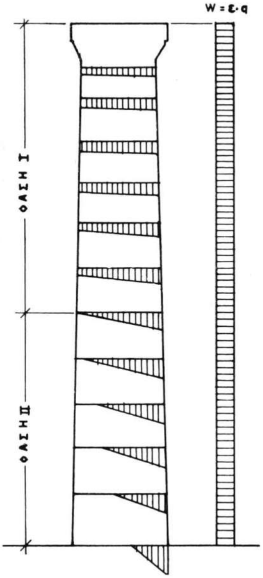


Fig. 2.1. Free column: Stress pattern on the base and the joints.

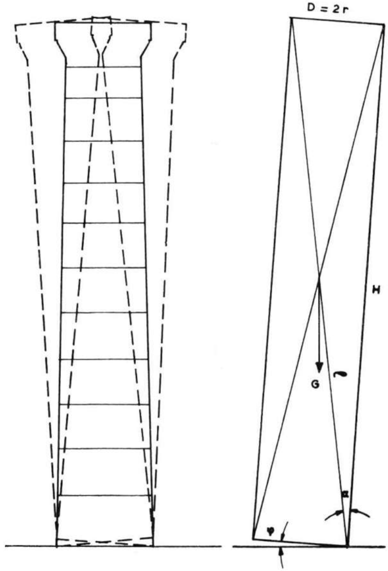


Fig. 2.2. Free column: Rocking vibrations.

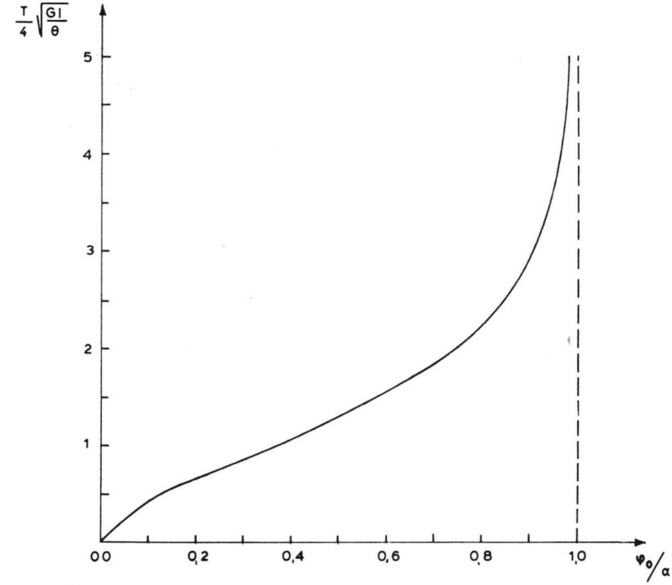


Fig. 2.3. Free vibration: (Φ_o T) diagram[5].

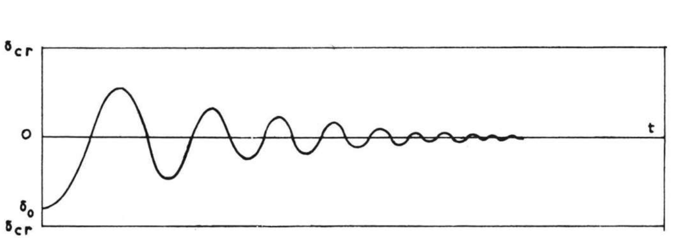


Fig. 2.4. Free vibration: (t, δ) diagram[7].

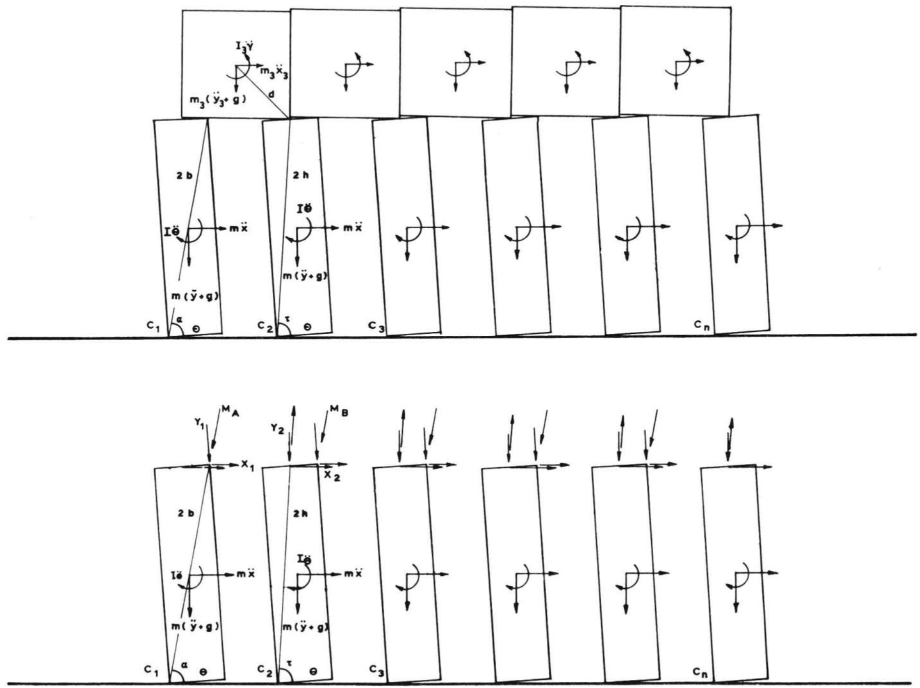
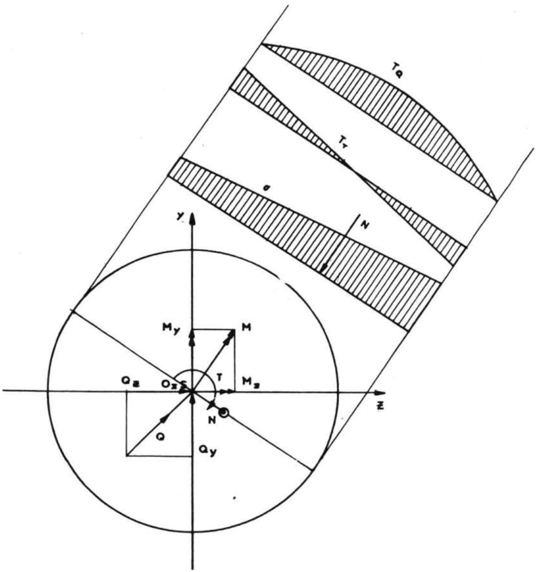
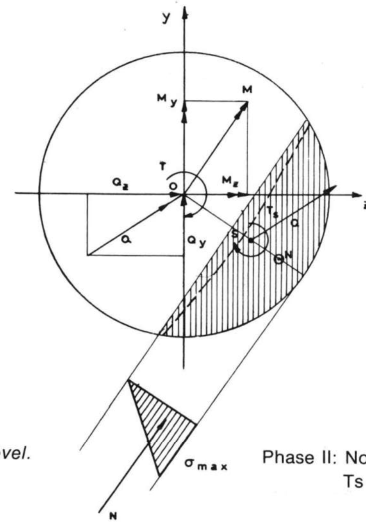


Fig. 2.5. Free vibration of a colonade[12].

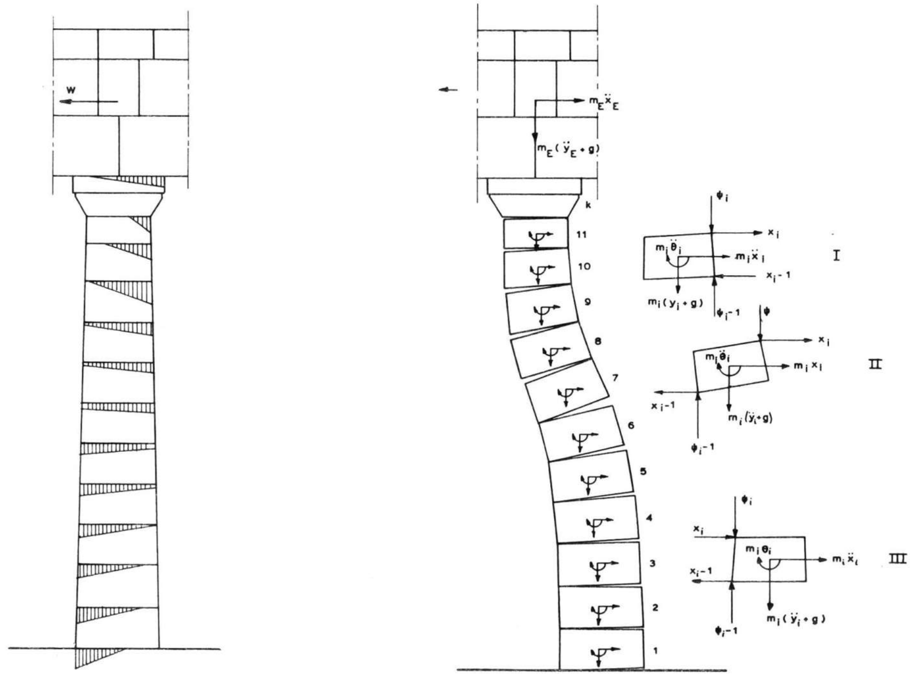


Phase I: Linear behaviour
$T_Q + T_r \leqslant \mu.\sigma$



Phase II: Non linear behaviour
$T_s = T - Q_y.Z_s - Q_zY_s$

Fig. 2.6. Forces on a joint level.



Phase II

Fig. 2.7. Shear deformation of a column.

Phase III

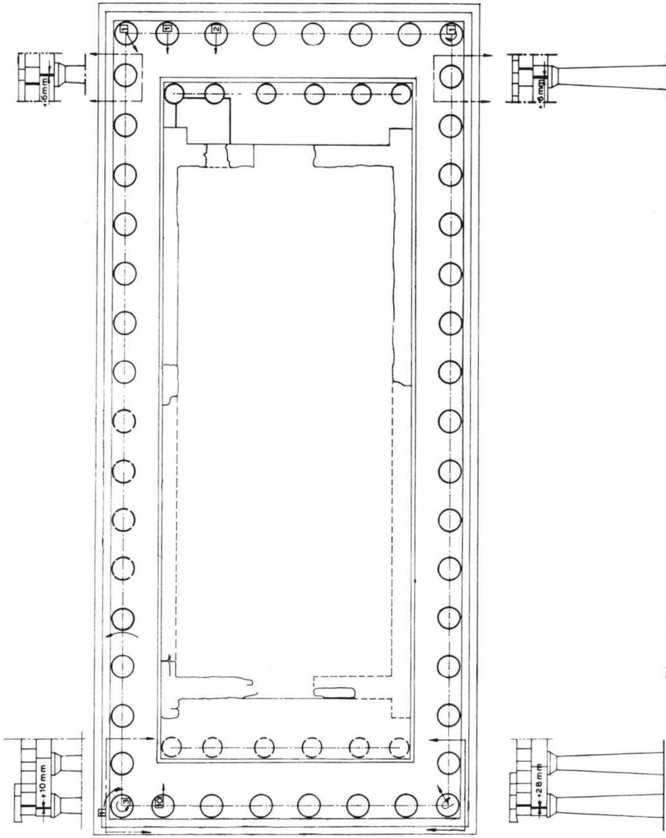


Fig. 2.8. Damages caused by 24 and 25.2.1981 earthquakes.

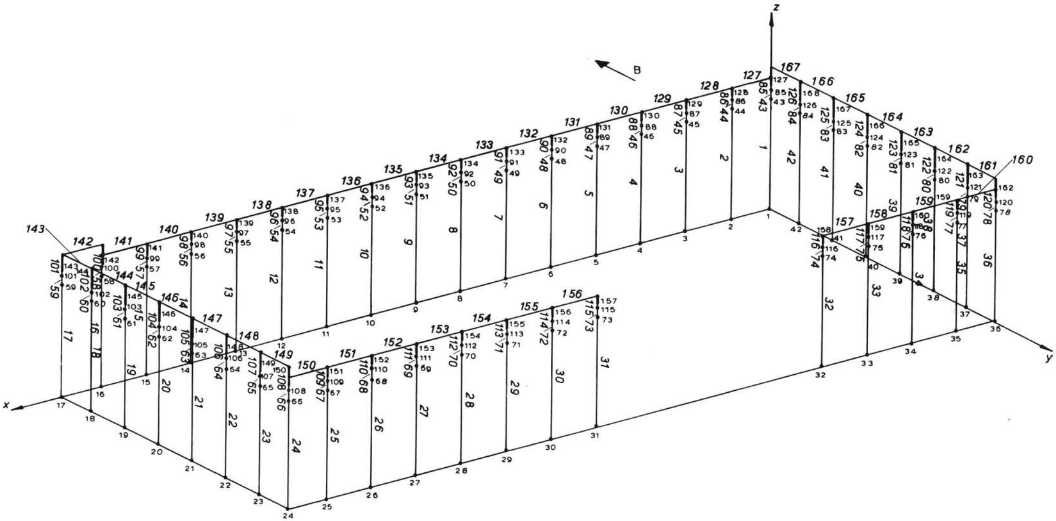


Fig. 3.1. Parthenon: Linear static analysis.
Existing situation. 3-D. Analytical model of the structure.

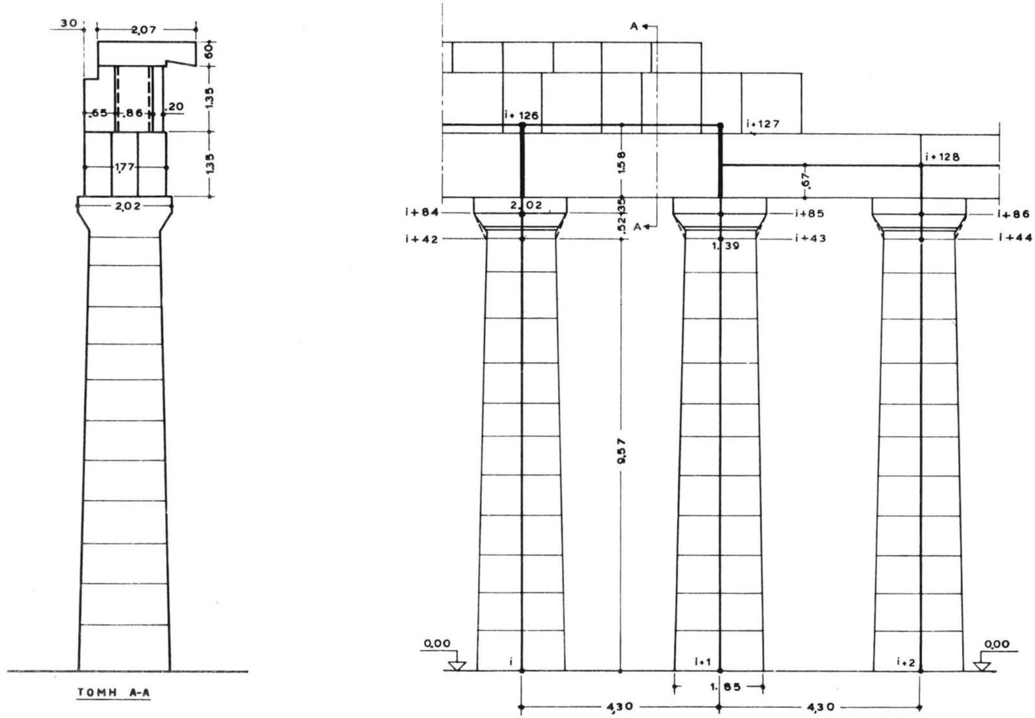


Fig. 3.2. Parthenon: Linear static analysis
Modeling of the structure – Dimensions.

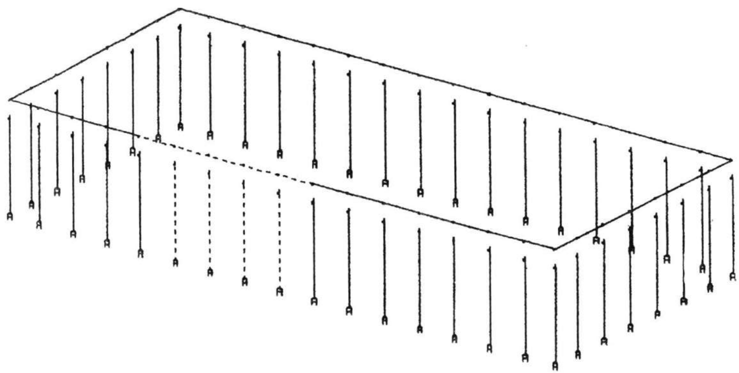
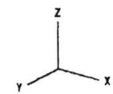


Fig. 3.3. Parthenon: Linear static analysis.
Computer plot for the model of the structure after the restoration.



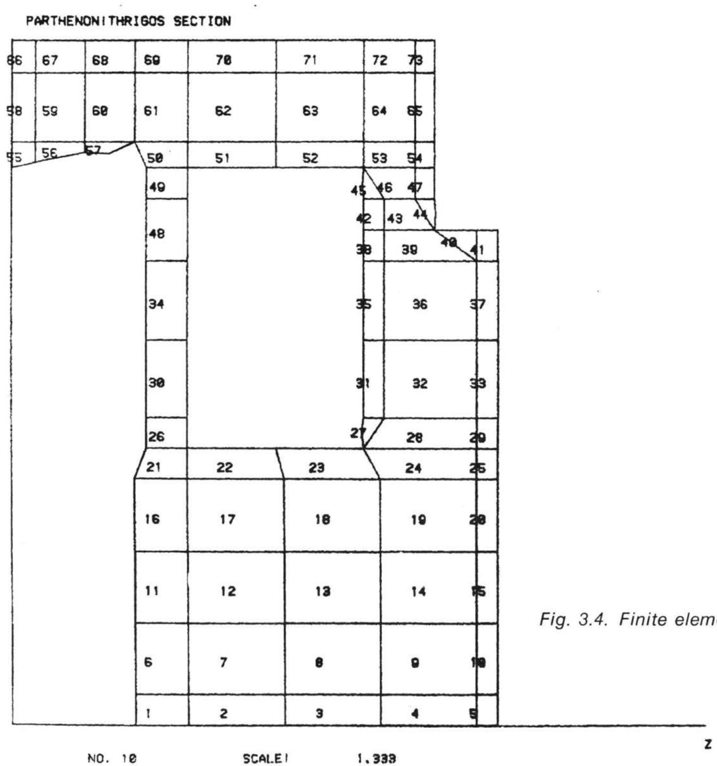


Fig. 3.4. Finite element analysis of the entablature section.

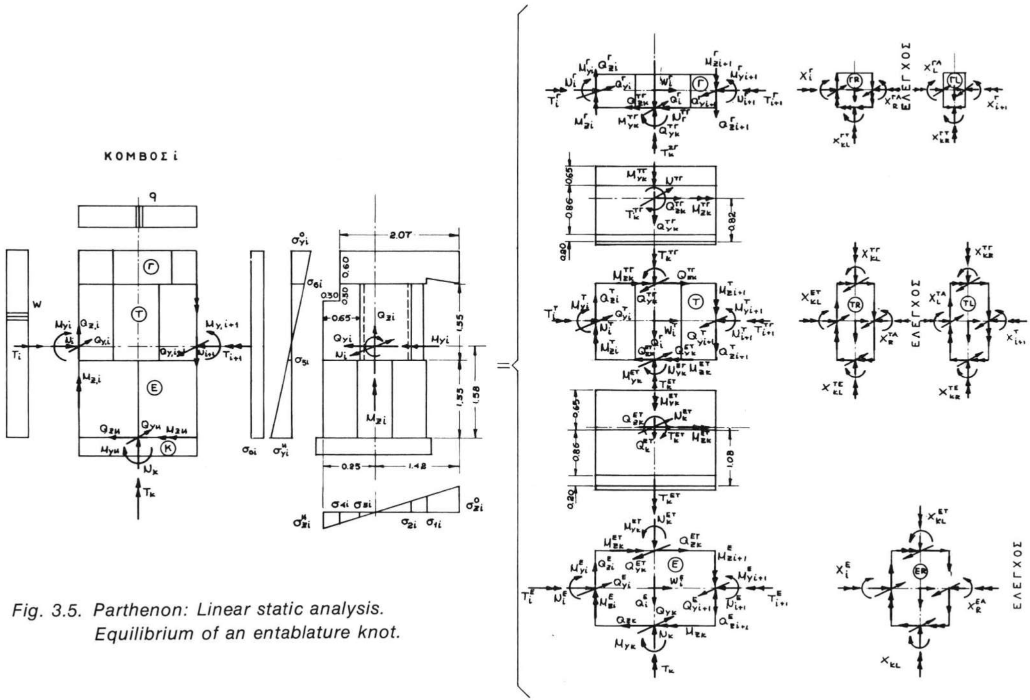


Fig. 3.5. Parthenon: Linear static analysis.
Equilibrium of an entablature knot.

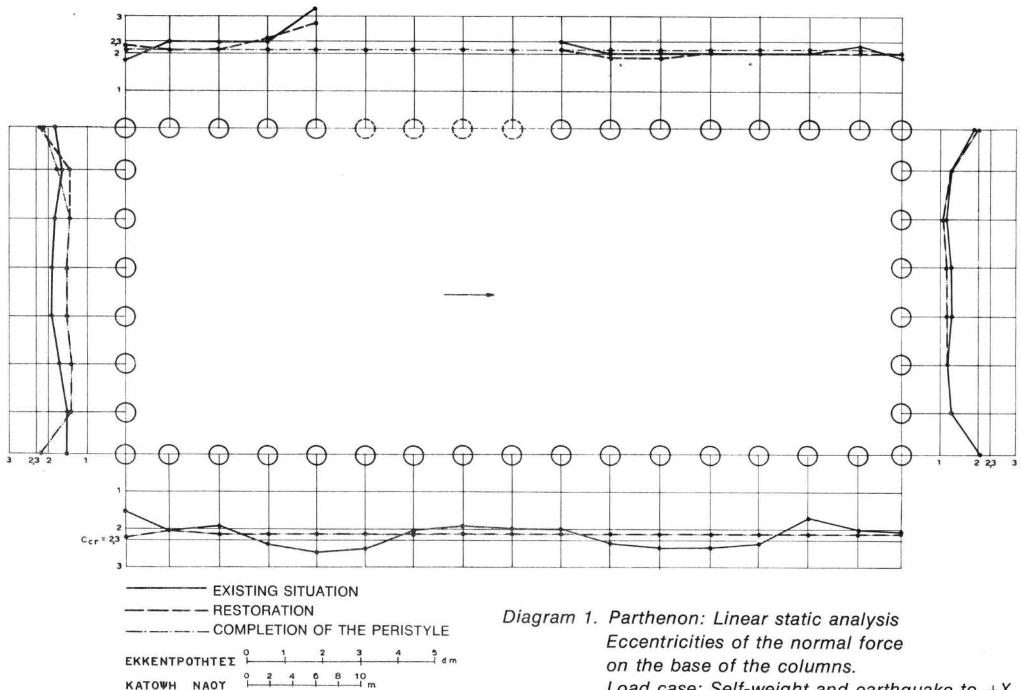


Diagram 1. Parthenon: Linear static analysis
Eccentricities of the normal force
on the base of the columns.
Load case: Self-weight and earthquake to +X.

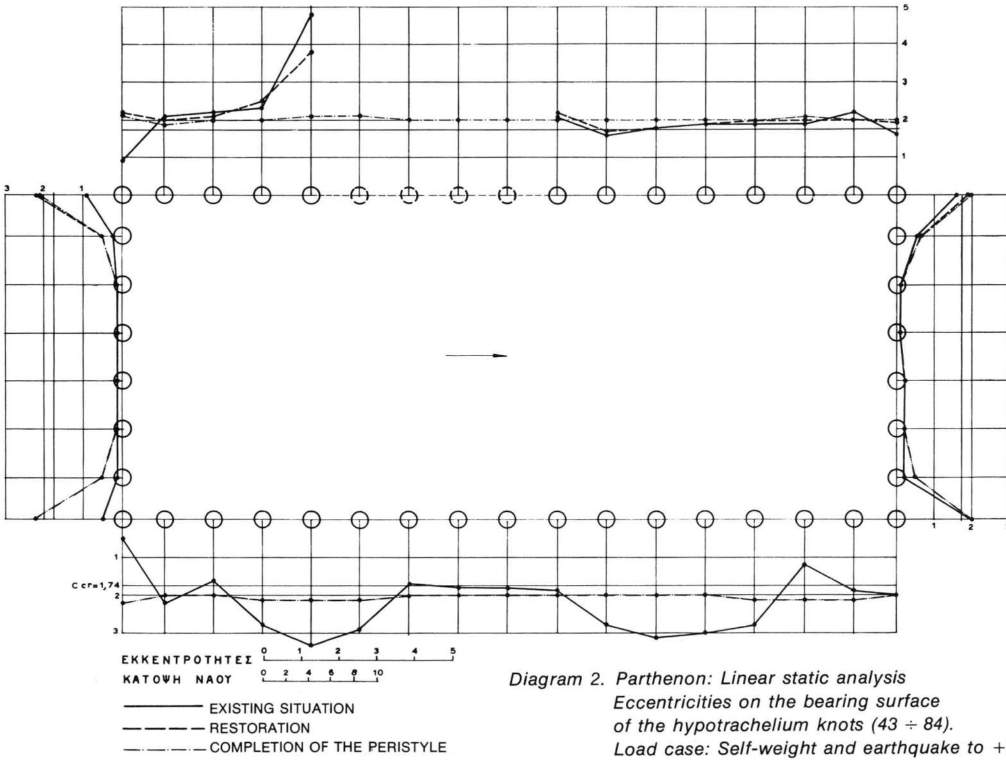


Diagram 2. Parthenon: Linear static analysis
Eccentricities on the bearing surface
of the hypotrachelium knots (43 ÷ 84).
Load case: Self-weight and earthquake to +X.

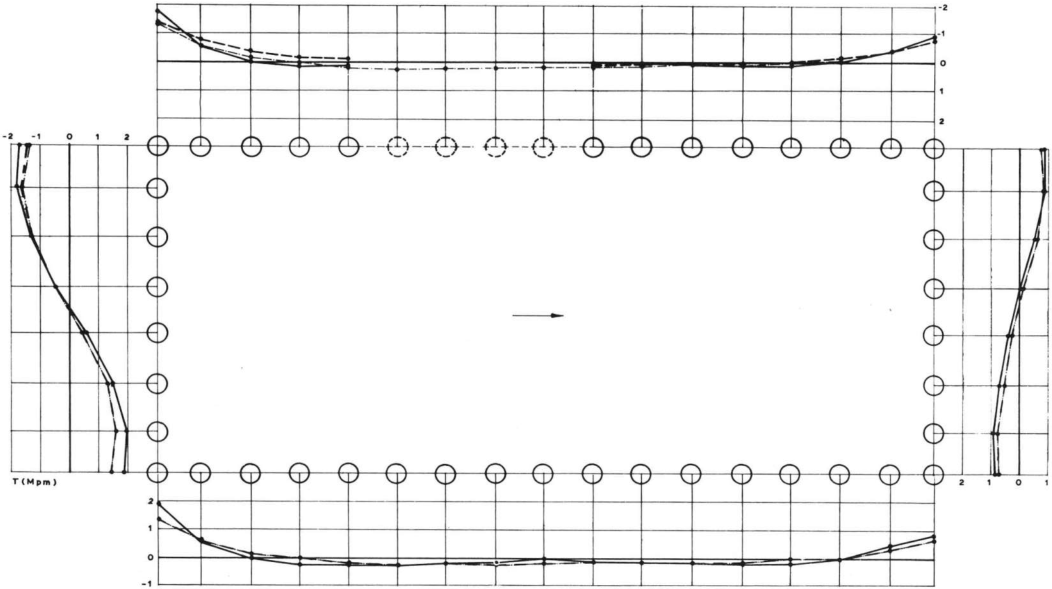


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Diagram 3. Parthenon: Linear static analysis.
T-diagrams of the columns.
Load case: Self-weight and earthquake to +X.

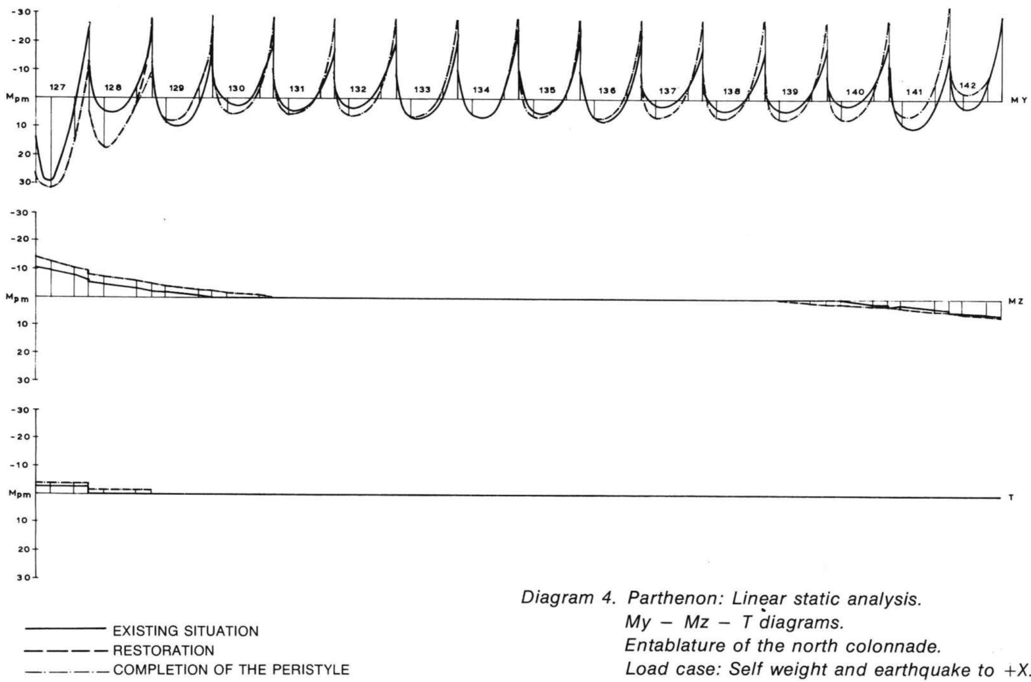

Diagram 4. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the north colonnade.
Load case: Self weight and earthquake to +X.

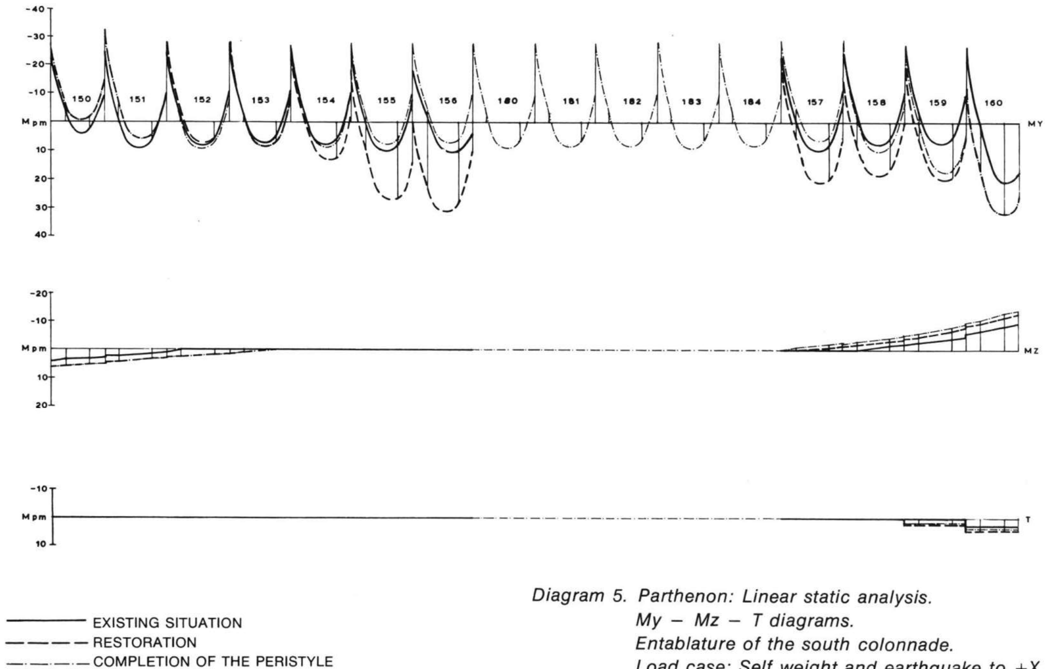

Diagram 5. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the south colonnade.
Load case: Self weight and earthquake to +X.

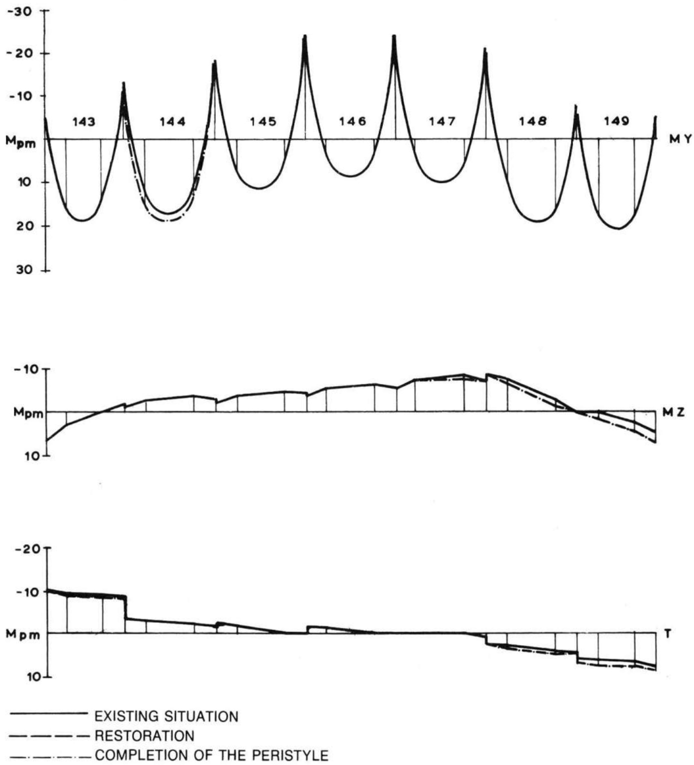

Diagram 6. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the west façade.
Load case: Self weight and earthquake to +X.

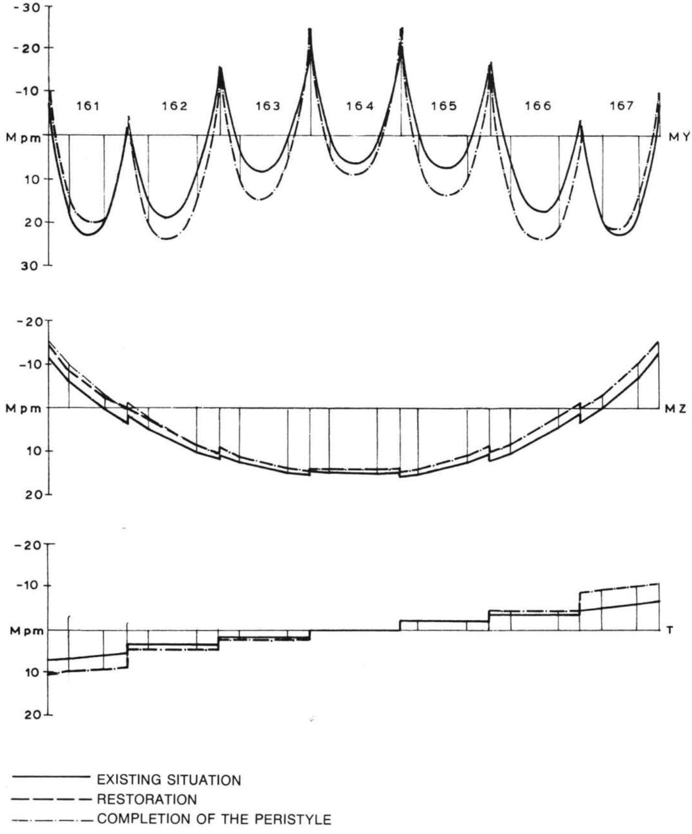

Diagram 7. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the east façade.
Load case: Self weight and earthquake to +X.

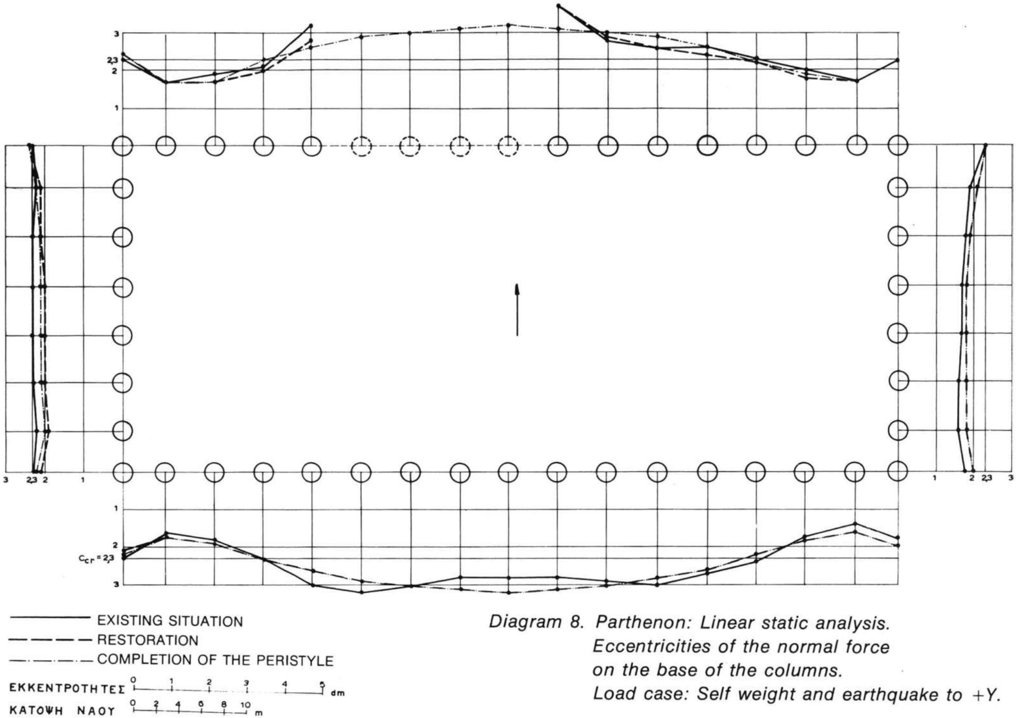

*Diagram 8. Parthenon: Linear static analysis.
Eccentricities of the normal force
on the base of the columns.
Load case: Self weight and earthquake to +Y.*

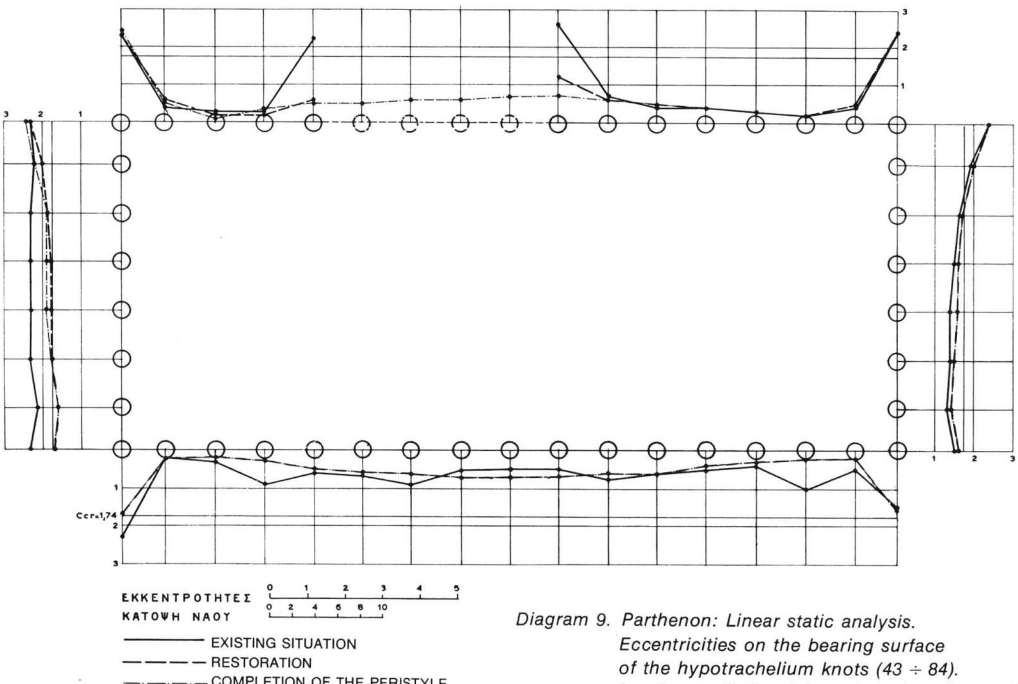

Diagram 9. Parthenon: Linear static analysis.
Eccentricities on the bearing surface
of the hypotrachelium knots (43 ÷ 84).
Load case: Self weight and earthquake to +Y.

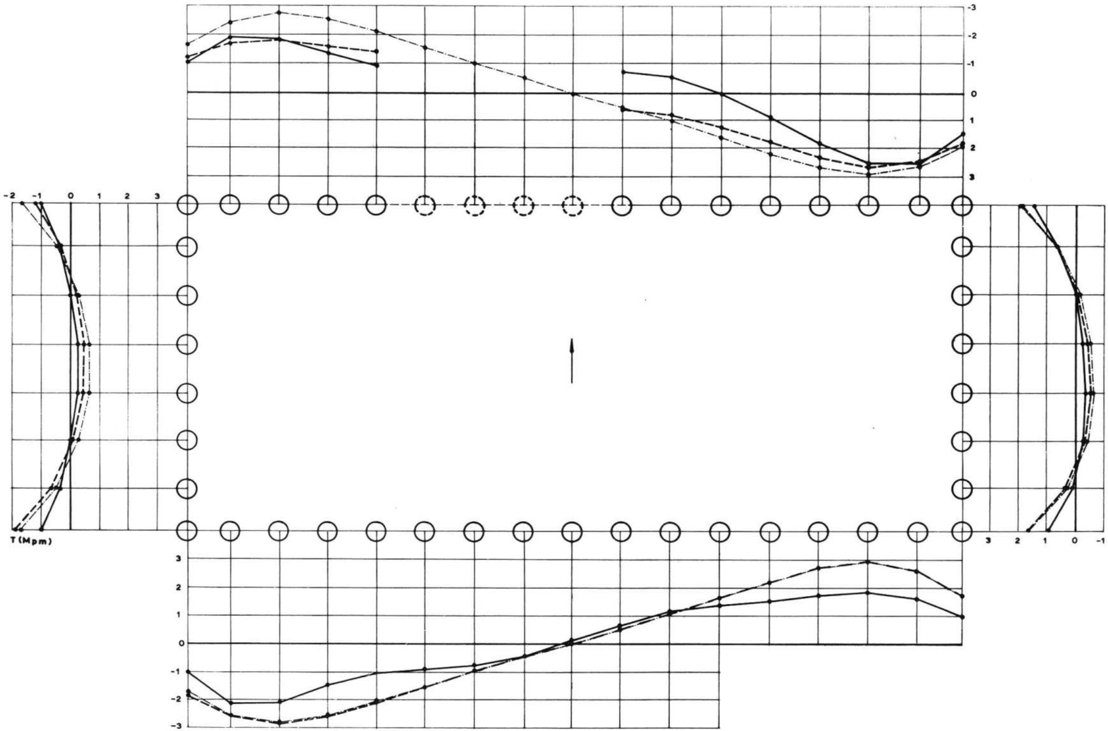

Diagram 10. Parthenon: Linear static analysis.
T-diagrams of the columns.
Load case: Self-weight and earthquake to +Y.

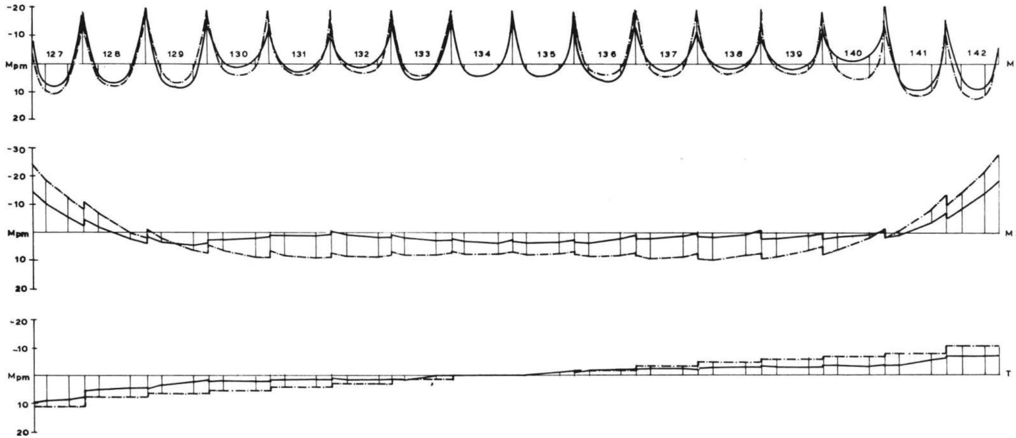

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Diagram 11. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the north colonnade.
Load case: Self weight and earthquake to +Y.

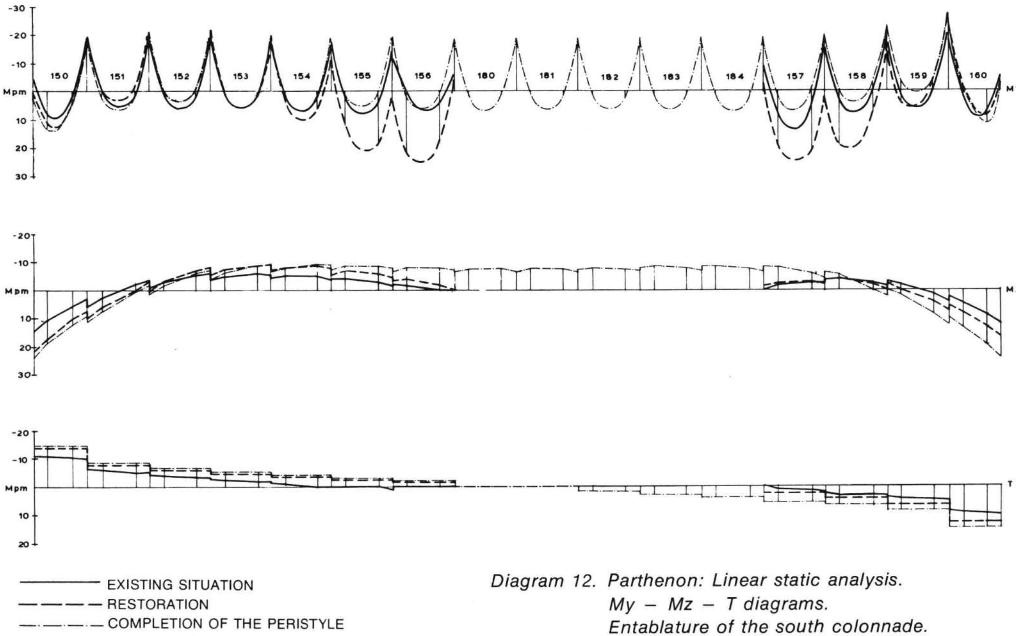

Diagram 12. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the south colonnade.
Load case: Self weight and earthquake to +Y.

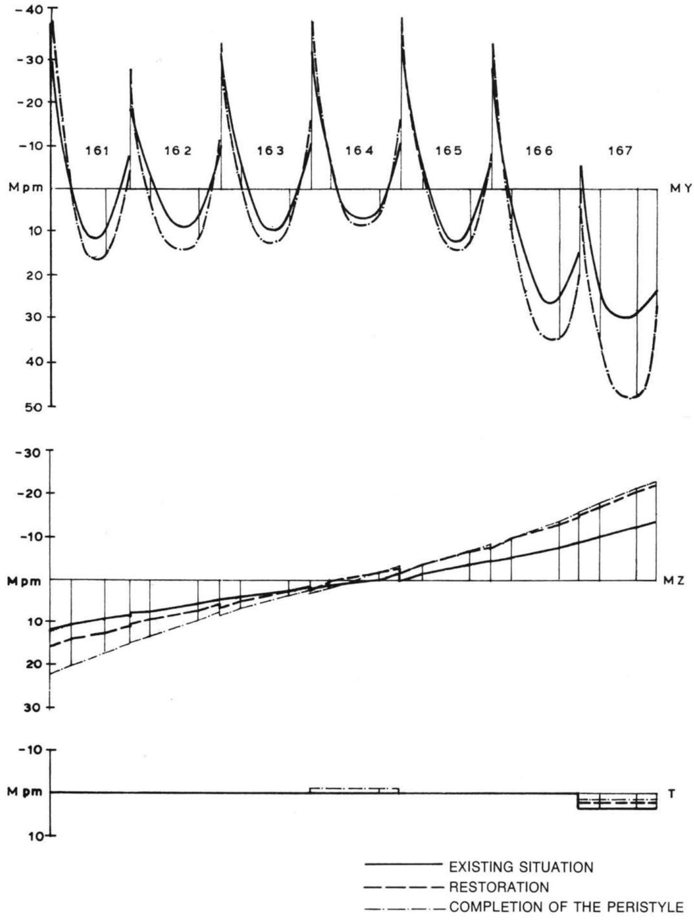

Diagram 13. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the north colonnade.
Load case: Self weight and earthquake to +Y.

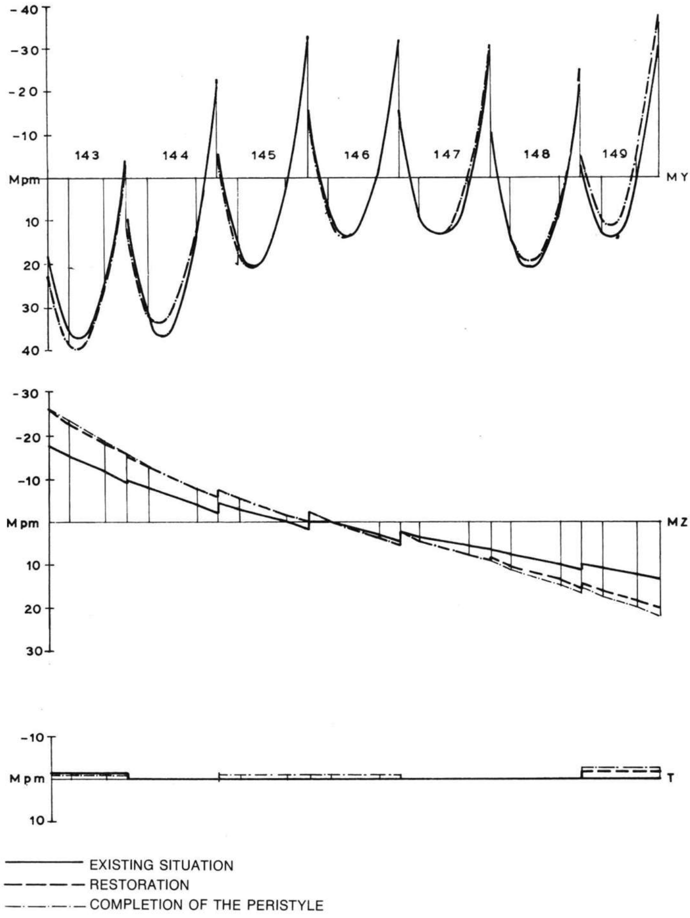

Diagram 14. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the west façade.
Load case: Self weight and earthquake to +Y.

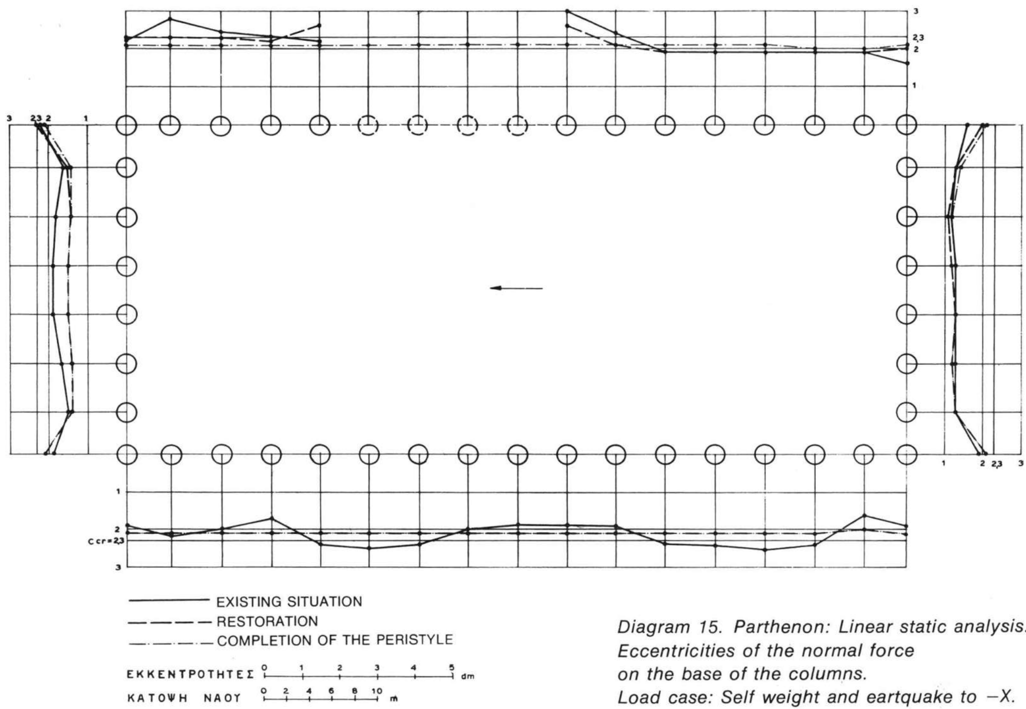

Diagram 15. Parthenon: Linear static analysis.
Eccentricities of the normal force
on the base of the columns.
Load case: Self weight and eartquake to −X.

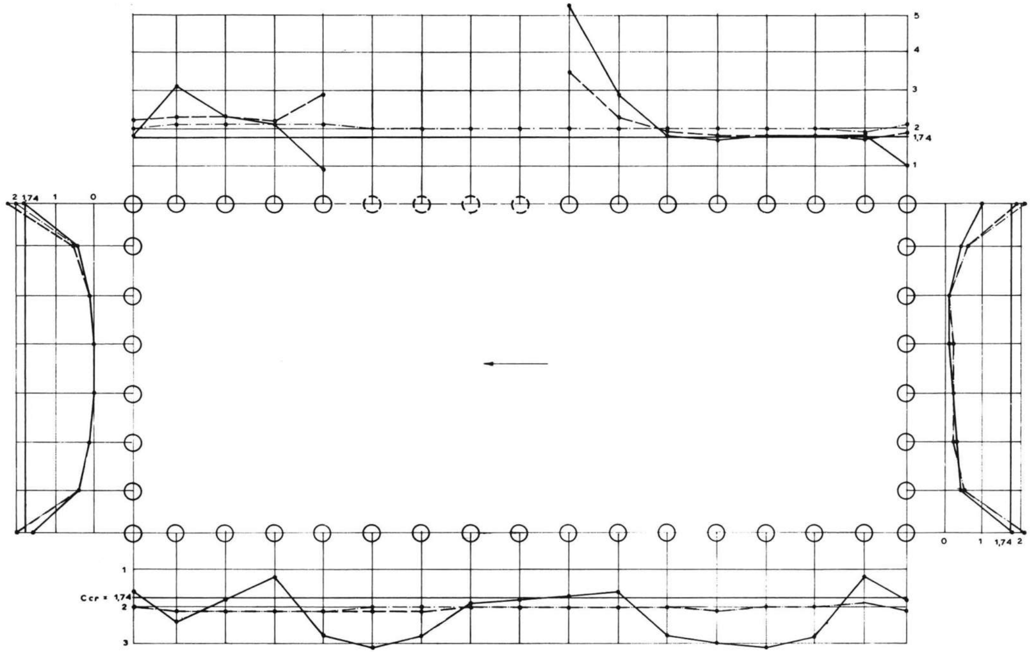

*Diagram 16. Parthenon: Linear static analysis.
Eccentricities on the bearing surface
of the hypotrachelium knots (43 ÷ 84).
Load case: Self weight and earthquake to −X.*

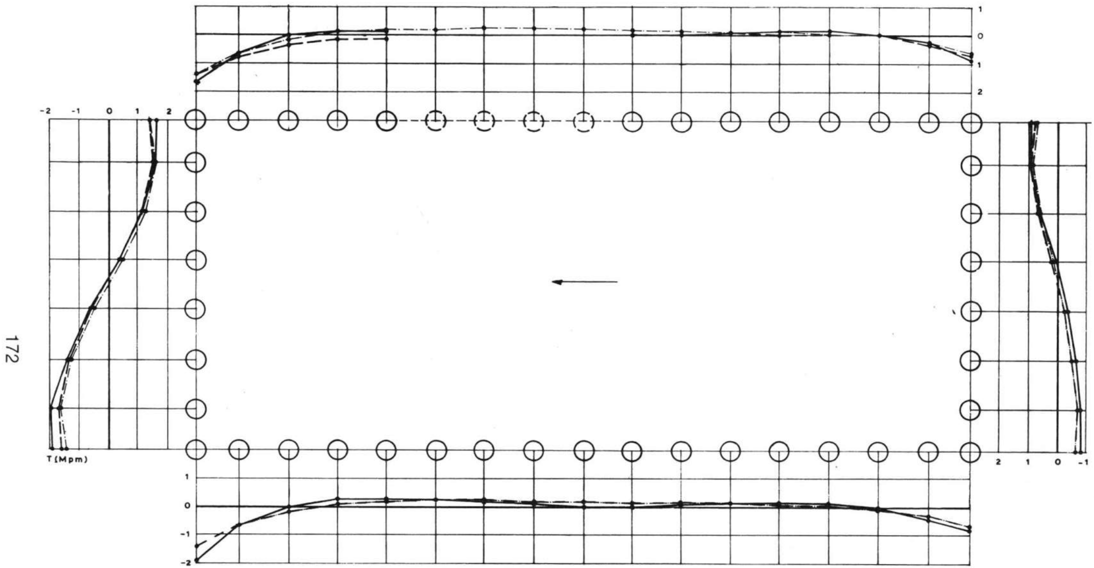

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Diagram 17. Parthenon: linear static analysis.
T-diagrams of the columns.
Load case: Self weight and earthquake to −X.

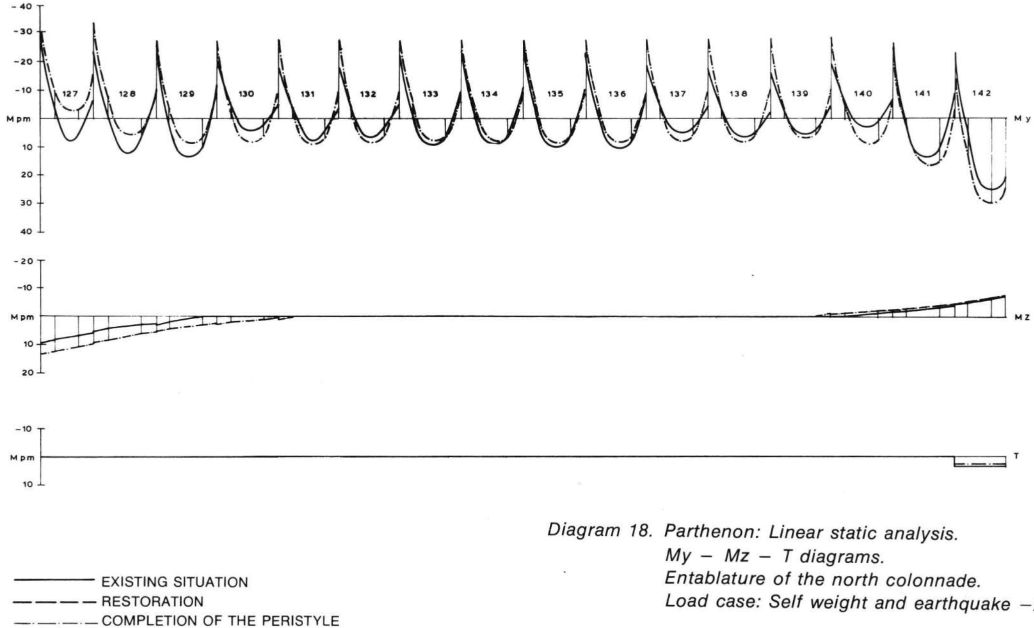
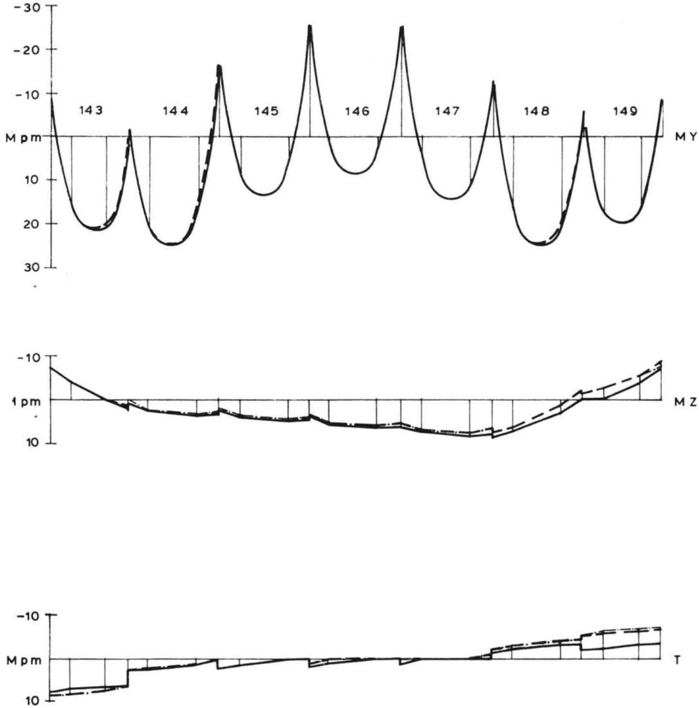


Diagram 18. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the north colonnade.
Load case: Self weight and earthquake –X.



EXISTING SITUATION
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Diagram 19. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the west façade.
Load case: Self weight and earthquake –X.

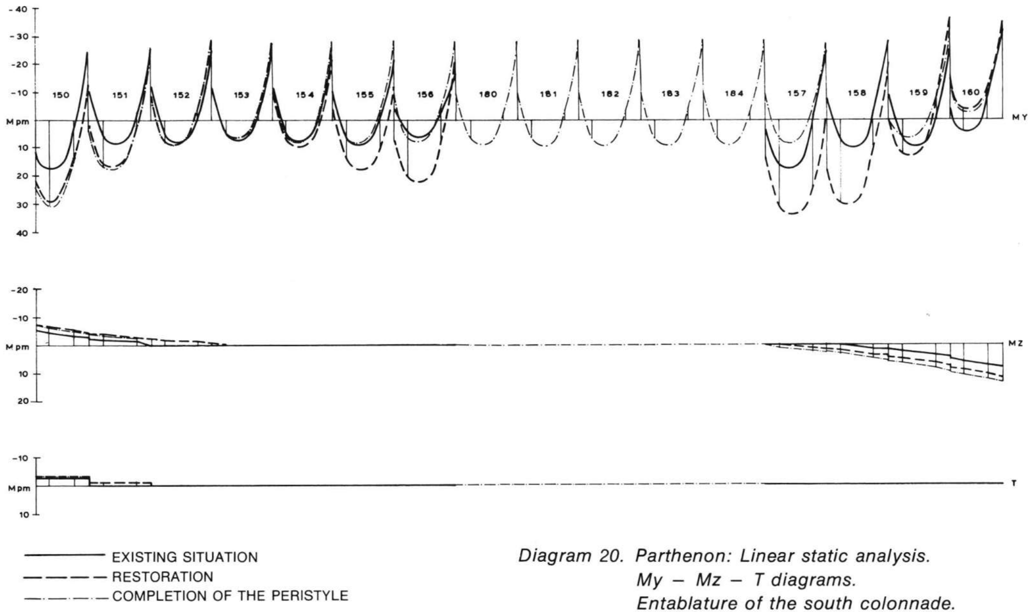


Diagram 20. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the south colonnade.
Load case: Self weight and earthquake –X.

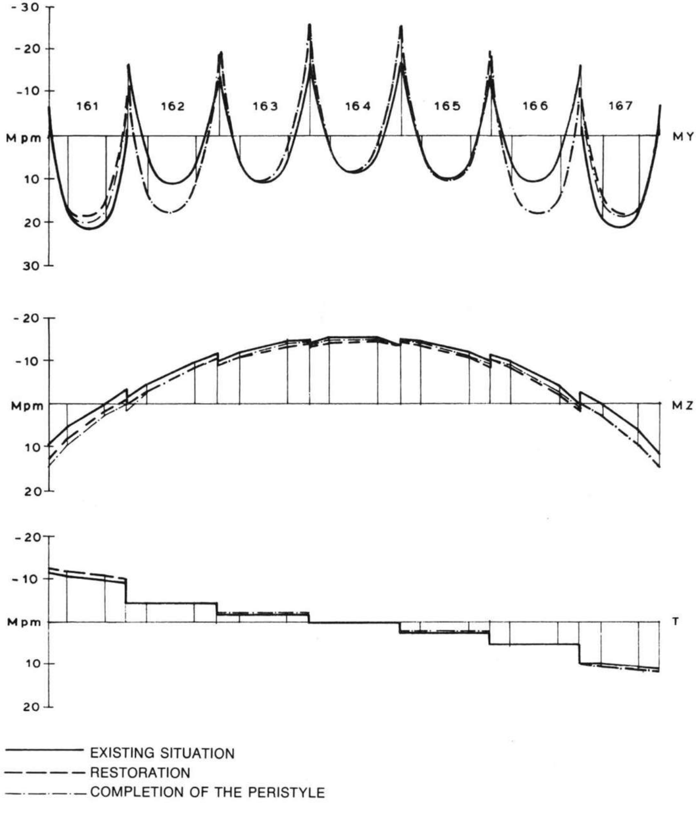


Diagram 21. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the east façade.
Load Case: Self weight and earthquake –X.

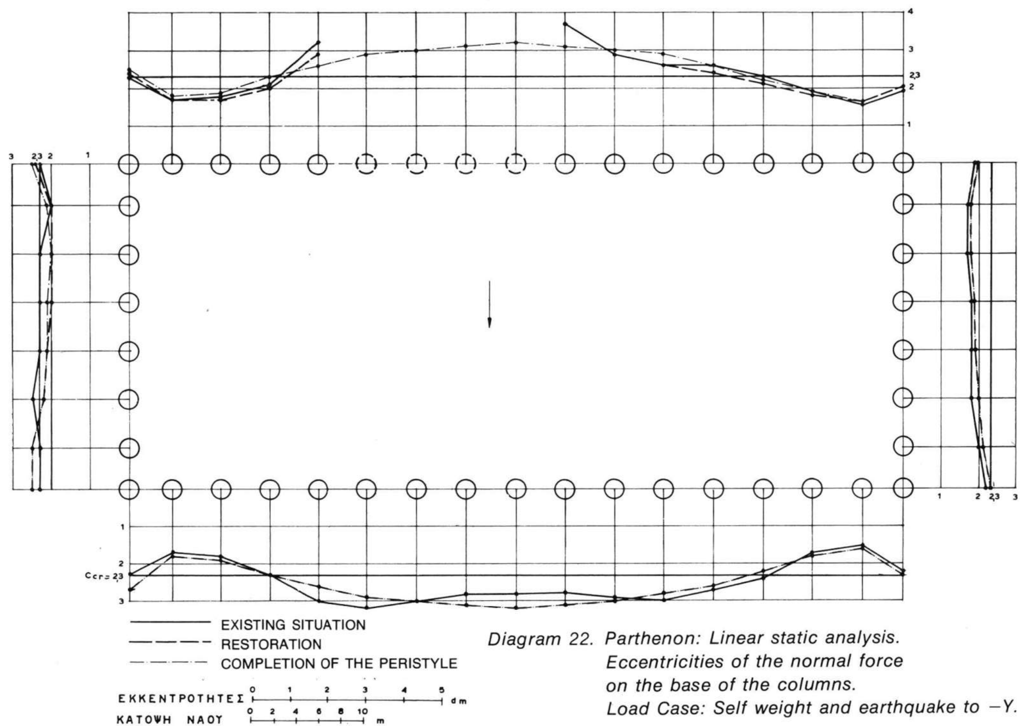


Diagram 22. Parthenon: Linear static analysis.
Eccentricities of the normal force
on the base of the columns.
Load Case: Self weight and earthquake to −Y.

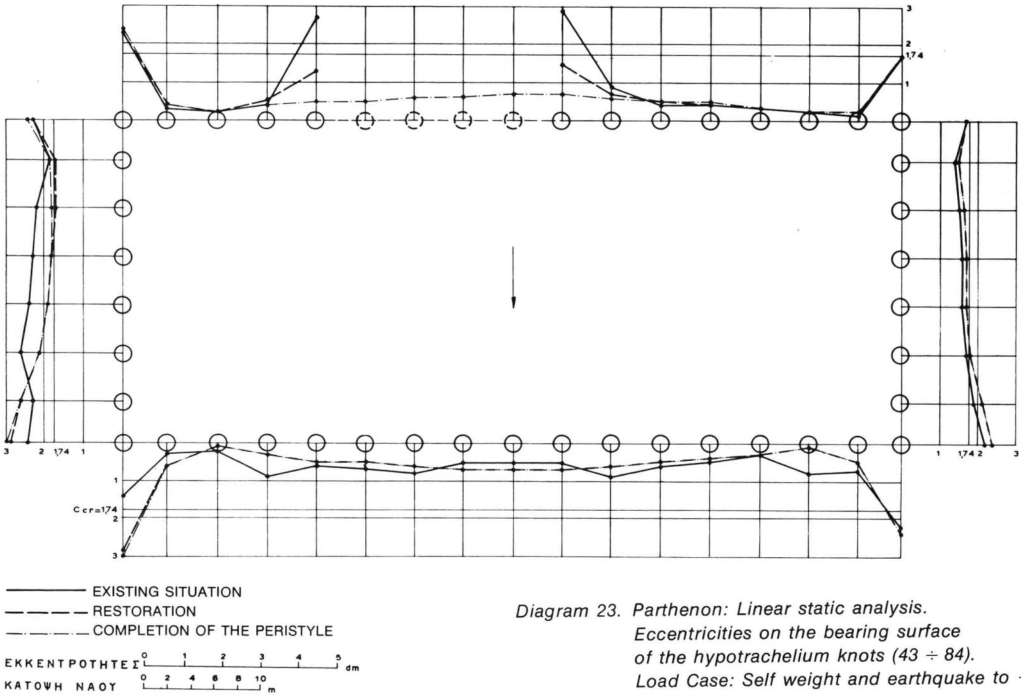


Diagram 23. Parthenon: Linear static analysis.
Eccentricities on the bearing surface
of the hypotrachelium knots (43 ÷ 84).
Load Case: Self weight and earthquake to −Y.

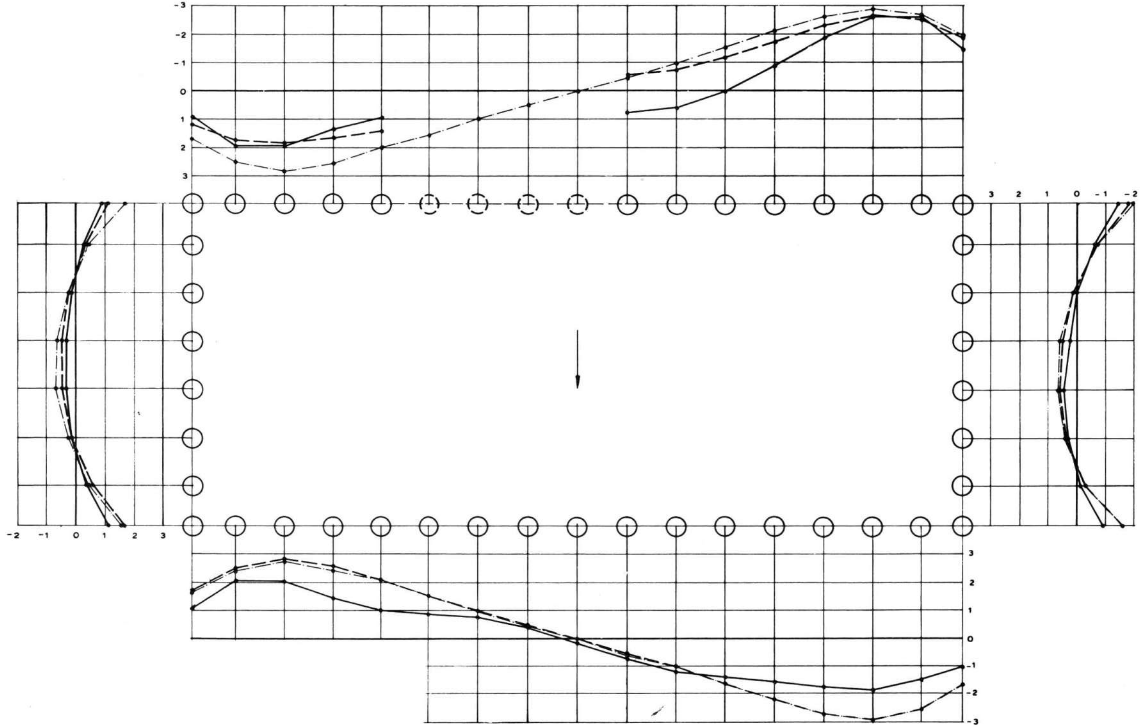


Diagram 24. Parthenon: Linear static analysis.
T-diagrams of the columns.
Load Case: Self-weight and earthquake to −Y.

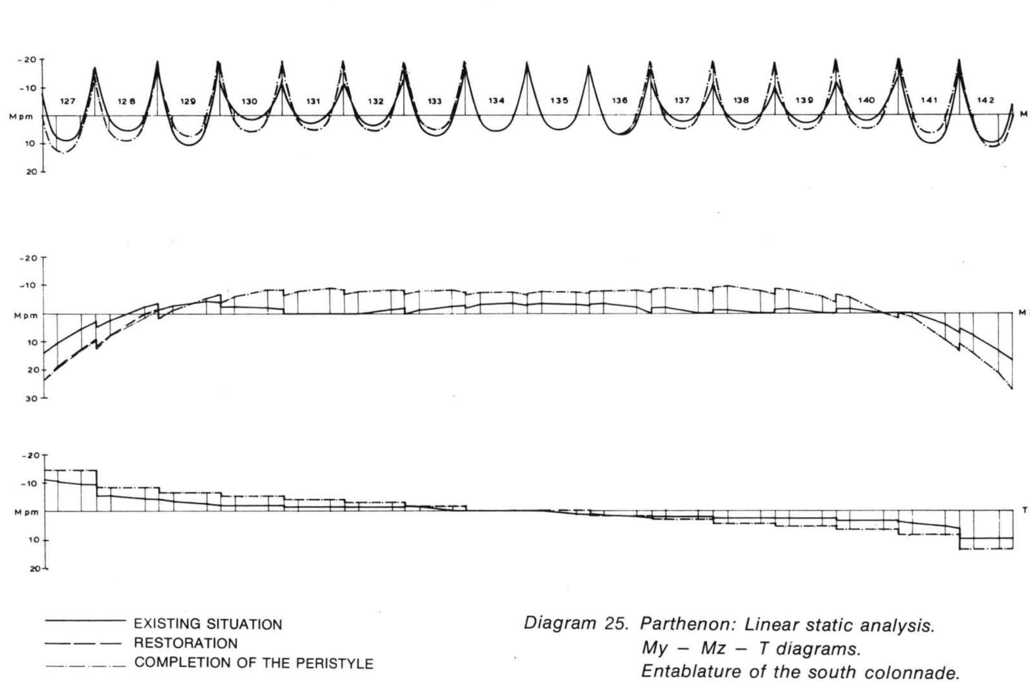


Diagram 25. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the south colonnade.
Load Case: Self weight and earthquake to –Y.

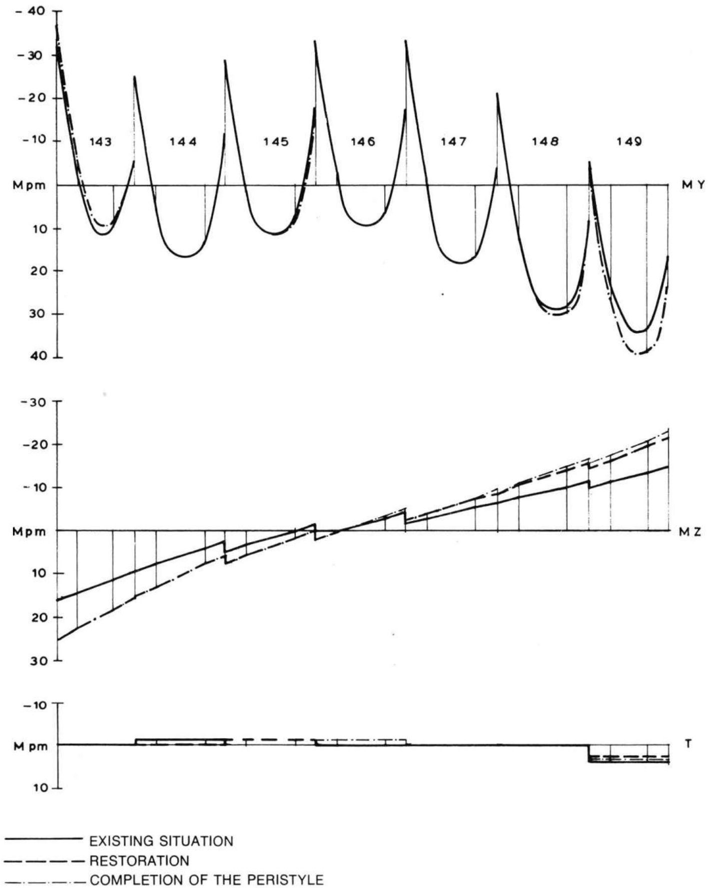


Diagram 26. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the west façade.
Load case: Self weight and earthquake to –Y.

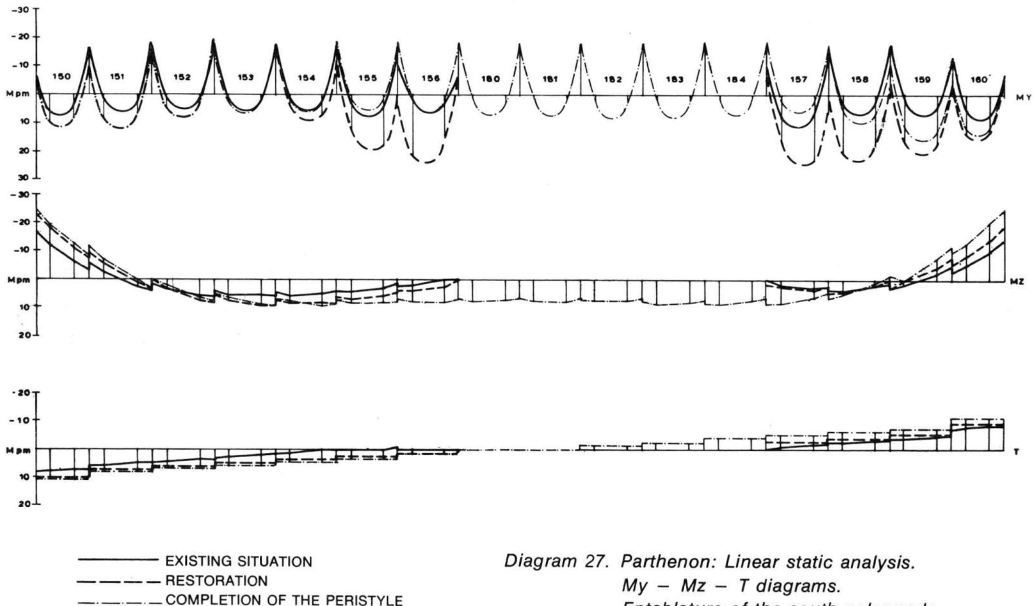


Diagram 27. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the south colonnade.
Load Case: Self weight and earthquake to –Y.

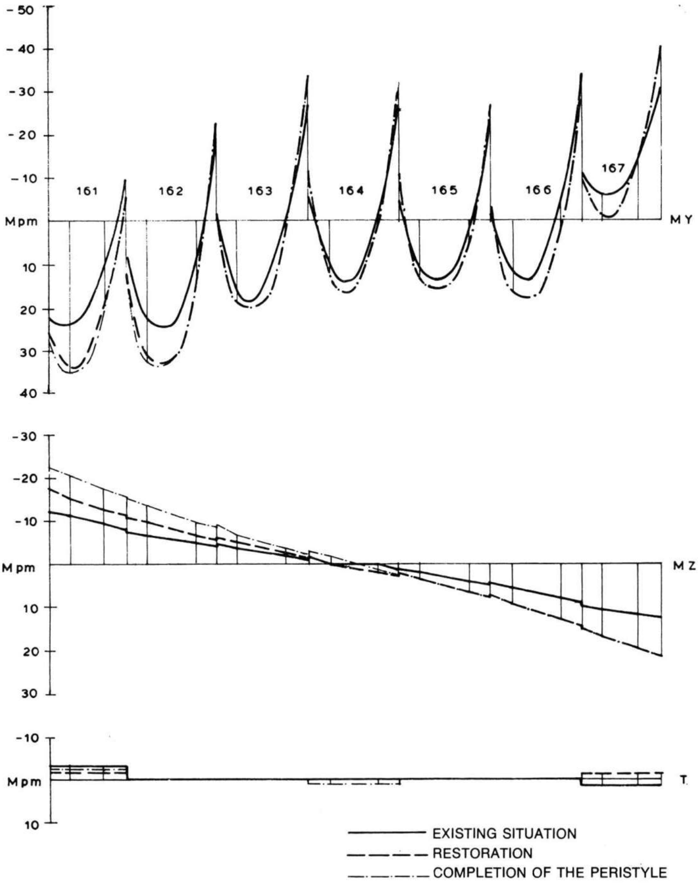


Diagram 28. Parthenon: Linear static analysis.
My – Mz – T diagrams.
Entablature of the east façade.
Load case: Self weight and earthquake to –Y.

3

DISCUSSION

DISCUSSION

The discussion followed general and detailed reports on the principles to be adopted, the program for restoring the Parthenon and on the special problems involved. The invited members of the meeting and interested persons in the audience all took part in the discussion. The discussion was concerned mainly with the following topics:

1. Principles and proposals for restoring the Parthenon.

2. Preservation of the sculptural decoration still in place on the Parthenon and proposals for placing copies of the sculpture now in various museums on the Parthenon.

3. The problem of the oxidation of the iron clamps and the possibilities for protecting the sculpture still in place on the Parthenon.

4. Measures to be taken in order to enable the Parthenon to withstand earthquakes.

5. Methods of documentation for the restoration proposals.

A word-for-word presentation of the discussion is precluded because of its length and because of technical problems in recording. Therefore the main critiques and opinions on the subjects listed above are summarized on the basis of tape-recordings of the proceedings.

1. Principles and proposals for restoring the Parthenon

The main discussion about the principles to be adopted, the extent of the operations and the proposed programs were as follows:

Mr. B. FEILDEN* spoke as follows:

First may I repeat my congratulations to the Committee for the Preservation of the Acropolis on their excellent presentation and the accuracy of their work.

The strategic problem seems to be how to protect the Parthenon against decay from the climate – especially atmospheric pollution and from the rusting of iron clamps which weaken its structure and to improving the monument's resistance to earthquakes using the minimum intervention so as to do least harm to the monument.

The Venice Charter is the Old Testament of conservation but within it is implicit the New Testament as Dr Erder, Director of ICCROM, puts it:

«I shall do no harm to the monument because I love it», and

«The minimum intervention does least harm».

There is a need to integrate the proposals which have been submitted to deal with the active causes of decay noted above. In the case of earthquakes I heartily endorse the recommendations for further studies using instrumentation on site, as the foundations on the South side together with unloading and reloading the ground here present special problems. It would harm the monument if the wrong measures were proposed against earthquakes so these studies are vital.

We have not been given technical details of how the architect intends to deal with cracks and fissures in the masonry. We do not know the rate of decay of the marble due to pollution and methods of dealing with lacunae have not been discussed. Lacunae present a problem. What is the proportion of the restoration that will be faced in new marble? How will the lacunae weather with time? The principle is that lacunae should, in visual terms, stand behind the ancient work; they should be less visible. This raises questions of the colour of the marble and its texture as well as detailed treatment. A good example of the treatment of lacunae is to be found in the Arch of Titus in Rome, whereas the Arch of Constantine is not nearly so successful. Is there possibly a darker grade of Pentellic marble which will be satisfactory?

The role of the architect is like the conductor of a piece of music. His multidisciplinary team are the skilled specialist instruments in the orchestra.

* Ed.N. Contributions marked with an asterisk were delivered in written form at the end of the meeting and are given here unchanged.

The conductor must not alter a note in the musical score but he can give a good or bad artistic presentation of the monument. Conservation is ultimately artistic. But it is dangerous to the monument for the architect to seek the «best» solution as it does not exist. All he can do to is find the «least bad» through multidisciplinary consultation.

I would like to see studies showing the position of all the iron clamps to be replaced, studies of earthquake strengthening, studies of the areas of lacunae that must be filled and drawings showing in perspective the effect of any proposals, for we must not neglect the landscape values as well as the poetic, symbolical and historic values of this wonderful ruin, the Parthenon.

It seems to me that we have been presented with a maximum intervention but what we recommend is the minimum intervention taking all factors into account. My position as representing ICCROM is to congratulate the committee and their architects on their presentation and to state that we are here to help. The conclusions and advice of the seismic group are particularly helpful and I support these. As a professional it is not possible to make a judgment as we have not been provided with sufficient information and possible alternatives. The architect must resolve the contradictions inherent in any great project such as this and produce a balanced judgent finding the «least bad» solution. I hope in the future detailed schemes will be presented for international appraisal.

Personally I am most impressed by the work that has already been done in a short time. Indeed, in all humility, I wish that I had been able to do as much before my major conservation projects, but the Parthenon is the wonder of the world and only the best is sufficient. We have come here because we love this marvellous monument and wish to help you. Congratulations on the useful work that has been done.

Mr. R. DI STEFANO* spoke as follows:

The delay in the distribution of the working documents as well as the language barriers, a problem which becomes more acute because of the lack of simultaneous translation, have not prevented me from understanding and appreciating the importance and the supreme quality of the analysis that have been made in the past and that are still carried out on the monuments of the Acropolis.

As far as the Parthenon is concerned the solutions proposed do not seem to be definite and free from any doubt. The problem is a very complex one and a solution cannot be easily found.

Among other considerations, we should bear in mind, that restoration does not mean the creation of new forms, but the conservation of the old in the present for the present and through the use of new restoration techniques.

Restoration – which is conceived as a mechanical reassembling of broken-up, still existing parts – has certain precise limits which are defined by what is «necessary» and not by what is «possible».

This means that in those cases where all the parts are present and as a result it is *possible* to reconstruct an architectural structure, this does not mean that this reconstruction is *necessary*.

The necessary is established, in its turn, on the basis of the critical and aesthetic judgement, on the one hand, and by the full respect of the balance between the historic instance and the aesthetic instance, on the other. This means that, generally speaking, the «necessary» coincides also with the «minimum intervention».

This is where the great difficulty of the restoration of the Parthenon lies. It is true that now, more than ever before, we should look for the most thorough and extensive coordination both of the theoretical and of the technical contribution of the specialists. We should have the greatest possible control of the work by the direction team of the restoration work (because we cannot have only one restorer). We should always keep an eye so, that the architectural inventiveness of the restorer does not prevail over the masterpiece (work of art) to be restored. Moreover so that the message that the monument wants to convey to us (the word of the past) is never cancelled by the loud and arrogant tone of our civilisation and of the technology of our times, which is capable of creating, above all, pollution, traffic, massive tourism, all of which are among the most real and fundamental causes of the degradation of the Parthenon.

Will it be possible to conserve the Parthenon (*in situ* and not in pieces in a museum) without intervening on the causes of its degradation, that is on the sources of pollution, by making an effort to reduce it to the lowest level or to remove them completely? What do you think of doing on this specific point?

This, among many other things, remains to be studied, in the framework of integrated conservation. For the time being, it is wise to follow the solution of «minimum intervention», if we do not want to make of the Parthenon a false and cold copy, through our concern to conserve only the matter and not the values of art and civilisation.

Mr. J. DIMACOPOULOS* spoke as follows:

The work report presented by Mr. Korres today contains what is no doubt the most penetrating analysis ever made. Accomplished by dint of hard work and understanding it deserves our praise and congratulations, especially when we consider that the author has presented only part of his work. Because this international meeting convened not long after the completion of M. Korres' report (on the proposals for the twelve Parthenon projects), this is the first time that the members of the Acropolis Committee (excepting Mr. Ch. Bouras) and the other participants have had the opportunity of seeing the detailed report.

The reasons which made it necessary to undertake conservation work on the Parthenon, or rather the building in the state to which earlier efforts had reduced it, especially Balanos' work fifty years ago, have been set forth *in extenso;* the same reasons led to the conservation program for the Erechtheum, presented at the meeting of December, 1977. I therefore shall not comment on Mr. Korres' proposals for means of fighting the three basic causes of damage which have existed in the past, exist now and which will exist in the future (namely, atmospheric pollution, rust from metal components used by Balanos and earthquakes – a topic now under intensive debate in another conference hall); I shall discuss proposals for other projects, that have aims above and beyond conservation, which the two gentlemen in charge of the entire report deem advisable to carry out now, together with the preceding projects. According to Mr. Ch. Bouras, the goal is to enhance the value of the building as a historical, archaeological and scientific document and as a work of art and object of admiration, to increase its educational value for visitors. These aims, however, are not, apparently, based on the Charter of Venice, but rather on some new principles, principles which are now put forward as the theoretical foundations for Mr. Korres' proposals and which, according to Mr. Ch. Bouras, are valid for all ancient Greek architecture in general. The last of these principles, nevertheless, tells us that we have an obligation to restrict to the minimum changes in the appearance of the monument brought about by our operations and sums up the most recent problems perplexing those occupied with the theory of how to conduct restorations in Europe.

The last principle sums up, in a way, as incorporated in the plans and proposals of Mr. Korres, my own objections and anxiety, which I shall now set forth in all sincerity and good faith.

I believe that the additional proposals, going beyond the work that is essential for conservation, are by no means a minor matter or of limited extent. On the contrary. Consider what is being proposed: the east and west façades to acquire an absolutely symmetrical composition by restoring both pediments complete with horizontal and raking cornices and the tympana, this to be accomplished by adding completely new blocks to the existing remains of ancient blocks (some of which themselves have to be eked out with new material); the greater part of the south wall, which was destroyed by the explosion set off by Morosini's cannon almost three hundred years ago, to be built up again, the only question being the precise height; virtually the whole east porch to be restored; in addition to all of this there are plans for a systematic detailed «healing of old wounds» as Mr. Korres characteristically designated his proposals, to use material to close up virtually all of the cracks and damage to steps, column drums, column capitals etc., damage that men have caused particularly during the most recent period in the life of the monument. Considering the nature of the proposed restoration, I do not believe that it would be possible for anyone to claim to be following the principle of keeping changes in appearance to a minimum, nor would it be possible not to admit that the proposal involves an utterly different, a new image of the Parthenon, absolutely unrelated to any way the Parthenon has looked to the civilized world for the past three hundred years, during which, I wish to remind you, the modern world came to know and admire this incomparable monument of classical antiquity. One must take into account that the proposals for restoring the Parthenon involve placing a great many copies of the sculptural decoration on the building, copies of the sculpture removed by Elgin and also those which we ourselves took away and housed in the Acropolis Museum. These copies would merely increase the educational aspect of the building at the cost of sacrificing authenticity, a disadvantage to which a further disadvantage is linked, namely the new material used to complete some hundreds of fragments of the originals and, also, the entirely new pieces which it will be necessary to add here and there. This would have three dire consequences:

1. The picture of the ruin would be obliterated and along with it the picturesque quality with which it has been endowed by time and historical destiny, including both the building itself and the surrounding area of the Acropolis with its ancient marbles scattered around, either left where they were or «put in order» by the various rebuilders.

2. The Parthenon would lose its historical significance to a considerable degree, especially in regard to recent centuries, a period during which the historical fortunes of the Parthenon are closely interwoven with those of the city.

3. The relationship with the other Acropolis monuments would be severely jolted, the equilibrium achieved by Balanos or, as it may be, we have been seeing it for the last half a century as an achievement of Balanos without being able to persuade ourselves, in the present state of affairs, that a new equilibrium could ever be attained. Mr. Korres has been led to overstep the bounds of even the new guidelines laid down by Mr. Bouras by means of the doubtful argument, that this project is justified by the necessity of rescuing the widely-scattered blocks from further decay, the blocks which he himself has so skillfully succeeded in identifying. And this is coupled with his enthusiasm for recovering the ancient glory and architectural distinctiveness of the Parthenon, as he typically reports. Thus, the final result is bringing together a mass of larger or smaller fragments belonging to the architectural blocks which, after being made up with a smaller amount of new material, are to be «reassembled» in their original places in the building, places from which they had been violently torn as a result of the historical fate of the monument, the Acropolis and the city; and, furthermore, the architecture is to be completed by some scores of copies of the sculpture or countless «healing of wounds». All of this gives us a vision of the «reversible» Parthenon in 2000 A.D., a vision so one-sided and narrow-minded that it cannot, I

think, elicit our assent. For these reasons I think, that all of these «opportune» large-scale operations should undergo radical reexamination followed by dialogue before any final decision be taken.

Mr. A. PAPANIKOLAOU noted that problems of the same sort had arisen during the Erechtheum conference of 1977, i.e. problems concerning methods, technique and extent of operations on the Acropolis buildings with such great historical and cultural significance for mankind. At that time it was thought that a special charter should be drawn up for operations to be undertaken on Acropolis monuments. That is not necessary. But in addition to the principles in the Charter of Venice, whose chief aim is to preserve the authenticity of the monuments, a supplementary proposition concerning the Acropolis monuments ought to be added, whereby the monument is to be preserved in a condition to withstand the ravages of time and to ensure a new static equilibrium (using the existing ancient material) that is capable of withstanding injurious physical factors, such as earthquakes, atmospheric pollution, strong winds etc. This proposition, were it to be adopted, would automatically raise the problem of reconciling the internationally accepted principle of introducing the least possible changes in a monument with the necessity of restoring badly damaged architectural blocks in order to establish the minimum safety standards for equilibrium in its rebuilt state. Mr. Papanikolaou said that this is the only way of satisfactorily determining the scope of operations on the entire monument or sections thereof.

Mr. W. HOEPFNER drew attention to the comprehensiveness and scientific precision of the «Study for the Restoration of the Parthenon» by Messrs. Bouras and Korres, and pointed out that no such study has ever before been made, perhaps, for any other building in the whole world. Their report made it clear that the suggested proposals for restoring the Parthenon are the result of long serious consideration of the problems and of a thorough investigation of each detail. If the proposed restoration is carried out the Parthenon will, indeed, look very different from the way it does today as a result of N. Balanos' operations. It is, however, by no means a foregone conclusion that it is necessary or even desirable to preserve unchanged the image of the Parthenon that merely mirrors the most recent episode in its long history up until now. Mr. Hoepfner stated that in the course of over two thousands years the Parthenon has assumed various forms, the most important of which is its original form in antiquity and not the romantic image of a ruin nor the fortuitous picture emerging from repairs done at the end of the 19th and beginning of the 20th centuries. The architect of today should concentrate on the original form of the building and in this spirit he may legitimately proceed to reerect the building, insofar as the preserved ancient blocks allow. The monument has to be protected as much as possible from physical damage such as rain, pollution etc. This can be achieved only by restoring the ancient cornices, whose original function served precisely that purpose: protection from the elements. For this reason, the Parthenon should, if possible, be rebuilt at least up to the height of the ancient cornice. Mr. Hoepfner asked too if any thought had been given to roofing the whole building in order to protect it, especially from rain.

Mr. G. LAVVAS spoke of the excellent work carried out by the research team that stands as a model for similar studies; he agreed that there is no need to leave the building in the form given to it by Balanos' restoration and that the proposed scheme would certainly improve and clarify the appearance of the building. At the same time it would not be right to overlook the fact that the Parthenon is not merely a monument of the 5th century B.C., it has a history of around two and a half millennia. Is it not possible that some of the proposed schemes, especially those meant to heal the wounds inflicted by historical events, would conceal precious historical evidence indelibly impressed on the building. One criterion for setting limits to the operations to be undertaken should be that the evidence for the history of the Parthenon should be preserved as it is, unchanged, without concealing the different ways in which a specific series of historical events have set their mark on this eminent monument.

Mr. G. GRUBEN stated that the anastylosis of a monument of such unique value as the Parthenon requires very great caution. He has the impression, however, that the proposals for rebuilding do not radically alter its form; the changes are minimal especially on the south and west sides. Certain special problems, nonetheless, require further clarification. There is a problem, for example, in restoring the colonnade of the pronaos, for which the reerection of five columns is planned. One should check to see if 70% of the ancient material is actually preserved, as Mr. Korres says, and also how much of the surface of the columns is preserved and clarify the method of restoring the column drums. A second matter to be cleared up is the method of filling in the gaps left by Elgin's seizure of the metopes. These gaps must be filled in before the cornices above them are reconstructed.

Mr. P. BIRDACHAS stated that the proposals for restoring the Parthenon take no account of its surroundings, i.e. the modern city of Athens. It is, however, a known fact that the buildings function now, as they did in the past, in direct relationship to their environment. Therefore the anastylosis of the Acropolis monuments should be combined with improving the standards of health and living in Athens.

Mr. N. CHOLEVAS also supported the principle of restricting operations on the Parthenon to the minimum. Although the principle of reversibility makes the proposed measures doubly safe, it does not solve the problem of the marks that time and history set on the building.

In the course of the discussion a main question was raised; if the proposed intervention aims in restoring the Parthenon in the form it had at a particular historical moment.

Mr. CH. BOURAS replied to the questions and objections reported above, first noting that only the first of twelve proposed projects, the one that involves reerecting the east façade, is fully worked out and ready to go, if approved by the specialists participating in the conference. The other eleven projects are still at the stage of preliminary studies, they are ideas which the team considers sound and worth developing. Naturally enough, some of these projects are not yet ripe for final decision. Many points having to do with the actual working procedures still have to be worked out and studied further. For example, in regard to removing the west frieze from the building, a suitable place for display in the museum would have to be found, whereas in respect to roofing the west wing problems concerning the static loads are still not settled, which stand in the way of coming to a final decision on the strain to which the columns would be subjected through the added weight of the ceiling. In this particular case it is possible to make a choice among several alternative solutions: rebuilding the marble ceiling or constructing a ceiling of some light material, wood or synthetic, which would look like a marble ceiling but place less strain on the architectural members supporting it. Mr. Bouras expressed the hope that in the future there would be other international meetings of specialists to examine the undecided points in depth and come to final decisions. Mr. Bouras said that a temporary roof for the whole building was out of the question for both aesthetic and practical reasons; the crane which has to operate inside the Parthenon could not function under a protective roof.

In regard to the criticisms, reported above, concerning the theoretical side and the guidelines for the proposed procedure, Mr. Bouras responded that every anastylosis is a controversial act bearing within itself the germ of inconsistency. No effort at anastylosis can ever be a total success from all points of view, historically, scientifically, aesthetically etc. Success depends on how well it is possible to establish a creditable equilibrium among the various desiderata and that is the goal of every restorer. The problem is solved by insuring that the procedure is reversible, which is accomplished by using strictly controlled methods and techniques. This is the aim in the case of the Parthenon, so that if future generations find the proposed anastylosis regrettable they will be able to return the Parthenon to its former state by removing the various additions. If the proposed plan is carried out the shape of the building will indeed change. But we must not ignore the fact that the form of the building as it now stands is entirely fortuitous, created by Balanos who stopped the rebuilding of the Parthenon where he did because of limited archaeological knowledge and the empirical nature of his enterprise. The aim of the present proposed projects is not by any means a revival of the Parthenon but to improve and increase its effectiveness as a historical, archaeological and scientific document and as a work of art and, above all, the preservation of the architectural blocks, scattered all over the Acropolis, that are daily being destroyed at an accelerating rate of speed. These architectural members are likewise ancient monuments transmitting valuable information and history; the best way of saving them is to reincorporate them in the building with which they constitute an inseparable whole. Lastly, as far as the problem of pollution and the deterioration of the Acropolis environment is concerned, this painful topic is a more general political and administrative matter, outside the limited scope of the activities of the Acropolis Committee.

Mr. M. KORRES stated that the proposed anastylosis never aimed at restoring the Parthenon to one of its past phases. In any case something like that would be impossible. The restoration will effect a new configuration, that is, a new general outline, which will depend mainly on the extent of our capabilities. Many of the proposals are not yet ready to be put into practice: for example, the alternate solutions given for building up the flank walls of the Parthenon cella do not imply any decision about the final form of this part of the building but simply supply the statistical information about the quantity of original material available for incorporation in the building. The final form will emerge from try-outs in which a choice will be made between an open stepped arrangement, more in accord with the image of a ruin, or a straight horizontal termination, more nearly approaching the original structure.

The reerection of the pronaos colonnade is the most venturesome of the supplementary proposals and comes last in the program: five columns will be reerected and the remaining parts of the ancient surface will be different on the outside eastern half of the columns from the inside western half. The western side will be plain; but the original flutes will be kept to a large extent on the east. A special study of the column drums will, of course, be done and an attempt will be made to determine the exact position of each. Up until now the architraves and column capitals of the pronaos colonnade have been investigated. When the report is finished it will be scrutinized at another meeting of specialists, when the final decision will be taken.

Mr. M. Korres replied to the criticism that the proposal to obliterate shell-marks from the siege of 1687 on opisthodomos columns involves the loss of precious historical evidence. He said that this objection would be valid only if the explosion had never taken place and the sole evidence for the siege of 1687 consisted solely of those traces. Since, however, the reerected Parthenon peristyle columns will bear eternal witness to Morosini's bombardment, the disappearance of scars from shells would certainly not alter the historicity of the building.

2. *Preservation of the sculptural decoration still in place on the Parthenon and proposals for placing copies of the sculpture now in various museums on the Parthenon*

The main discussions about this subject were as follows:

Mr. G. DONTAS * spoke as follows:

I am deeply impressed by the tremendous labours accomplished by Mr. Korres and the highly scientific methods he employs. I would like to make some observations on the proposal to place casts of some of the Parthenon sculpture on the building for educational reasons and in order partially to recapture the marvellous way in which the architecture and sculpture originally went together. Naturally I appreciate both the purpose and the significance of the proposal and also the effect that such a restoration would have on the great masses of visitors to the Acropolis.

On the other hand I fear that the addition of a lot of casts would «falsify» a monument of unique artistic worth and that it would introduce an intrusive element of stage scenery entirely out of keeping with its profoundly sculptural organic character. It may well be that this type of supplementary restoration is admissible in monuments of later times in which optical, decorative or illusionistic effects constitute virtually the sole means of expression, but in monuments of classical antiquity and earlier times the architecture of which has strong tactile values (to use Wölfflin's term) the use of copies should be limited to the places where they are absolutely necessary, as in the case of the Caryatids which had to be replaced by copies because of the necessity of preserving the originals from inexorable decay and of filling in a vital gap in the architecture of the building. Such operations, nevertheless, should be few and far between for the reasons I set forth. Perhaps, and I repeat perhaps, it is legitimate to substitute copies only in the case of sculptures which have been or will be taken down from the Parthenon for preservation and conservation.

Mr. Dontas then requested further clarification on plans for protecting the metopes still *in situ* which, no matter how poorly preserved, are an important part of the classical decoration of the building.

Mr. CH. BOURAS replied that in his opinion the metopes should be removed from the building as quickly as possible, especially those at the NW corner that are fairly well preserved, whereas the others were chiselled off in early Christian times. In any event the Acropolis Committee has not yet come to a final decision about what is to be done with the metopes and with the west frieze. Removing the metopes from the building is easy as it is a simple matter to shift the cornice blocks above, but removing the frieze involves dismantling for the first time the blocks of the course over the frieze that have not been disturbed since ancient times.

Mr. K. JEPPESEN expressed reservations as to whether casts could possibly be a convincing substitution for the original sculpture. It would be important, however, to indicate the places formerly occupied by sculpture. This could perhaps be done with schematic flat plaques.

Mr. G. DESPINIS stated that the sole means of saving the Parthenon sculpture, at least at present, is to put it in the museum and substitute casts on the building. The sculpture of the Parthenon had already begun to disintegrate in the last century, as Michaelis' appeal to the First International Archaeological Congress in Athens, makes clear. At that time Michaelis went back to his earlier suggestion of placing a protective roofing above the west frieze similar to that which was constructed nearly seventy years later. If the removal of the sculpture be delayed, in a few years there will be nothing left of the frieze and metopes except for the backgrounds. Mr. Despinis was in full agreement with the proposal of placing casts of sculpture on the building, especially pediment sculpture whose lower surfaces are preserved: Figures D and E, F, K-L-M of the east pediment and Figure A of the west pediment. Endeavours should be made to save all of the marble fragments scattered around the Acropolis since the time of the large-scale excavations at the end of the last century, just as much as for the Acropolis buildings. Some of them are very important monuments, such as the bases of votive offerings that can be identified with those reported by Pausanias and preserve sculptors' signatures and traces of attachment for statues. All of these fragments together with the scattered fragments of sculpture on the Acropolis and its slopes, in the Asklepieion, in the theatre of Dionysos etc., should be protected in roofed areas. The work of the Acropolis Committee for saving the monuments should be accompanied by efforts to find sheltered areas for all of these precious antiquities, which only in this way may be rescued and studied.

Mr. H. KIENAST agreed that the sculpture must be removed from the Parthenon but he expressed a deep sense of uneasiness at the idea of replacing them with casts. This plan, suggested as a temporary measure today, could become permanent and final tomorrow, since there is no reason to believe that the original sculptures will return one day to their places. Is it possible that taking the easy way and replacing the sculpture with casts would lead to much more sweeping substitutions for buildings and complexes in the future? Mr. Kienast, thus, preferred Mr. Jeppesen's suggestion of substituting not casts but simple plaques indicating the original positions of the sculpture.

Mr. L. BESCHI said that in a way he felt morally responsible for the catastrophic acts perpetrated by his fellow-countrymen Morosini and Titta Lusieri to which all of the serious problems of the present day hark back. He stated that all of the sculpture still *in situ,* including those preserving but faint traces of carving, should be taken down from the building as soon as possible and replaced with casts. This kind of procedure is admissible and has been successfully carried out in Italy. In similar ensembles of sculpture and architecture at Florence, such as Orsanmichele or Giotto's campanile, the sculpture has been taken down, removed to the Museo dell'Opera del Duomo and replaced by casts. The proposals for placing casts of the Elgin marbles on the temple are sound and should be carried out. Had they not been carried off by Elgin, they would be in place today and would present the same problem as the remaining sculpture. This too should be transferred to a museum and replaced with casts on the building. Many different ways of making casts should be tried out so as to achieve the best possible artistic results and preclude any alteration or distortion in the texture and character of the Parthenon, a unique work of art that can never be created again. On the other hand, the proposed substitution of schematic plaques would certainly «falsify» the building fatally. It is true that copies of the sculpture would change the Parthenon as we see it today. This image of the Parthenon merely represents, after all is said and done, one phase of reconstruction which there is no reason to maintain unchanged. Insofar as the preserved ancient material is available, one should aim at recovering the pre-Elgin phase of the Parthenon and, in certain sections such as the east porch, the pre-Morosini phase.

Mr. F. BROMMER spoke as follows:

Als Rodenwaldt sein Buch schrieb über die Akropolis, standen ihm die Aufnahmen von Hege zür Verfügung, und er hat sie verglichen mit den Aufnahmen nach den alten elginschen Abgüssen, und hat die fürchterliche Verschlechterung des Zustandes von 1801 bis 1929 festgestellt und darüber einen Aufsatz in der Berliner Illustrierten Zeitung vom 28. April 1929 geschrieben mit einem Aufruf, der ungehallt verschollen ist. Nun sind zum

Glück die Arbeiten aufgenommen worden, aber ich frage mich, was geschieht mit den Skulpturen? Man hat zum Glück die Kekropsgruppe und die Figur W aus dem Westgiebel entfernt und in das Museum gebracht, so dass diese Skulpturen geschützt sind. Und man hat sie durch Gipsabgüsse ersetzt, und die ganze Prozedur ist ohne Schaden vor sich gegangen. Man könnte nun den Westgiebel noch weiter durch Gipsabgüsse füllen, wie das Professor Berger vorgeschlagen hat, und man sollte dasselbe für den Ostgiebel tun, die Originale entfernen und so viel wie möglich Gipsabdrücke hineintun. Und der nächste Schritt wäre die Erhaltung des Westfrieses, der auch am besten in einem Museum untergebracht würde, ebenso wie die Metopen, die sich noch an dem Bau befinden.

Man hat den Eindruck, dass die heutige Bearbeitung des Parthenon von Seiten der Naturwissenschaftler und der Architekten in besten Händen ist, aber ich bin nicht darüber informiert, was man mit den Skulpturen vorhat; sie müssen dringend geschützt werden. Denn jede antike Architektur kann durch neue Stücke ersetzt werden aber keine antike Skulptur kann durch neue Stücke ersetzt werden. Was verloren ist, ist rettungslos verloren.

Mr. M. KORRES* spoke as follows:

The speaker took his stand on the subject under discussion after carrying out a systematic analysis and appraisal of the various values of the monument[1]. *Analysis* and *appraisal* are used in the absolute meaning of the terms. The single manifold and vast value of the monument as a whole *may* also be analyzed as a number of separate values each with its own nature. These values are not indefinite; they are capable of being defined, measured or, at the least, evaluated. The evaluations allows us to draw the scientifically indispensable comparisons. The rightness or wrongness of an opinion or decision is independent of the manner in which it is formed, i.e. by instinct or through analysis. But when it is a question not of *forming* an opinion but of *supporting* it, then it is eminently useful to elucidate the manner in which an opinion is formed in order to set the stage for dialogue, all the more so when there are differing views.

I believe that replacing the marble originals with copies is the best thing to do under the present circumstances if, in fact, the experts are not mistaken in stating that the marbles are suffering damage from being exposed to the atmosphere.

As far as the *artistic value* of the sculpture is concerned there is no difference between the original and a copy, just as there is no difference in literary worth between the author's autograph manuscript and the printed book[2]. It is

1. The evaluations and comparisons given here in a simple and generalized form are drawn from a lengthy analysis, worked out in full detail.

2. The speaker's remarks to the conference was cut short at this point. Because of

true that the original sculptures have other valuable qualities besides the artistic qualities, just as an autograph text may be not only a literary work but also a historical document and a souvenir valuable for its associations. However, according to the premise initially stated, we are dealing here with the analysis of *individual* values, principally with the artistic value only. Something will be said about the others later on.

Let us assume that we are confronted with an original and next to it a copy faithfully reproducing the tiniest perceptible details of form, colour, tone and texture.

If we believe that the original has a greater artistic value we are, in fact, trapped in a methodological difficulty: we are talking about the artistic value but we actually mean the total value whose glamour entrances us. (Let it not be supposed that the man who isolates the different kinds of values in obedience to the requirements of the scientific method is out of sympathy with those who are charmed solely by the magic of the intricate total value of artworks).

If the physical substance is the medium for a spiritual work of art, then a faithful copy comprises two art works: firstly it continues to be a work by the creator of the original in *all of its integrity* and in addition it documents the skill of the copier. It is to be taken for granted that *respect* for the original precludes using the original method of production and leads to mechanical methods of copying so that, as far as the technical characteristics of the copy are concerned, no confusion between the two could arise.

The other values: There are many other values besides the artistic value, for example historic, memorial, economic, social, conceptual, and all of these values are of course accompanied by a totality of meanings (in the sense described by semantics). Of course the media transmitting the artwork (marble, copies in any material, photographs, printed matter, drawings, texts, reports etc. comprise the documentation of the artwork and of its functions. The most valuable of all of these is, naturally, the original material of the artwork, not only for itself but also as a historical document and as a memorial (memorial both figuratively and literally, i.e. an object which evokes memory, collective memory with all of its emotional impact).

The original, as an object, has one more dimension than the copy: time. Whereas the physical properties of the original are copied and *transferred* to various other representations, the antiquity or authenticity of an artwork is an exclusive, *non-transferable* sovereign property. A long time-range is not, to

lack of time and because of a feeling that part of the audience was reacting unfavourably the speach was not finished with the result that the little that was said was misinterpreted.

be sure, a rare thing, but here we are not talking of biological or geological eras but of historic periods. That is, however, the ultimate distinction. It would not be right to distinguish various categories, such as historical buildings, historical sites, historical trees etc., because we are concerned with the dimension and function in historic time and not with the physical material. If, however, such a distinction were to be made, that would be a methodological error, confusing the value of historical associations with artistic or other values.

By analyzing and evaluating the scale of values and comparing individually isolated values of the Parthenon among themselves and with those of other monuments, the present writer is absolutely convinced that the Parthenon is extremely valuable as a historic monument and a memorial of great import. Nevertheless, in respect to these values the Parthenon is comparable to a great number of other monuments. The artistic value of the Parthenon is in the end so immense that it automatically takes precedence over other one of its values. Furthermore it is the concensus of opinion that few other monuments are comparable in respect to artistic value. This evaluation cannot be a matter for doubt, not even from the standpoint of contemporary critical theories, unless it be those attempting to relativize values, overrating the influence of ideologies and self-interest on the quality and the means of judging artworks.

1. Removing the original sculptures diminishes the antiquity-value of the Parthenon, but lengthens the life of the originals inside the museum.

2. Not to replace the sculptures (both those which may be removed in the future and those which have already been removed in the past) with good copies is equivalent to sacrificing a large part of the artistic value of the monument for the sake of avoiding a comparatively minor sacrifice of the antiquity-value (bearing in mind that the artistic value is paramount while the antiquity-value is comparable with that of hundreds of monuments).

3. The present artistic worth of the building is not harmed by replacing the sculpture with copies; on the contrary it is increased, *the added value already belongs to it,* as stated in the beginning. The antiquity-value (authenticity) is diminished but to a much lesser degree than the increase in artistic value. The sculptures are almost completely protected in the museum; the visitor has the possibility of viewing the sculpture both on the building from afar and in the museum close up. The value of these artworks will, naturally, endow the museum with unique excellence.

Lastly, Mr. J. ŠRÁMEK, reporting on substances from which copies may be made, suggested using polymers instead of cement. Mr. Šramek stated that polymers are superior to cement because of their elasticity and light weight, producing much less of a load on the supporting structure and he expressed his conviction that the various difficulties in using polymers (colour changes, cracks etc.) could be eliminated.

3. *The problem of the oxidation of the iron clamps and the possibilities for protecting the sculpture still in place on the Parthenon*

During a special closed session the chemical engineers and the chemists discussed the problem of the oxidation of the clamps and dowels, especially in those parts of the Parthenon which will not be dismantled during the proposed intervention and the possibility of protecting the sculptures in place on the building, especially the west frieze. The chemical engineers and the chemists reached certain recommendations (see p. 235f.) which Mr. TH. SKOULIKIDIS communicated to the other members of the conference.

This was followed by some requests for more information, particularly about protecting the west frieze.

Mr. Th. Skoulikidis answered that the team of chemical engineers think that at the moment there is no way of stopping sulfur dioxide from attacking the marble. Consequently, the frieze must be moved into a museum. It will, however, take quite a long time before this is done and in the meantime methods proposed for protection could be tried out experimentally on other marbles, not on the west frieze. If these methods prove effective, they could be temporarily used for the sculpture on the building, until it can be moved into a sheltered place. These methods are not, of course, a permanent answer. They merely slow down the rate of formation of the gypsum film as long as the sculpture continues to be exposed to atmospheric damage.

Mr. Skoulikidis stated that the possibility of returning the sculpture to its original position on the monument is not to be ruled out. That depends mainly on finding a suitable protective coating for the surface of the marble and on cleaning up the atmosphere. It is highly probably that a suitable coating will be found, since thirty to forty laboratories outside of Greece and the Physio-Chemistry Laboratory of the National Technical University of Athens have been working on this project for quite a few years, conducting around ten thousand experiments on Pentelic marble sent to them. The process by which marble turns into gypsum is now fully understood; it was discovered in the Physio-Chemical Laboratory of the National Technical University of Athens. It would take fifteen to twenty years to purify the atmosphere to the point of halting the damage to the marble. If in the future, nevertheless, the requisite conditions were to be fulfilled, it will be possible to return the sculptures that have been removed to their buildings.

4. *Measures to be taken in order to enable the Parthenon to withstand earthquakes.*

The problem of the monument's antiseismic protection was discussed by civil engineers and seismologists in a closed session. This team reached certain recommendations (see p. 234f.) which were communicated to the other members of the meeting by Messrs. R. MAINSTONE and C. SYRMAKEZIS. A discussion followed in the course of which Messrs. R. Mainstone, F. Petrofski and N. Ambraseys made the following comments and supplementary proposals about the program of study and research and about the methods to be adopted in view of the final decision to be taken in the future.

Proposals from R. MAINSTONE*

I should like to offer a few further comments after subsequent discussions with other participants and with Mr. K. Zambas. These refer mostly to the Recommendations of the Civil Engineers Group (p. 234f.).

Structural Objectives: Objective 3 perhaps requires some clarification. The point being made is that any design for strengthening the structure should concentrate on minimising the risk of any part of it falling down in a future earthquake rather than on achieving particular distributions of stress or keeping stresses below certain limits.

Further Study: Underlying all the recommendations for further study were a keen sense of the shortcomings of our knowledge of the present state of the structure and the likely character of future seismic excitation, and of our ability to make truly relevant analyses of the dynamic response, plus a feeling that it would be professionally irresponsible to approve or undertake any drastic interventions until these shortcomings had been made good wherever possible.

My own feeling (which was not fully shared by all those present) is that it would be impractical to aim at undertaking a rigorous non-linear dynamic analysis of response to a precisely defined seismic hazard as one now does in designing certain modern structures. I do not think we can hope in the reasonably near future to quantify the level of safety that would be provided by given strengthening measures. But we should be very certain that all actions taken will lead to worthwhile improvements in safety.

At present I think that there is still doubt about the effects on overall safety of, in particular, interconnecting the columns in different ways through the epistyles. The emphasis in developing more realistic analytical tools should therefore be on clarifying such effects. Would it, for instance, be desirable to have near-rigid interconnections around the corners of the structure and over the next two or three columns with weaker connections designed primarily to absorb energy elsewhere?

In relation to absorbing energy, I feel strongly that the aim should be to do so without departing more than necessary from the present construction details and other traditional practices. I threw in the suggestion that there should be an investigation of the possibility of improving the absorption capacity by seating the epistyles on sheets of lead on the capitals.

Overall Objectives: The final note in the Recommendations reflected a recognition that the structure could be strengthened and safeguarded in various ways depending on the extent to which further anastylosis, the addition of new material, or the introduction of new construction details, were allowed. One might for instance allow no more than repairs of a very local kind to the standing masonry after removing rusting iron wherever possible. Or one might go considerably further than the present proposals and allow substantial addition of new material to make good losses about which there is little or no doubt. There would, for instance, be several merits in reconstructing parts of the lost roof to give protection not only against rain but also against the worst temperature fluctuations at epistyle level. These are matters that can properly be decided only from all points of view together and on the basis of a full study and presentation of all the possibilities.

In this connection I also feel that some clarification of the concept of «reversibility» is desirable. In the strictest sense I think it is an impossible ideal. And as a guiding principle it can be and was clearly being interpreted in some very different ways.

Proposals from J. PETROVSKI*

Comments and recommendations for improvement of the seismic resistance of the Parthenon in the process of preservation and restoration

The studies presented during the Committee meeting on archeological, architectural and atmospheric polution aspects of the monuments of Acropolis and in particular on the Parthenon are performed in consistent and very systematic manner and they are of extreme importance for improvement of the value and performance of the preservation and restoration process. The presented earthquake resistance analysis of the Parthenon by K. Zambas is significant effort for the initial stage of consideration of earthquake resistance of the monument in the existing conditions. However, for the needs of improvement of the earthquake resistance in the process of preservation and restoration of the Parthenon, it will be of basic importance to perform consistent and systematic studies on seismic aspects comparative with the studies performed on archeological and architectural aspects.

Considering that the monument, as it exists, could be very vulnerable to the earthquake ground motions even of lower level of acceleration (Corinth earthquake of Feb. 24, 1981), safety of the monument and major preservation steps are governed mostly by selection of seismic safety criteria.

In order to select appropriate solution for improvement of the seismic stability of the structural system of Parthenon and to develop consistent seismic safety criteria, the following groups of questions could be considered for organization of studies and performance of research work and design.

A. Seismic hazard evaluation and selection of expected earthquake ground motions

1. Probabilistic seismic hazard study of the site and determination of the expected levels of earthquake ground motions for different return periods.

2. Microtremors and shear wave velocity measurements of the hill and structure.

3. Determination of the range of dynamic amplification factor.

4. Development of integral hill-structure seismic instrumentation system to record small, moderate and strong earthquakes.

5. Selection of suitable earthquake time histories for the specific site conditions, topography and the range of earthquake magnitudes using existing strong motion records for similar conditions obtained at other sites in the country or other countries.

B. Field and laboratory dynamic studies of existing structures

1. Determination of dynamic properties of the isolated structural members and integral existing structural system by field non-destructive ambient vibration tests.

2. Model study of structural fragments and existing structural system on the two-componental shaking table with simulation of the selected earthquake time histories.

3. Specific model study of the rocking vibration of the pier elements.

C. Development of seismic safety criteria, mathematical modeling and dynamic response analysis

1. Preliminary determination of acceptable seismic safety criteria for the expected earthquake ground motions and different seismic hazard levels.

2. Mathematical modeling and development of specific computer programs for dynamic response analysis based on field and laboratory experimental studies.

3. Dynamic response analysis of the existing structural system and assessment of seismic stability for considered levels of seismic hazard.

4. Determination of seismic safety levels of existing structural system for

the considered hazard levels and conclusions for the needs for improvement of the existing structural system (peristyle continuity).

D. Improvement of the existing structural system and verification of seismic safety

Principal need for the improvement of the existing structural system is due to disintegration of the original structural system and unavoidable collision between structural elements created by earthquake ground motions. Consequences caused by disintegration of the structural system are resulting in much more unfavourable conditions in dynamic response of structural system, and collision between structural elements is resulting in development of high concentration of shear stresses and cracking of structural elements.

For the improvement of the existing structural system and verification of the seismic safety, the following basic topics could be considered:

1. Improvement of the existing structural system by integration along all periferal and incorporation of seismic energy absorption elements in the superstructure elements to avoid collision.

2. Development and testing of suitable seismic energy absorption elements.

3. Dynamic response analysis of the improved structural system for considered levels of seismic hazard.

4. Model study of the improved structural system on the two-componental seismic shaking table by simulation of selected earthquake ground motions with considered levels of seismic hazard.

5. Verification of the achieved seismic safety criteria based on analytical and experimental studies of improved structural system for expected levels of seismic hazard.

Proposals from N. AMBRASEYS*

On the protection of monuments and sites in seismic areas[1]

During this century earthquakes have caused a total death-toll throughout the world of about one and a half million, and damage has exceeded a conservative estimate of several thousand million US dollars per year on average. The damage caused to historical monuments is inestimable. Earth-

1. Ed. N For technical reasons (see p. 187) Mr. Ambraseys' oral contribution and general discussion was recorded incompletely; consequently only a part of his presentation is included in these proceedings.

quakes in the last three years alone have obliterated or damaged beyond repair historical sites in Burma in 1975, Italy and Guatemala in 1976 and in Romania in 1977.

Despite the scientific and engineering achievements of recent years little has been accomplished for the protection of historical monuments in seismic areas. This is partly due to the fact that historical monuments are extremely complicated structures, and partly due to the lack of data concerning the behaviour of such structures under earthquake conditions. Almost all monuments extant in earthquake regions have in fact been subjected to a number of destructive or damaging earthquakes, and they have survived through a process of natural selection. They are a small fraction of the total number of structures that existed in early times, and they represent today a small sample of the best final design and construction which has been achieved through the ages by trial-and-error techniques or by chance.

The inherent structural complexity, variability of building and foundation materials, as well as their final state of repair, makes each historical monument a special case for study. It is simply not possible to devise rules-of-thumb or general recommendations for their protection against earthquakes that will be generally applicable or effective without adapting them to local conditions, which may vary even within the same structure.

It is therefore only through the thorough study and analysis of existing monuments, their building and foundation materials, and their behaviour during past earthquakes that our assessment and mitigation of damage can advance.

This can best be achieved by initiating a continuing effort for the close examination of historical structures of different types and for the study of their behaviour under earthquake conditions. Until recently, too much attention was paid to spectacular destruction of monuments and too little to similar structures which survived undamaged through the same intensity earthquake. Undamaged structures represent in themselves a body of evidence from which valuable lessons can be drawn for their own protection, as well as for the protection of other constructions.

As a first step an attempt should be made to concentrate research and field studies on a variety of structures classified broadly into the following groups:

1. Free-standing, slender structures, such as columns[2], minarets and towers;
2. Column-and-beam structures, such as Greek and Roman temples;
3. Occidental and oriental dome and vault roofed structures;

2. The attached Annex shows preliminary results from the study of structures belonging to the first group.

4. Special structures, such as aqueducts, bridges, retaining walls, archways and ivans or open-fronted vaults.

Subdivision of these groups will begin to emerge only as the results of individual studies become available, particularly with respect to building materials and methods of construction.

The first step would be to prepare seismic maps of historical sites and a documentation of earthquake damage to monuments. This will tell us something about the buildings themselves and also something about the earthquakes that have affected them. This will also help to classify these structures into different groups.

The means of obtaining the relevant information should include studies that can predict their earthquake response and also field studies from which factual data can be obtained, i.e. field trips on historical monuments in seismic areas and also on seismic areas near monuments. The following approach for the initiation and development of research in these fields may be considered.

A. Preparation of seismicity maps of historical sites

Such maps will show the seismic risk implicit in different sites. Maps may be prepared for each country, making use of existing seismic zoning maps on which the location of historical sites and monuments of different groups is also shown. These should be accompanied by an explanatory text in which other pertinent information regarding the sites is also given, e.g. state of preservation, relative importance, damage sustained by earthquakes and foundation conditions.

Such maps will be reviewed at regular intervals of time and kept up to date with respect to changes in seismicity and earthquake effects on monuments. They will form a basis for classifying different types of monuments at risk, and they will also assist in the evaluation of long-term seismicity studies of the region.

B. Documentation of earthquake damage to historical monuments

This will require the detailed historical, analytical, experimental and field study of a selected number of monuments belonging to different groups that are known to have been affected by earthquakes. Such a study may disclose early methods or repairs and strengthening and their long-term efficacity; it will also provide a better understanding of the state of preservation of the monuments. At the same time the investigation of the accumulative earthquake effects on the structures will provide an indication of the severity of past earthquakes.

C. Earthquake response characteristics of structures

At this moment there is a lack of information concerning the dynamic properties of almost all classes of monuments. This information is needed for the assessment of their response to earthquake ground motions.

A selected number of structures should be tested for their response characteristics under ambient vibration conditions, and if possible under higher stress levels. Their relative stiffness and damping characteristics should then be assessed. Foundation compliance and the effect of repairs whenever possible should also be included in the assessment.

D. Field study of historical monuments in seismic areas

Any improvement in the assessment and mitigation of earthquake damage must be based on the accumulation of reliable observational data. It is the most effective approach whereby we can use our theoretical and experimental knowledge to the fullest extent, knowledge gained in the field study of monuments affected by recent and earlier earthquakes.

The objective of field studies should be to investigate the causes of damage or lack of damage to historical monuments for the purpose of adding to scientific and practical knowledge, which can be used for the safeguarding of monuments. After destructive earthquakes, field studies to examine those historical monuments which have been affected can best be organised by ICOMOS in consultation with UNESCO, UNDRO and other organisations who often dispatch Reconnaissance Missions to epicentral regions. Such missions can also be organised by ICOMOS in consultation with the local authorities of the affected region, and dispatched with the financial support of UNESCO or of an ICOMOS fund specifically provided for this purpose.

Missions may also be sent out to study the effects of earlier earthquakes on specific monuments. Their objective, in consultation with, and with the cooperation of the appropriate local authorities, would be to make a thorough documentation of past earthquakes in the vicinity of the monument, make detailed maps and study any earthquake effects on the ground itself and on the monument, and evaluate the present state of preservation of the structure. Results from such studies would add valuable information to (A) and (B).

ANNEX I

It is usually considered rather improbable that early tall, slender structures such as towers and minarets, as well as other simpler constructions liable to easy destruction by earthquakes, can stand for many centuries in seismic regions. The mere fact that quite a few of this type of construction such as slender free-standing columns of Greek and Roman temples, are still to be found in a state of tolerable preservation in various parts of the world has led to the belief that these parts have been free from destructive earthquakes.

But the evidence available, based on both field observations and analysis, suggests that this may not be true. It can be shown that in contrast with other types of more robust structures, which appear to be more stable under earthquake conditions, free-standing columns on competent foundations are more earthquake resistant than might be expected and consequently their survival over the centuries is neither surprising nor should it be interpreted as implying low local seismicity.

It has long been known that well built, slender, free-standing structures can come through an earthquake unscathed. In almost every destructive earthquake in the Eastern Mediterranean region and in the Middle East, these simple structures, such as columns of Greek and Roman temples and early minarets, survive undamaged in the same earthquake that has caused spectacular destruction around them.

In the Gediz earthquake of 1970 at Cavdarhisar (about 10 kilometres from the epicentre and less than 20 kilometres from the fault-break which was associated with this magnitude 7 earthquake) free-standing columns and their architraves of the 2nd century A.D. temple of Zeus of Aizanoi were left standing, surrounded by the damaged modern houses of the village where the intensity of shaking exceeded VII (MM). What collapsed was only a group of three columns, already weakened by the loss of almost half of their lowest drum which was removed long ago for the sake of whatever lead or iron had been used in the joining of the drums to their base, Plates 1 to 3.

The earthquakes of April 1965 and September 1966 in the Peloponessus, both events of magnitude 6, had little effect on the free-standing columns of the temple of Apollo at Bassai, except to aggravate their foundation stability which had already decreased due to differential settlements of their stylobate, Plate 4. The near-by town of Andritsaina was seriously damaged by the shocks and the intensity of shaking there exceeded VII (MM).

Eight out of the twelve minarets in the centre of the city of Skopje survived almost intact after the earthquake of 1963 which almost totally destroyed the city with an intensity of about IX (MM), Plate 5.

Well-built minarets of ashlar masonry construction have also survived destructive earthquakes in Anatolia and in the Balkans.

The destructive earthquakes of 1858 and 1928 that completely ruined the old and the new towns of Corinth respectively, failed to overturn the seven monolithic columns of the temple of Apollo which have remained erect since 1795.

During the last few centuries, the temple of Artemis at Jarash has been shaken by many destructive earthquakes. Eleven columns of the temple are still standing, although some of them, nevertheless, are tilted considerably out of true, one of them actually rocks in a high wind.

The seventeen huge columns of the temple of Bacchus at Baalbek, which rise to a height of 18 metres, have withstood severe shaking particularly in 1756 and in the 19th century. With the exception of one column of the south face which now leans against the cella (Plate 6), all the others are erect.

Columns are circular shafts, sometimes monolithic but more often constructed in drums. With the exception of very hard or heavily jointed rock they were fluted. Mortar between drums was unnecessary because the blocks were so truly laid that the stability of the columns depended on gravity. Metal dowels connected the drums in the centre.

Columns of the Doric, Ionic and Corinthian orders have a height, including their capital and base, of about 5.0, 9.0 and 10.0 times their base diameter respectively. Table 1 gives a list of 34 temples from which it can be seen that early Doric columns were treated with caution, being extremely stout and closely spaced with broad capitals to reduce the span of the massive architrave lintels, their heights on average being about 8.0 metres. With time, columns became progressively taller, thinner, and more widely spaced; the capitals narrower and lighter. Ionic columns have an average height of 15 metres and Corinthian about 17.0 metres.

The material used for the construction of columns was usually limestone, marble, andesite or hard travertine, of an average bulk density of 2.7 t/m^3, compressive strength of 0.8 kb, and a shear-wave velocity of 2,100 m/sec. The average angle of shearing resistance mobilised between drums is difficult to assess and it depends on the way in which the drums were laid. For rough contact surfaces peak values of the angle of shearing resistance should be around 35° to 40°. However, when after being placed in position, drums were caused to revolve around a central pivot until, by the attrition of sand inserted for the purpose, they rested absolutely truly on the drum beneath, angles of shearing resistance should have residual values of about 28° to 35°, considering the very low normal stresses of a few kilogrammes per square centimetre between drums.

In spite of its simplicity and relative uniformity, each column is a special case and its mechanical properties, as well as those of its foundation, are not easy to determine. Much of the damage to columns that has led to their premature overturning by earthquakes has been due to the deliberate hewing of their drums for the lead of their dowels, Plate 3. The robbing of lead dowels was common practice among villagers and nomads for many centuries, and it is one of the prime causes that has hastened the collapse of columns. Cutting off a wedge from a drum creates a metastable shaft, and since it is easier to hew columns at their base from the steps of the crepidoma, their collapse in the event of an earthquake is more likely to be away from the cella.

The collapse of columns is seldom attributed specifically to earthquakes. Occasionally it is ascribed to deliberate demolition for use of the fragments as building materials or for making lime (1750 Zeus Agrigentum; 1759 Olympeion Athens; 1764 Zeus Euromos; 1795 Apollo Corinth). More often there is a total lack of information about the cause that had led to collapse. Thus, the gradual decrease in the number of columns standing at Apadana in Persepolis (from more than 20 in 1621, to 19 in 1627, to 17 in 1677, to 15 in 1787 and to 13 since 1841, with one of the capitals precariously overhanging its shaft since 1765) cannot be attributed solely to earthquakes without further study of their remains.

An earthquake may bring about the collapse of a relatively rigid, freestanding body such as a column of a Greek or Roman temple, on one or a combination of the following ways: by causing the column to slide off its base or higher up the shaft on joints between drums; by setting the column rocking with the result that it overturns; by progressively inducing excessive permanent tilting of its foundations; or by causing drums of weak or damaged rock to fail in compression due to bending or rocking.

It can be shown that an intact, free-standing column with or without its architrave will tend to fail through excessive rocking on its base when shaken by a real earthquake, rather than failing due to shear failure or crushing of its drums. Also, it can be shown that the «intensity» of the earthquake ground motions required to bring about the collapse of a column through rocking is much higher than might have been expected.

Let us consider the response to an actual earthquake of a column resting on its stylobate. For small amplitude ground motions, columns of the architectural orders considered here, i.e. of an aspect ratio in excess of 4, will respond in bending rather than in shear, with a fixed-base frequency f_f which, for the cases considered, is given in Table 1. For an average stereobate four times less rigid than the columns ($S' = 1050$ m/sec.), the wave number for Doric columns is about 9, which implies that foundation compliance may decrease fixed-base frequencies by about 20%. For Ionic-Corinthian columns, the wave number is about 20 and the stereobate-column interaction will have little effect on their frequency in bending.

Columns, therefore, once excited into oscillation will continue to respond in bending, provided the shear strength that they can mobilise at their base is sufficient to prevent sliding and also, provided their response acceleration S_a remains below the critical acceleration $k_r g$ which if exceeded will set the columns rocking.

It can be shown that the conditions under which a column can slide on its base are given by $k_{s1} \geqslant \sin(\phi)$ for an oblique ground motion, and by $k_{s2} \geqslant \tan(\phi)$ for a purely horizontal motion. The conditions required to initiate rocking are $k_{r1} = (1 + a^2)^{-1/2}$ for an oblique motion, and $k_{r2} = a^{-1}$ for an horizontal motion, where *a* is the aspect ratio of the column (height/diameter) and $k_{ij}g$ is the minimum response acceleration required to bring about sliding or initiate rocking.

It becomes apparent, therefore, that since the response acceleration $k_s g$ required to cause sliding is larger than that needed to set the column rocking, i.e. $k_s > k_r$, the early stage of column response in bending will be followed by a phase of rocking. This is true not only for monolithic columns, but also for individual drums of aspect ratio as low as 1.7, which if forced to rock may also be displaced by turning sub-horizontally about the point of rocking. This type of displacement between drums, often attributed to sliding, can be brought about by very small angles of tilting of the drums.

Accelerations greater than $k_r g$, therefore, may set a column to rock, but will not necessarily overturn it. Whether overturning through rocking can be brought about by an earthquake will depend upon how, and for how long, inertia forces happen to apply on the column, i.e. on the induced amplitudes and also on the periods of the successive acceleration pulses, which, for real earthquakes, are much shorter than the rocking periods of columns. Acceleration, therefore, is not a criterion of dynamic stability and its use in problems of transient loading may lead to erroneous conclusions. Frequencies f_r corresponding to rocking up to 50% of the tilt required to cause instability, are shown in Table 1.

If we take as a measure of the earthquake «intensity», the value of the velocity response spectrum of the ground motion at long periods S_{vr}, we find that the «intensity» required to overturn a column is so high that before a column is overturned most other ordinary man-made structures around it should have collapsed (Appendix I). Figure 1 shows a plot of the «intensity» S_{vr} versus the height of the columns of the temples listed in Table I. It also shows the levels of S_v associated with a number of recent earthquakes (Table II).

From Figure 1 we notice that intact Doric columns are unexpectedly stable and capable of resisting severe ground motions corresponding to spectral values of 40 to 70 in/sec. with a 50% probability of survival. This observation seems to be supported by the fact that of the 19 Doric temples sampled in Figure 1, only two have lost all their columns during the past 24 centuries. These are the temple «C» at Selinus and that of Zeus at Agrigentum. The former, damaged by the small Christian settlement that had grown up around it, fell in an earthquake a millennium after it was built; its colonnade was reerected in 1926. The latter was deliberately destroyed in the 6th century A.D. The disappearance of its ruins was completed by earthquakes and wanton quarrying in the 18th century.

From Figure 1 we also notice that the weakest Doric columns belong to the temple of Zeus at Nemea which was built on relatively soft ground. Its columns, three of which are still standing, are indeed unusually slender for this order, and the drums of many other columns lie where they fell, presumably in an earthquake in the 4th century A.D.

Compared with Doric columns, intact Ionic and Corinthian columns seem to be less resistant; they are capable, however, of surviving with a fair chance quite strong ground motions, corresponding to spectral values of 25 to 50 in/sec. Their relatively lower resistance is perhaps corroborated by the much smaller number of Ionic temples that have survived with erect columns. Only six of the thirteen temples listed in Figure 1 have columns that are still standing.

From Figure 1 we also notice that the maximum value of S_{vr} for Ionic and

Corinthian columns is about 50 in/sec., while for Doric columns this value is much larger. It may therefore be expected that Ionic and Corinthian columns could be overturned more easily by both near, as well as distant large earthquakes that can produce such large S_v values at long periods. Far-field ground motions from large magnitude earthquakes, particularly in alluvial deposits, are in fact more likely to develop substantial ground amplitudes associated with short frequencies that are also close to the rocking frequencies of columns at large angles of tilting. An extreme case of short frequency loading, not due to an earthquake, is that of the 1852 thunderstorm in Athens which overturned one isolated column of the temple of Olympeion. In the open terrain in which the temple is located, an extreme gust speed of 75 m/sec. sustained for about 4 seconds, is sufficient to overturn the column. It is not unlikely, therefore, that large, distant or intermediate-depth earthquakes, like the recent event in Romania (Figure 1, BU) or like the Eastern Mediterranean shocks of 1856, 1886 and 1926, may affect Ionic and Corinthian columns more than ordinary dwellings.

Conclusions

The present analysis is only approximate and the number of case histories tested is rather limited. Nevertheless, both calculations and field evidence suggest that columns in fact have been subjected to a number of earthquakes during their life-time, and they have survived because, among other reasons, they are more stable against earthquakes than might have been expected.

Consequently, the mere fact that such structures are still standing on various sites should not be taken to mean that these sites have been free from destructive earthquakes.

Columns, particularly of the late Ionic and Corinthian order, are more easily overturned by distant or intermediate large earthquakes and by exceptionally high winds.

Columns and other simple, free-standing structures, may be used to assess probable maximum ground motions associated with local and regional earthquakes over a period of one to two millennia. From the study of the behaviour of such simple structures over the centuries one may draw valuable lessons which may be applied to other structures.

Modern structures differ in many respects from old ones and to judge future damage from century-old case histories can be seriously misleading.

APPENDIX I

Although it is not possible to predict the actual sequence of pulses associated with an earthquake, a general type of ground motion may be assumed which will consist of randomly-distributed pulses of equal probability of acting in opposite directions. For such a motion, which will essentially have a constant average undamped velocity response spectrum S_{vr}, the average change of the velocity of the column over the duration of an earthquake will be zero. As a first approximation, therefore, the total energy required to tilt the column up to its critical angle will be $^1/_2$ mgR(a)$^{-2}$, where R is the distance between the centre of gravity of the rocking system from the point of rotation. This total energy of vibration will be provided by a ground motion when this energy becomes equal to $^1/_2(I_o)$ (i)$^{-2}$ S^2_{vr}, where I_o and i are the moment of inertia and the radius of gyration of the system with respect to the axis of rotation. It can be shown, therefore, that there is a 50% probability that a column will overturn if:

$$S_{vr} > 102(a)^{-1} \{H(a)^{-1} (1 + a^2)^{1/2}\}^{1/2} \quad \text{(in in/sec.)}$$

Figure 1 shows a plot of S_{vr} versus the height of the columns (H) that belong to the temples listed in Table I. Table II gives some typical S_{vr} values and their associated ground motion characteristics of a number of recent destructive earthquakes.

Figure 2 shows a plot of S_{vr} versus the frequency of rocking F_r that corresponds to tilting 50% of the critical angle (a)$^{-1}$, together with the response spectra of two ground motions produced by earthquakes of magnitude 7.0 in the nearfield (EC, El Centro) and in the far-field (BU, Bucurest) for comparison. It must be pointed out that there is no actual correspondence between S_{vr} and f_r as the latter quantity varies continuously with the angle of rocking and consequently the plot of f_r shown in Figure 2 is only meant to show the frequency drift and also the level of S_{vr} with respect to real earthquakes.

For the purpose of illustration, consider a Doric and an Ionic column being shaken by an El Centro-type (EC) earthquake. If the columns were monolithic and rigidly fixed at their base so that they could not rock, they would respond in bending with mean frequencies of f_{fd} = 12.5Hz and f_{fi} = 3.6Hz respectively. From Figure 2 we notice that the columns would have to resist lateral forces of the order of 60% and 95% of their weight. In reality, columns are not rigidly fixed at their base nor between drums, so that they will begin to rock as soon as the lateral inertia forces induced by bending exceed about 20% and 10% of their weight respectively. In other words, their response in bending will be arrested on the dots shown in Figure 2 and the columns will start rocking, shear being prevented by the fact that $k_s > k_r$.

This will result in shortening their response frequencies from f_f to f_{rd}^1 or f_{ri}^1 or 0.8 and 0.6 Hz for angles of tilting of 10% of the critical angle (point B in Figure 2). For larger amplitudes of rocking corresponding to 50% and 90% of the critical angle, the motion will become too slow as compared to the ground motions, and frequencies will drift to points C and D of Figure 2.

TABLE I

	C	O	H	H/d	f_s	S_{vs}	k_{r1}	f_f	F_r	S_{vr}
1. Aphaia, Aegina	V	D	5.3*	5.4	41.2	1.0	18	16.0	0.32	43.6
2. Apollo, Bassai	V	D	5.9	5.1	42.3	1.0	19	14.9	0.30	48.7
3. Apollo, Corinth	VI	D	7.2	4.1	30.2	1.4	24	15.4	0.27	68.2
4. Apollo Didymeus, Militus	III	I	19.2*	9.7	–	–	10	2.4	0.17	46.1
5. Apollo (G), Selinus	VI	D	16.1	4.7	–	–	21	5.9	0.18	86.8
6. Artemis, Ephesus	IV	I	16.5	9.0	17.6	2.1	11	3.0	0.18	45.9
7. Artemis, Jarash	II+	C	13.2	9.1	–	–	11	3.7	0.20	40.7
8. Artemis, Magnesia	II	I	13.3	9.5	18.5	2.2	10	3.6	0.20	39.1
9. Artemis, Sardis	II+	I	17.7	8.9	–	–	11	2.9	0.17	48.2
10. Athena, Assos	VI	D	4.7	5.3	28.6	1.1	19	18.2	0.34	41.9
11. Athena, Paestum	VI	D	5.4	4.2	52.3	0.7	23	19.9	0.31	56.9
12. Athena, Priene	IV	I	12.3	9.5	24.7	1.3	10	3.9	0.21	37.6
13. Athena, Syracuse	V	D	8.7	4.4	–	–	22	11.7	0.25	68.9
14. Bacchus, Baalbek	III+	C	18.3	10.0	16.5	2.1	10	2.5	0.17	43.5
15. C Selinus	vi	d	8.7	4.8	24.3	1.7	20	10.8	0.25	63.5
16. Concord, Agrigentum	v	d	6.7	4.6	35.7	1.2	21	14.5	0.28	57.5
17. Dionysus, Pergamon	II	I	10.2	9.9	–	–	10	4.5	0.23	32.8
18. Hera, Agrigentum	v	d	6.4	4.7	–	–	21	15.1	0.29	55.6
19. Hera, Paestum	v	d	8.8	4.1	26.7	1.6	24	12.4	0.24	74.1
20. Hera, Sele Paestum	VI	D	6.2	4.8	39.5	1.1	20	15.2	0.29	53.3
21. Herakles, Agrigentum	VI	D	10.0	4.8	–	–	20	9.5	0.23	67.7
22. Jupiter, Baalbek	II+	C	20.1	9.0	14.7	2.4	11	2.5	0.16	50.8
23. Olympeion, Athens	II	C	17.2	10.2	–	–	10	2.6	0.18	41.4
24. Parthenon, Athens	V	D	10.4	5.6	23.9	1.7	18	7.8	0.23	59.5

25. Poseidon, Sounion	V	D	6.0	5.9	41.5	1.0	17	12.7	0.30	42.5
26. Segesta	V	D	9.1	4.7	–	–	21	10.6	0.24	66.3
27. Serapis, Ephesus	II+	C	14.0*	9.3	–	–	11	3.5	0.20	40.9
28. Theseion, Athens	V	D	5.7	5.6	44.1	1.0	18	14.1	0.30	43.7
29. Zeus, Aizanoi	II+	I	9.6*	9.7	29.9	1.3	10	4.9	0.24	32.5
30. Zeus, Agrigentum	V	D	16.8	4.1	13.7	3.0	24	6.5	0.18	101.5
31. Zeus, Magnesia	II	I	6.7	9.5	42.0	0.9	10	7.1	0.28	27.7
32. Zeus, Nemea	IV	D	10.3	6.5	27.3	1.4	15	6.7	0.23	50.5
33. Apadana, Persepolis	–	–	19.8	13.2	–	–	8	1.7	0.16	34.3
34. Karnak	–	–	21.0	6.0	–	–	16	3.6	0.16	78.1

Notes:

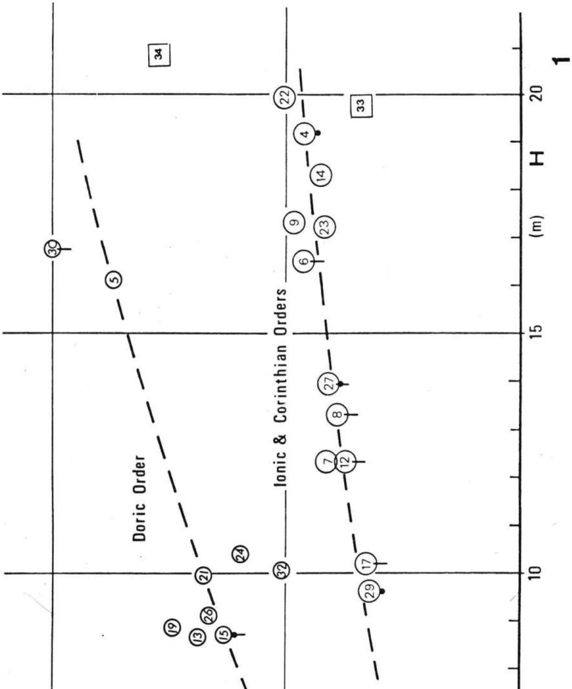
C = century (+ A.D.) of construction
O = architectural order
H = height of column in metres, including base and capital; asterisk indicates monolithic column
H/d = aspect ratio *a*; height/diameter ratio of column
f_s = fundamental frequency in shear of temple as a whole, (HZ)
S_{vs} = undamped spectral velocity required to initiate sliding of capitals if temple was complete, (in/sec.)
kr1 = minimum response acceleration ($k_{r1}g$) required to initiate rocking of column
f_f = fundamental frequency in bending of column (Hz)
f_r = rocking frequency at tilt, 50% of the critical angle (Hz)
S_{vr} = undamped spectral velocity at which probability of overturning is 50% (in/sec.).

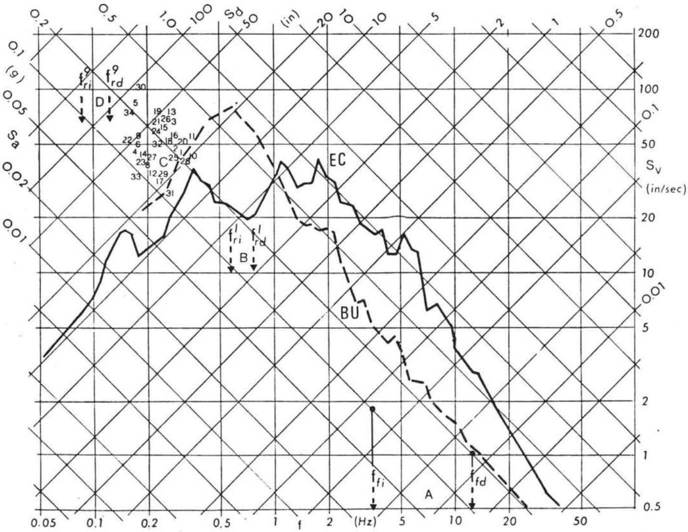
TABLE II

			M_s	d (km)	a (%g)	f (Hz)	S_v (in/sec.)	S_v (in/sec.) at f< o.3Hz
Bucurest, Romania	Bu	1977	7.2	190	21	0.6	82	40
El Centro, USA	EC	1940	7.0	14	33	1.8	44	30
San Fernando, USA	SF	1971	6.6	8	125	2.5	110	50
Leukas, Greece,	LK	1973	5.8	16	52	1.4	52	30
Parkfield, USA	PK	1966	5.5	5	51	1.3	77	30

Notes:

M_s = surface wave magnitude of event,
d = focal distance
a = maximum ground acceleration recorded
f = frequence of maximum response velocity S_v
S_v = maximum relative velocity response for 2% critical damping.


Doric Order
Ionic & Corinthian Orders
S_vr
in/sec
100
50
0
SF
BU
EC, PK, LK
H (m)
5
10
15
20
1



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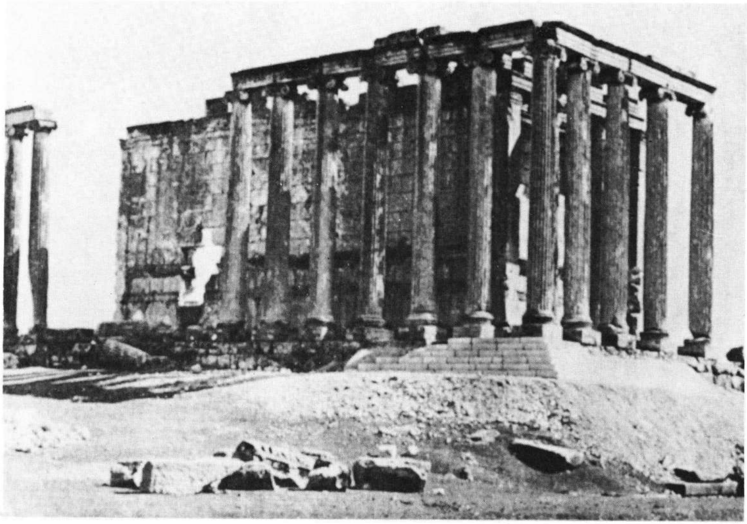


Plate 1. The temple of Zeus at Aizanoi (Cavdarhisar) before the Gediz earthquake of 1970.

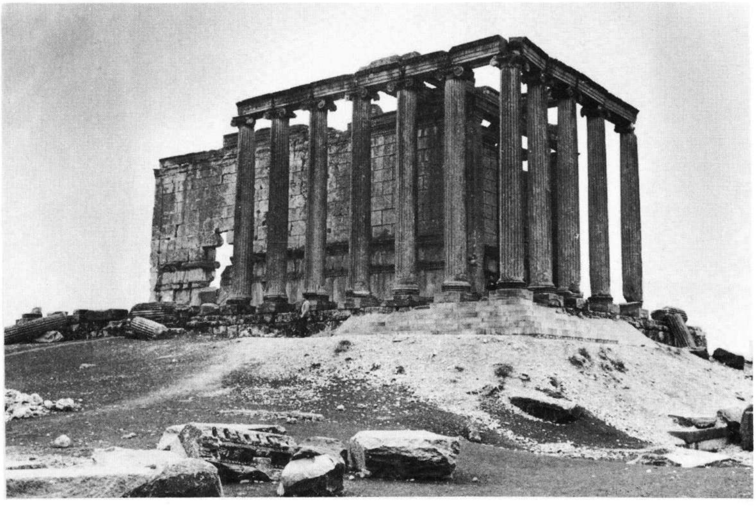
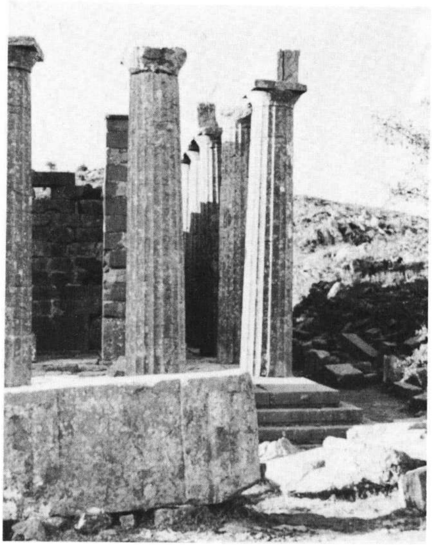


Plate 2. Same view as in Plate 1, shorthly after the 1970 earthquake. Notice in Plate 1 the three columns that collapsed had already lost half of the lowest drums which had been repaired.

Plate 3. Typical damage of hewn column at Aizani.



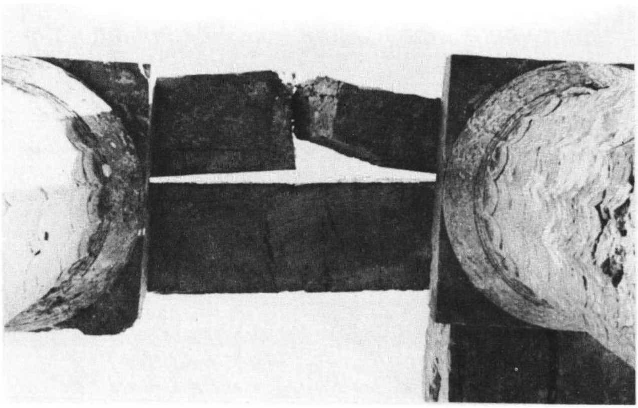


Plate 4. Leaning columns and damaged lintel of the temple of Apollo at Bassai after the earthquake of March 1965.

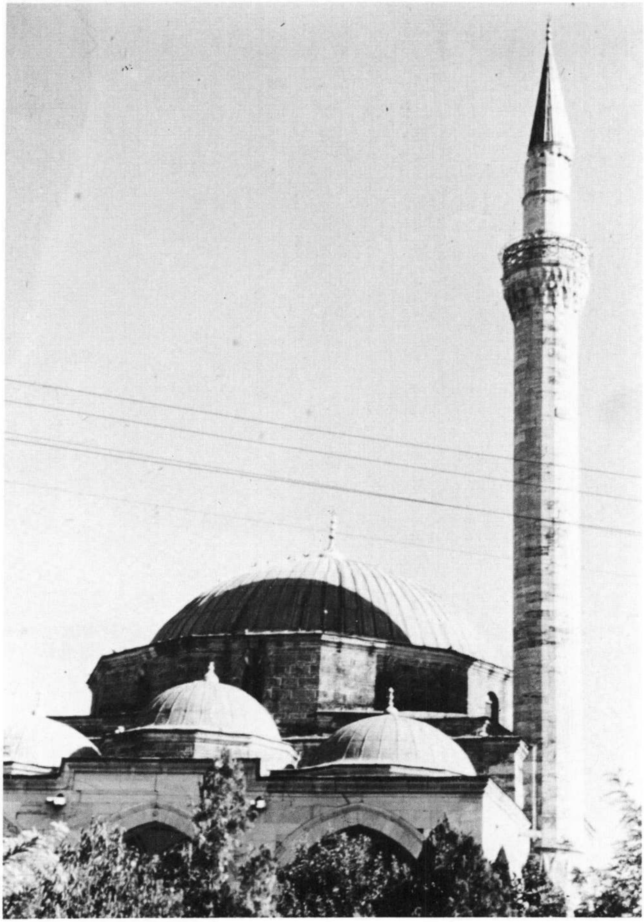


Plate 5. One of the minarets in Skopje after the 1963 earthquake.

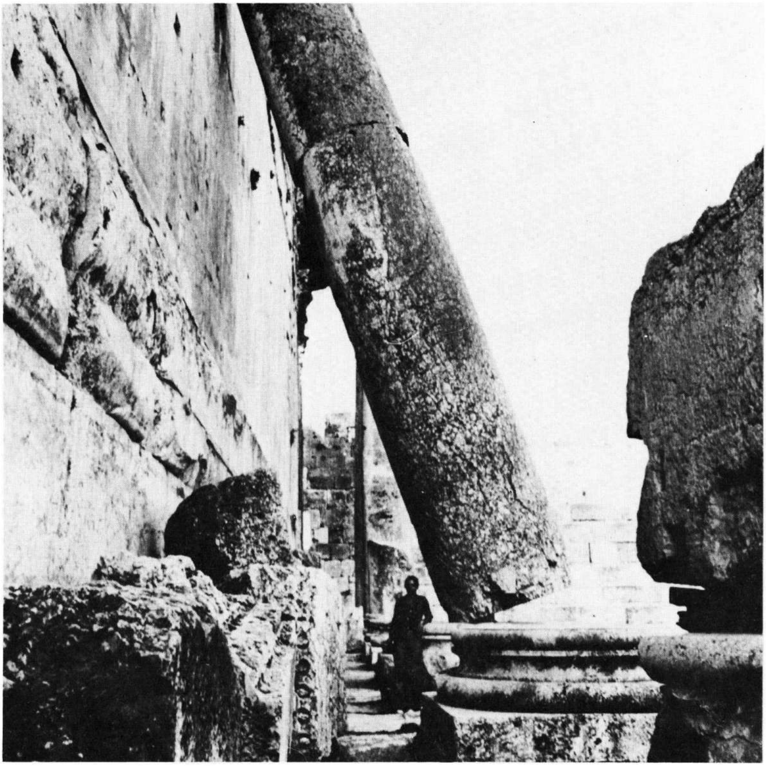


Plate 6. One of the columns of the temple of Bacchus at Baalbek leaning against the cella wall. Notice that inspite of the concentration of stresses at its contact with the base, the drum did not crush nor the upper drum slide at its contact with the lower drum.

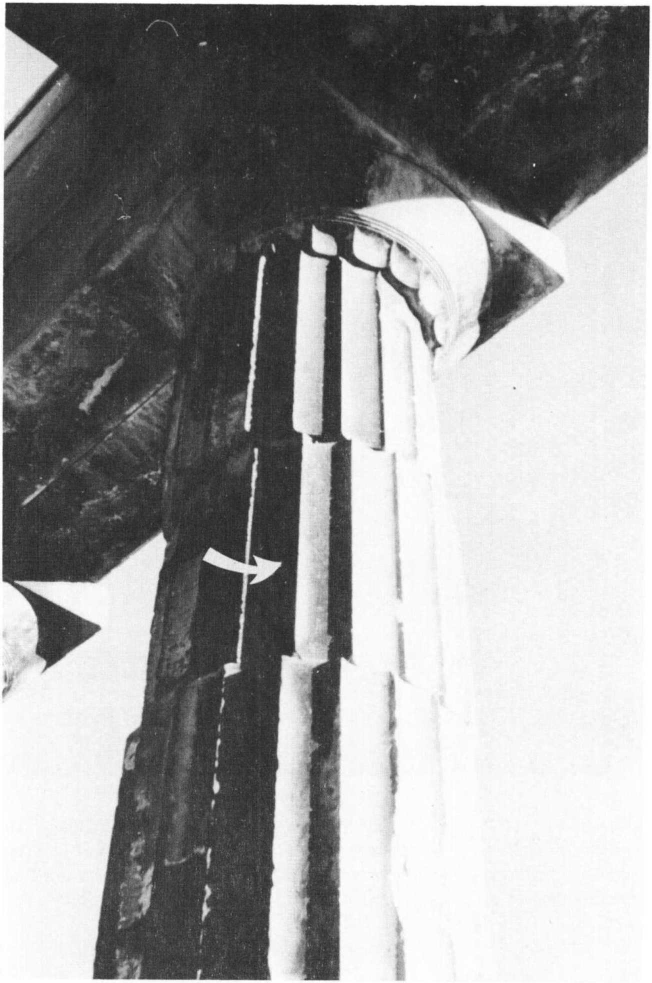


Plate 7. Displaced drums, most probably caused by a combination of rocking and turning of middle drum.

5. *Methods of documentation for the restoration. Proposals*

During the course of the discussion some of the members of the meeting requested further information about the documentation of Mr. Korres' researches by means of drawings and photographs and about the proposals for restoring the Parthenon.

Mr. KORRES said that the drawings recording the work are done according to the priorities of the project. The east façade has been drawn up at a scale of 1:10 for the overall drawings and at 1:5 and 1:1 for the details. The pediment sculpture has been drawn up at 1:2.5 and 1:1. All of the plans and drawings have a standard format: DIN Ao measuring 1.20 × 84 m. The pronaos has been thoroughly recorded in plans and drawings at a scale of 1:10 and 1:20. The entire cella has been measured and drawn up at 1:50. Measurements have been made of the crepidoma of the peristyle, the opisthodomos cornice for its whole length and the ceiling of the west wing. The outer face of the south wall has been recorded; photogrammetry will probably be used to record the inner face. In addition, parts of the Parthenon were drawn up as the need arose, e.g. details of the intercolumniations on the S. side and parts of the cornice of the N. colonnade. Altogether there are a hundred drawings supplemented by about five hundred inventory cards recording the disiecta membra. Except for the plain wall blocks all of the scattered architectural blocks of the Parthenon have been recorded on white cards, format DIN A4, in full detail at a scale of 1:10 or 1:20. The wall blocks whose original position in the building could not be determined were recorded on a chart.

Mr. Korres further reported on methods that he used in his work to ensure accurate measurements and on techniques of using endoscopy on the interior of the building – with mirrors or with electrical endoscopes or a combination of the two.

Mr. CH. BOURAS added that in the course of the Parthenon project the photographic documentation will be completed. A camera mounted on top of the crane which is to be installed in the building will make it possible to photograph all parts of the building, especially the superstructure, from many different angles. Mr. Bouras noted that photogrammetry will be little used for the Parthenon. This method, which has obtained very good results for monuments of other periods, is not of much use in recording monuments of classical antiquity, as has already been shown in the case of the Erechtheion, where very high standards of accuracy are required, involving tenths of millimetres. Such accuracy can be achieved only by geometric measurements or by a combination of the two methods.

During the course of the discussion Mr. NAQVI, the UNESCO representative, appreciated the efforts shown by the Acropolis Committee for the protection of these unique monuments and stressed the continuous interest of the UNESCO for the progress of this conservation programm.

At the end of the discussion the proposals and conclusions that had been formulated by the three teams of archaeologists and architects, civil engineers and seismologists, and chemical engineers, were read out.

Mr. G. MYLONAS, Chairman of the Committee for the Preservation of the Acropolis Monuments, declared the Parthenon meeting closed. He thanked the members for participating and stated that the exchange of ideas during the meeting had been fruitful and extremely useful. Mr. G. Mylonas assured the members of the meeting that the Acropolis Committee would take their proposals and recommendations into account and that they would be of great assistance in the difficult task undertaken by the Committee: the preservation of the Acropolis architecture of highest importance for the cultural history of all mankind.

4

RECOMMENDATIONS

RECOMMENDATIONS
BY THE GROUP OF ARCHAEOLOGISTS AND ARCHITECTS

1. The program of study and documentation of the structure of the Parthenon and its dismembered pieces was widely and deeply admired, but it is recognized that more detailed study of the stones scattered on the Acropolis is of prime importance.

2. In general the need to keep intervention to a minimum, at the same time as improving the stability and earthquake resistance of the structure as a whole, was stressed. The desirability of retaining evidence of later phases of the Parthenon's history was also accepted. Some compromise was needed between these often conflicting principles, taking into account the internationally accepted values and criteria used in conservation.

3. Great importance was given to the reversibility of the proposed measures, so that any work that later seemed undesirable could be removed.

4. The need to protect the monuments of the Acropolis from further decay by removing the basic cause, atmospheric pollution, is an essential element of any restoration programme.

5. The need to remove the ironwork from previous restorations was generally agreed, and the possibility of removing iron corrosion without moving undisturbed blocks would be welcome.

6. A number of speakers stressed the desirability of removing the sculpture still on the building to the safety of a museum. The problem of any replacement with casts needs further discussion.

7. The urgent need for one or more new museums near the Acropolis was emphasized. In the meantime provisional rescue measures for the west frieze are needed immediately.

8. The studies for the first two programmes were accepted as ready for immediate implementation.

9. There was a general wish that the full report should be more widely available.

10. Further consideration of the later programs is needed and it is suggested that there should be a series of international working sessions with a smaller number of participants to allow the close cooperation of experts in different fields. It is essential in that case that working papers covering the static, aesthetic and technical options should be available three months in advance.

The text of the recommendations has been composed by the following participants of the meeting: J. Coulton, G. Gruben, W. Hoepfner, G. Lavvas, D. Linstrum, A. Papageorgiou-Venetas.

RECOMMENDATIONS BY THE GROUP OF CIVIL ENGINEERS AND SEISMOLOGISTS

The group of civil engineers and seismologists concentrated on the structural and particularly the seismical aspects of the proposed works. They congratulated their Greek colleagues on the studies already made, but, being very conscious of the uniqueness and supreme importance of the Parthenon, of the lack of experience in undertaking similar work, and of the many other aspects to be considered, felt able only to make limited recommendations at the present stage.

They viewed as the first priority the halting of the present continuing deterioration of the marble masonry, especially that which was due to the corrosion of embedded iron. Where this was possible only by dismantling some of the blocks of marble, the dismantled blocks should be temporarily stored until a definitive scheme was agreed for their reerection.

The structural objectives in the definitive scheme for the entire structure should be:

1. The minimum interference necessary to halt deterioration and ensure future safety.
2. Good energy absorption capacity.
3. A criterion of stability or limited displacement rather than a stress criterion.

The group considered, however, that a final decision on the scheme to be adopted called for further study in the following areas:

1. More precise quantification of the seismic hazard by field instrumentation and investigation of past earthquakes.
2. A full survey of the existing conditions of the monument (cracking, embedded iron, etc.) and continued monitoring of it.

3. The development of more realistic analytical tools to assist in assessing stability under seismic excitation, with the emphasis on types of analysis that will assist in making the particular design choices that must be made, plus validation of these tools by testing, as appropriate.

4. Study of the likely effects of unloading and then reloading the substructure by dismantling and reerecting parts of the structure.

5. Study and development of possible techniques for improving energy absorption without, if possible, departing significantly from the traditional construction details.

The group emphasised, however, that the clarification of objectives, including any precise structural criteria, was a matter for joint decision by archaeologists, architects, engineers, geologists, materials scientists and seismologists and that these professions must continue to work closely together in pursuing the agreed objectives, preferably on an international basis.

The text of the recommendations has been composed by Dr. R. Mainstone in collaboration with the other members of the group of Civil Engineers and Seismologists.

RECOMMENDATIONS BY THE GROUP OF CHEMICAL ENGINEERS AND CHEMISTS

1. As the Parthenon will not be completely dismantled some iron clamps will be left in place. Any corroded iron producing mechanical stress in the marble and any iron stains will have to be removed. To this purpose tests are to be carried out:

– with chemicals such as neutral solutions of thioglycolic acid, gallic acid or any other chemical that might prove effective for the said purpose without damage to the surrounding marble.

– on systems simulating as much as possible the actual situation on the Parthenon so that the practical details of the intervention can be worked out.

2. With respect to the west frieze of the Parthenon the only possible action that can be taken at the moment is the removal of the frieze into a museum destined to house it, where it is to be kept under appropriate environmental conditions. The reason for the removal of the frieze is the same as that for the removal of the Caryatids, i.e., deterioration of the marble due to air pollution.

Until the time that such a museum is ready to house the frieze, tests are to be carried out for in situ protection, i.e., the diminution of the actual sulphation rate of the frieze. Experiments with the possible attachment of a transparent case with conditioned nitrogen gas circulation or just a free-flow of nitrogen gas over the frieze are to be carried out. The use of any polymeric material on the sculpture is excluded.

The text of the recommendations has been composed by the following scientists: E. Charola, N. Beloyannis, L. Marchesini, E. Papakonstantinou-Zioti, G. Schwab, Th. Skoulikidis, J. Šrámek.

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