Maria Koui · Fulvio Zezza · Dimitrios Kouis *Editors*

10th International Symposium on the Conservation of Monuments in the Mediterranean Basin

Natural and Anthropogenic Hazards and Sustainable Preservation

Springer

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on the Conservation of Monuments
in the Mediterranean Basin

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Editors

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Preface

This volume contains the proceedings of the 10th International Symposium on the Conservation of Monuments in the Mediterranean Basin held in Athens, Greece, from 20 until 22 September 2017.

The symposium, following previous symposia in Bari (1989), Geneva (1991), Venice (1994), Rhodes (1997), Seville (2000), Lisbon (2004), Orléans (2007), Patras (2010), and Ankara (2014), was organized by the National Technical University of Athens (NTUA, School of Chemical Engineering, Department of Materials Science and Engineering) and the Region of Attica of the Hellenic Republic.

This international symposium provides a forum for scientists, technicians, and experts in the area of conservation and restoration of monuments to present their work and exchange ideas and experiences.

During the Athens 2017 Symposium, new research was presented that deepened the existing knowledge regarding issues surrounding culture heritage preservation, refers to the monument damage hazards that originate from both natural and anthropogenic effects, as well as to the technologies used for sustainable damage rehabilitation.

A large array of topics encourage scientists to discuss and share the challenges that they encounter regarding their monument projects in the Mediterranean Basin. Thus, the symposium was addressed to engineers, architects, geologists, restorers, conservators of artifacts of different materials and other specialists in the decay and restoration of monuments. It also appealed to as well as archeologists, art historians, and scientists in the fields of physics, chemistry, and biology. Furthermore, the symposium was aimed at cultivating interest in cultural institutions involved in heritage management and manufacturers of building treatment products.

For the 2017 symposium, more than 220 authors, attendees, exhibitors, and sponsors, participated from Algeria, Belgium, Canada, Cyprus, Egypt, France, Germany, Greece, Italy, Japan, Jordan, Mexico, Serbia, Slovenia, Spain, Turkey, USA, United Arab Emirates, and United Kingdom, applied for participation.

All papers have been critically reviewed by the members of the Scientific Committee, to whom I express my deepest gratitude for their assistance and cooperation in this very important aspect of the symposium.

I express special thanks to Professor Dimitris Kouis, Dr. Vasiliki Dritsa, Amani Christiana Saint PhD candidate, and Mrs. Rozita Tampakopoulou for their crucial contribution to the success of this symposium, as well as for their contribution to the preparation and edition of this volume.

Many thanks should be given to all the Organizing Committee members for organizing the sessions and their excellent work. To them great thanks are attributed by the IGCMM.

Last, but not least, I extend my gratitude to all sponsors for their financial support.

Athens, Greece
September 2017

Maria Koui

Organization

The 10th International Symposium on the Conservation of Monuments in the Mediterranean Basin was organized by

- National Technical University of Athens (NTUA, School of Chemical Engineering, Department of Materials Science and Engineering)
- Region of Attica of the Hellenic Republic

Under the auspices of

- The International Group on the Conservation of Monuments in the Mediterranean Basin (I.G.C.M.M.)

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Part I

Opening Speeches

Welcome Speech

1

Maria Koui

Ladies and Gentlemen,

My dear colleagues and friends,

In my capacity as the Coordinator of the Organizing Committee of the 10th International Symposium on the Conservation of Monuments in the Mediterranean Basin, it is my great pleasure to welcome you to Athens.

I hope that the Symposium will be an opportunity for fruitful discussions, strengthening the already existing ties and establishing future collaborations.

In recent years, the political situation in the Southeastern Mediterranean has brought to the forefront a key consideration concerning the destruction of cultural heritage sites and environments: armed conflicts erupting between various population groups, which had coexisted for a long time and developed significant cultural, artistic and philosophical legacy in the region, are playing a significant role in the destruction of the cultural heritage in the region.

The disastrous events in Syria, especially in Palmyra, a city crowded with monuments of the Hellenistic-Roman era, constitute a contemporary example of human absurdity. These events drove to the complete loss of monuments that belonged to cultures and religious faiths of a distant past, which had nothing to do with the contemporary ideological-philosophical controversies.

The enormous damage in the urban plan and historic cities museums, such as Damascus or Aleppo, makes us sad and highlights the importance of intensifying the efforts to discover the best methods for protecting and legally defending cultural heritage worldwide. In parallel, it is important to apply both proven and new methods for restoring damage to buildings and monumental ensembles that belong to our rich cultural heritage.

Apart from anthropogenic hazards events, such as war, seismic activity remains the most common cause of monument and historic residential complexes destruction. In our days, we have witnessed a series of seismic events to the Mediterranean basin, especially in the earthquake-prone regions of Central Italy and the Greek islands, most recently in Lesbos and Kos as well as in the neighbouring coasts of Turkey.

Keeping in mind the above, we realize that recording the great wealth along with the artistic and historical elements comprising each impressive monument, is a fundamental task of cultural preservation.

It is self-evident that these records will act as the core information, for every attempt to restore monuments damaged by an unpredictable, anthropogenic or natural cause disaster.

Technological evolution (especially information systems) enabled the production of three-dimensional digital models for existing monuments, even for those that are currently undergoing the process of restoration. These models allowed us to understand fully the architectural composition of monuments and to propose more accurate methods for restoring their structure, in comparison with the old time-consuming manual depiction and design.

We anticipate with great interest the presentations and the fruitful dialogue that will take place during the Symposium on the natural and the anthropogenic hazards risk factors of monument destruction and the appropriate methods for their sustainable conservation.

We also look forward to being informed regarding the methods that can be implemented or are already being applied in the continuous effort of scientists and stakeholders for restoration and rehabilitation of monument damages, as well as proposals for their sustainable preservation.

A useful tool, at a political level, will be ideas and examples of managing cultural heritage, so that the monuments continue to be an endless source of light and inspiration, for people who work for their protection or live with them,

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respecting the testimony they provide concerning the historical period of their creation. Above all, however, as a tangible proof of the complexity and creativity of the human nature, which, when not engaged in destruction, and enjoys periods of peace, can create works of high art.

Concluding, we hope for the era when the cultural monuments created by communities of different cultural backgrounds will enjoy universal respect.

In these three days of work, we will have a chance to listen to approximately 85 communications, either in an oral or a poster presentation, delivered by participants from 19 countries.

It is my obligation to thank some organizations and some individuals. Specifically, I would like to thank:

- All the members of the Scientific Committee for their essential effort and cooperation in this important aspect of the Symposium.
- All the members of the Organizing Committee and the Symposium secretariat, especially Professor Dimitris Kouis, Dr. Vasiliki Dritsa, Dr. Ekaterini Ftikou and PhD candidate Amani-Christiana Saint.
- The Symposium organizing institutions, the Department of Material Science and Engineering of the National Technical University of Athens and the Region of Attica. Especially I would like to thank both Evi Apostolaki, Regional Vice Governor for Culture and Theodoros Angelopoulos, Advisor for Cultural Infrastructure Development and Promotion Services for the Region of Attica.
- All the sponsors for the significant support to this Symposium.
- The President of the Symposium Professor Fulvio Zezza, Dr. Dimosthenis Giraud, Professor Benno Albrecht, Professor Enzo Siviero and Dr. Nicolas Avdelidis, who have kindly agreed to give us the opening and the invited lectures.

Last but not least, I would like to thank you for participating in this Symposium.

I wish you a fruitful and pleasant stay in Athens.

Athens, September 2017

Natural and Anthropogenic Hazards and Sustainable Preservation

2

Fulvio Zezza

The International Symposium on Monument Conservation in the Mediterranean Basin opens today at the National Technical University of Athens. The closeness to the Acropolis and the impressive Parthenon, the most famous monument of the classic antiquity, convey a strong emotion to the participants host in conference really in Greece, the cradle of the classicism and the source of the ancient learning which pervaded the Occident. I thank the academic authorities of the Athens University for the appreciated support to develop our interdisciplinary program started almost 30 years ago with the establishment of the International Group IGCMM (Figs. 2.1 and 2.2).

Athens is the tenth meeting place where the International Group goes back to turn the scientific interest to the monuments of the Mediterranean belt where is concentrated the largest and most important historic, archaeological, architectonic, and cultural patrimony in the world. The vulnerability of its monuments and their conservation is the basic objective of the International Group which operates in accordance with the Convention for the Protection of the World's Cultural Heritage stated by the 175 member states of UNESCO at preserving the cultural identities. As this cultural duty toward the world property exceeds the national geographical borders as our scientific interest is inclined to all the Mediterranean monuments, symbols of the great civilization of the past. The scientific initiative of the International Group, born from a lack of coordination among the Mediterranean countries, contributes to interdisciplinary research turned on the risk conditions along the Mediterranean Basin exposed to common sources and effects of damage. Initially, the cooperation launched in the recent decades by European Commission Research Areas through the programs Environment and Environment-Climate for the Protection and Conservation of Europe's Cultural Heritage has favored the efforts in order to evaluate common information and strategies. To achieve this objective, it was decided to try and understand the causes, mechanisms, and consequences of the damage and to develop practices and technologies on a sound scientific and technical basis. The theme of the Athens Symposium, concerning hazards and sustainable preservation headed to monument damage, follows this mark and looks over the weathering processes, primed by the physical, chemical, and biological agents, and the equally important effects of the dynamic systems of the Earth, which enhance the damage.

The monumental patrimony of the Mediterranean belt can be divided conventionally into two principal categories: the former includes the archeological heritage, which dates from the prehistoric age to the fall of the Roman Empire, and the latter comprises the patrimony belonging to the Middle Age and the Modern epochs such as churches, castles, fortified systems, historic centers, and palaces. The knowledge disseminated by the International Group through the Proceedings of the multidisciplinary meetings is integral part of the extraordinary stratification of the findings already published.

In the last century, a growing rhythm has damaged a great number of monuments in more and more short periods. The architectonic structures, composed by different kinds of building materials, react to the wide range of stresses; therefore, stone decay as well as natural and anthropogenic hazards proceed at the same rate and go to rack and ruin the monument. Among the sources are remarkable those belonging to air pollution (Fig. 2.3).

The great variety of compounds which circulate in the atmosphere enhances the stone damage. The airborne of organic and inorganic pollutants tends to accumulate on the exposed surfaces of the monuments and reacts with the mineralogical components of their substrates lacking in any form of regeneration. The industrial development had a relevant

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role in the formation of black crusts and patinas which cover and disaggregate the substrates: in particular, the black crusts composed by gypsum, supplied by SO_2 and Ca_2 ions, are today the most visible effect of the aggressiveness suffered by the monuments.

In addition, an important role in stone decay is covered by a natural pollutant: the marine aerosol, which provokes disaggregation, exfoliation, cracking, fissuring, and detachment. Source and effects of the sea salts along the coastal areas were debated really in the 1st International Symposium. The marine aerosol is directly introduced in the atmosphere by the sea; its annual quantity achieves 10^9–10^{10} tons/year so that the dry depositions, the rain waters, and those of condensation contribute notably to the ruin of the cultural patrimony (Figs. 2.4 and 2.5).

Fig. 2.1 Symposium logo

The effects of the marine aerosol as well as those of the anthropogenic pollutants are diversified place to place along the Mediterranean belt depending on the features of the coast, the climate, the sources, and the concentration of pollutants which circulate in the atmosphere. Further investigations still need in this sector to understand more deeply the mechanisms of the weathering processes primed by the complex interrelation between pollutants and environmental changing (Fig. 2.6).

Of course, showier are the effects of the anthropogenic hazard in urban areas subjected to the confused growth. Irreparable infringements have been often registered in consequence of the untidy urban development scored by threats linked to slope instability, inadequate alarm systems, open spaces reduction, buildings and infrastructures without maintenance, industries too much near to the buildings, and faulty supervision of the constructions at risk. Besides the carelessness and the negligence toward the cultural patrimony have favored the ruin of monuments located in metropolitan areas already crippled by defacements and infringements, illicit excavations and thefts, fires, and shattering (Fig. 2.7).

Unfortunately, the anthropogenic hazard includes the effects provoked by wartime events, which have caused during the centuries losses and notable violations. The same Parthenon, for instance, was reduced to ruin in 1687 when, during the siege of the Venetians placed the Acropolis came into possession of the Turks which had a great stock of gunpowder in the citadel and stored it in the temple, a shot of mortar fell really the Parthenon. A learned traveler, the Italian Scrofani, who in 1794–1795 takes a journey in Greece and visited the Acropolis, wrote "...what a scenery, what a pity are these effects which strike the sight and the hear…over-

Fig. 2.2 The Acropolis of Athens, Ippolito Caffi (1809–1866), Museo Correr, Venice

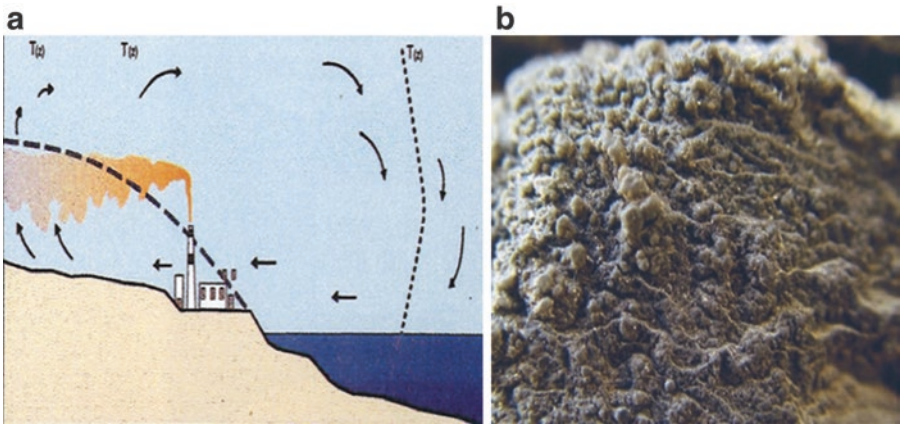

Fig. 2.3 (**a, b**) Scheme of the circulation regime of the sea breeze on the shores of the Mediterranean Industrial development and formation of black crusts

Fig. 2.4 (**a, b**) Salt spray and its effects

come by emotion the foot advances towards the naos of the temple where the Athena statue was adored....” (Fig. 2.8).

Nowadays, unfortunately the sad sight of monuments victims of the foolish acts is still more terrible because man commits to destroy the monuments in order to remove the “memory” of those peoples who in the millennia defended against the barbarities the symbols of own civilization. Undoubtedly, this kind of destructions is a shock for the public opinion; for our part, we interpret as a moral duty to rise again those monuments by means specific proposals to recover the extraordinary ruins (Fig. 2.9).

At the right time, also the geological risks release the tremendous sight of the happened catastrophic events. Seismicity and volcanism, floods and landslides, active tectonic, and subsidence threaten the safety of the architectonic structures. In monument conservation, the incidence of the geological hazards of the Mediterranean region on monument is not yet attempted or undermined besides it is to dispose the mapping of the area at risk in little or great scale. This field needs specialized investigations to forecast the effects of the hazards taking into account the interrelation between the vulnerability of the element at risk and the consequences of the expected catastrophic event.

A monument cannot be summarized in a small stone samples to analyze in laboratory but represent a structure which reacts to a range of stresses. According with this point of view, the debate within the International Group has always aimed at developing a synergic action devoted to a better understanding of the damage. Really in coincidence of Bari Symposium, in 1989, the participants wished to return periodically to confront on conservation, a science articulated in character and, then, multidisciplinary. Starting from the specific and necessarily by-sector researches, the findings have been placed in a wider framework so that the elements of knowledge acquire an added value particularly suitable for the acceptable safety standards.

A correct procedure to the stone conservation foresees the development of three phases of investigation: anamnesis, diagnosis, and therapy. Besides, within the Symposia of the International Group, the findings have been derived also by investigations which dedicate more space to the interrelation monument site. On this matter the failures have been

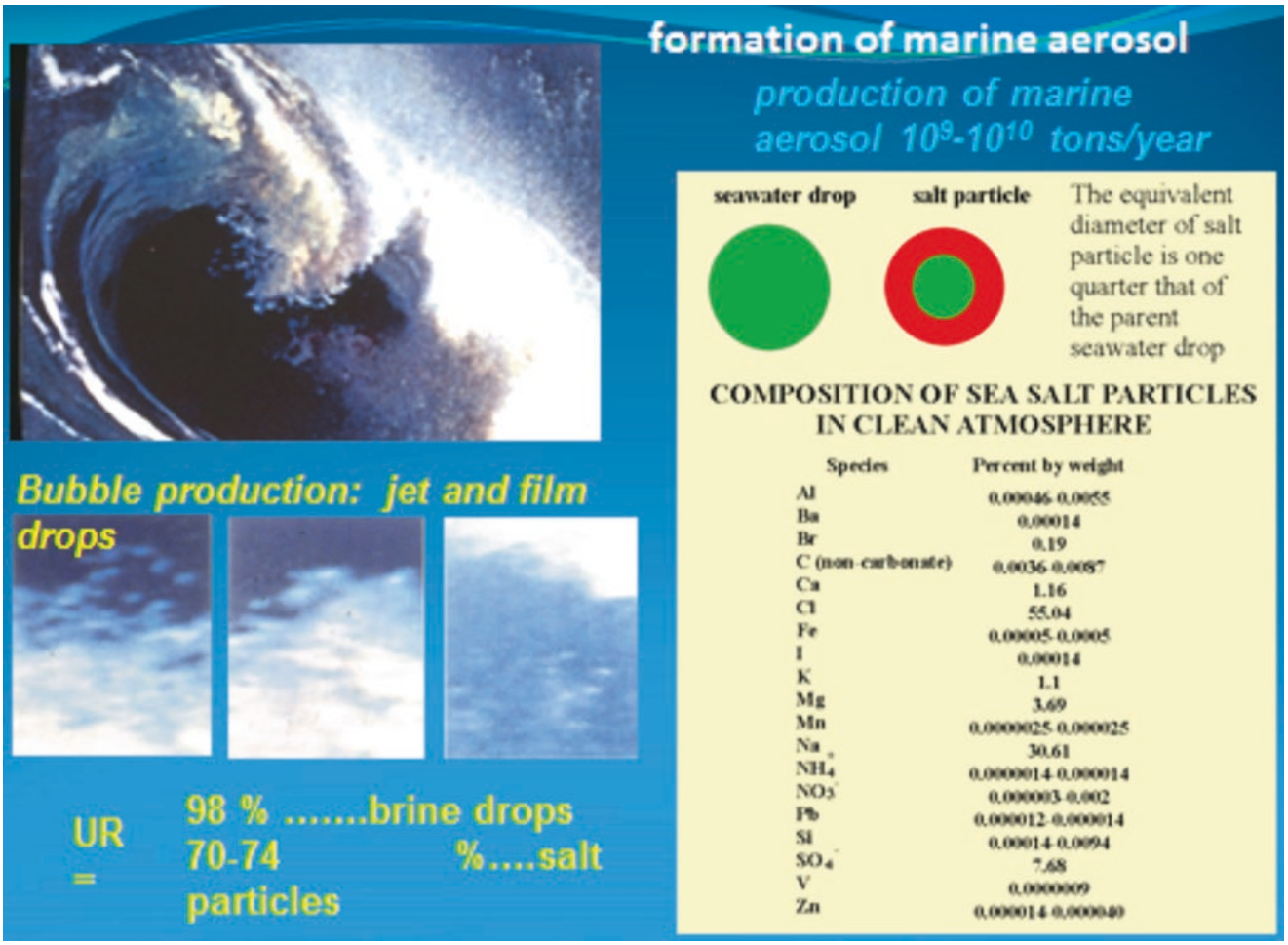

Fig. 2.5 Formation and production of marine aerosol

interpreted according with the dynamics of the architectonic structure, considered as a whole, and dependent from the characteristics of the sites, the intrinsic features and the environment which provoke aggressions of prolonged or sudden action (Fig. 2.10).

Therefore, the principal tasks of each Symposium have turned around the basic sector of the safeguard related to the building materials and the vulnerability of architectonic structures and archeological areas. Of course, the themes of the Symposia have been focused on different aspects of the conservation, and each theme has been supported by contributions which have treated always the historical, technological, and structural aspects of monuments, the properties of the building materials, the environmental parameters, the analytical techniques and the methodologies of investigation, the conservative products and the methods for the conservative intervention, the territorial investigations, the natural risks, the rehabilitation technologies, and the strategies for planning and management. The portrait of the International Group is the inventory of the Symposia by means the findings disseminated through the Proceedings periodically published (Fig. 2.11).

The knowledge of the extraordinary Mediterranean system heritage-environment started in the 1st Bari Symposium (1989) based on the theme of the sea salt damage in coastal environment. The second venue was Geneva (1992) selected at achieving new knowledge on the marble provenance, behavior, and conservative intervention. In Venice (1994) and in Rhodes (1996), further knowledge was added on the weathering forms and the analytical methodologies as well as on the conservation technologies for monument and historic complexes. The Symposia of Seville (2000) and Lisbon (2004) faced up, respectively, with the theme of cultural cities and that of the investigation methodologies headed to the recovery of the cultural heritage. In Orleans (2007) was highlighted the relation "water cultural heritage" taking into account the monumental patrimony of the Loire valley. It was surprising to clarify the meaning of the site's identity using the natural resource water and the cultural wealth as project instruments. Water defines the richness of a territory and, before becoming an economic issue, contributes to the modeling of the landscape and the location of the historical patrimony such as churches, abbeys, defense systems, and ancient bridges. Patras (2010), in turn, gives a further

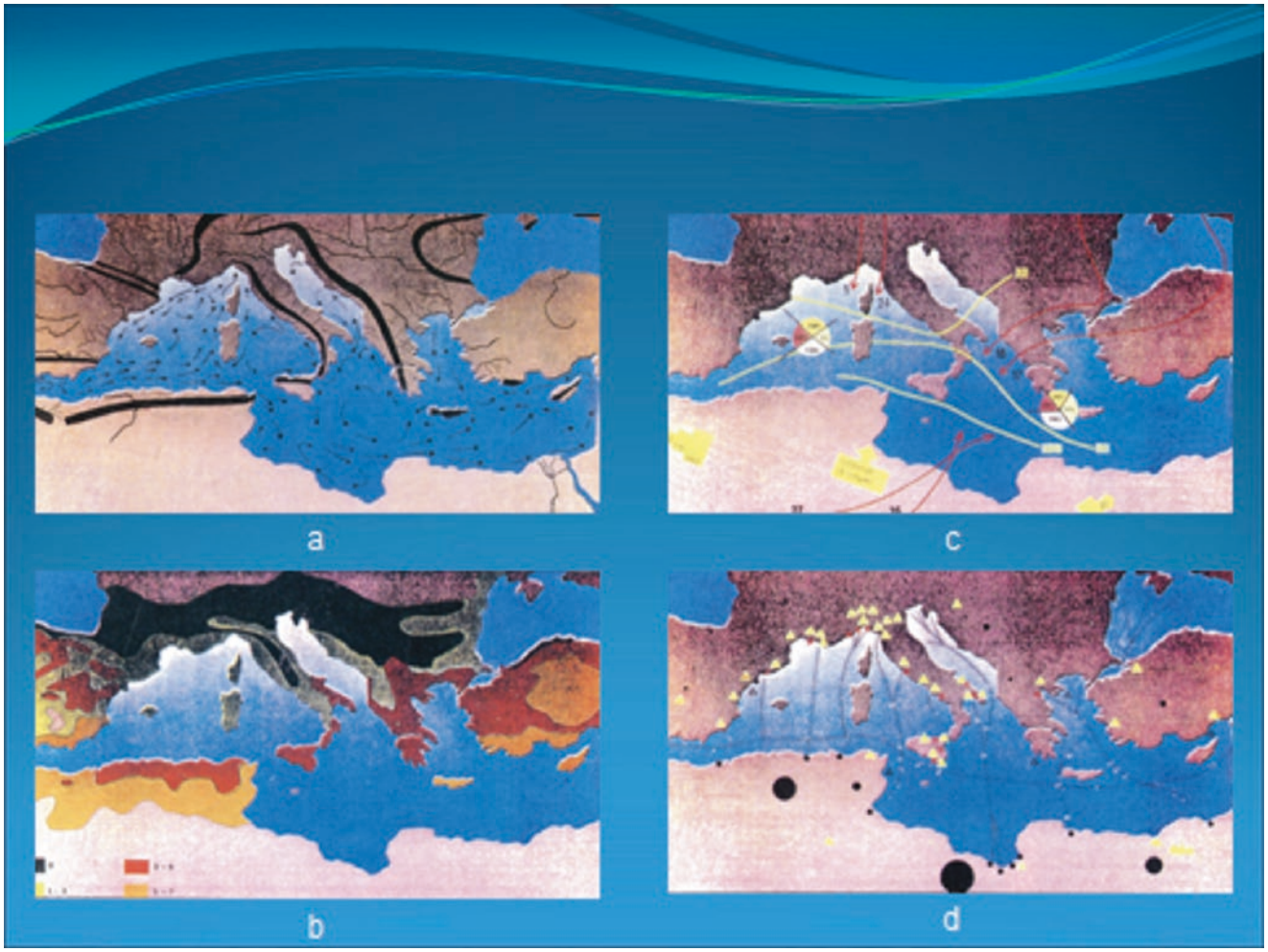

Fig. 2.6 Morphology, climate, and pollutants of the Mediterranean Basin mountain systems: (**a**) dry months, (**b**) dust loading, (**c**) oil production, and (**d**) transport

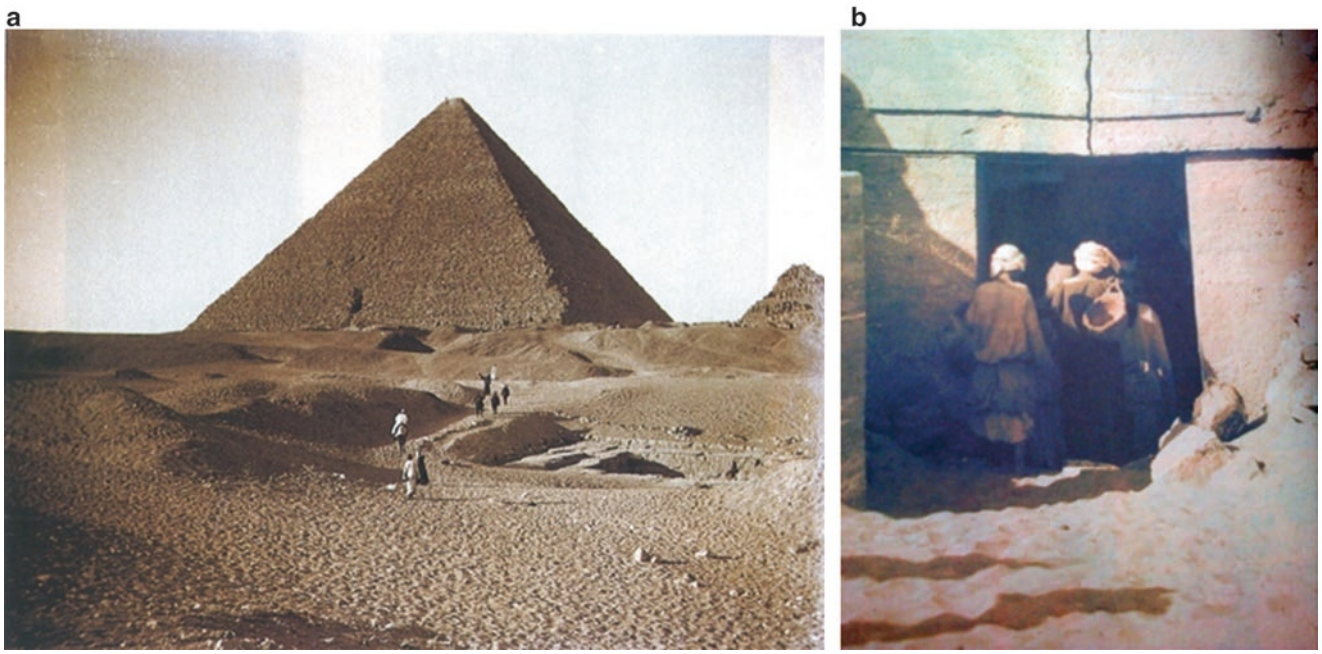

Fig. 2.7 Infringements of archaeological and metropolitan areas crippled by illicit excavations and thefts

Fig. 2.8 In 1687 a shot of mortar fell the Parthenon

Fig. 2.9 Palmira, destruction of monument victims of the foolish war events in Syria

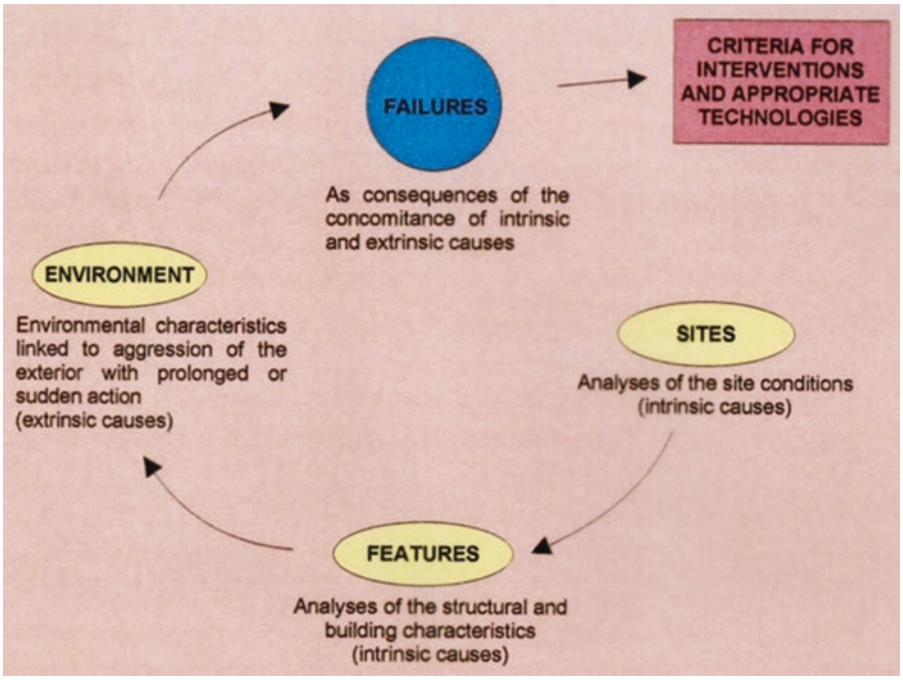

Fig. 2.10 Methodological approach to sustainable monument conservations

Fig. 2.11 Proceeding covers of the International Group IGCMM Symposia, 1989–2017

opportunity to highlight the focal points of the monument damage hazards and those of the rehabilitation technologies, inside of which are placed equally important topics, from the damage forms to the conservation products, from the test application to the prevention measures for the monitoring and the maintenance, and from the construction to the restoration. At least, the Symposium of Ankara (2014), focused on integrated rehabilitation methodologies in conservation, has stimulated new proposals as answers referred to the following two important questions: (i) no future damage for the structures to be protected must be derived from the applied products and (ii) the rehabilitation and protection works performance must continue for the structure lifetime.

The Athens Symposium, based on monument hazards and sustainable preservation, still aims to deepen the knowledge in these sectors. Starting from the damage stone, which represents one of the most visible aspects of the conservation, we will discuss on the fair products and technologies in conservation and rehabilitation to contrast or to mitigate the occurrence of sudden and long-term events. The Symposium intends to contribute at achieving future perspectives within the complex system heritage-environment.

In monument conservation, the risk conditions are matter of growing concerns. In risk management, it is a common task to furnish advanced knowledge referred to the three different risk components: damage, vulnerability, and value of the element at risk. In this way, the International Group intends to supply further findings for the mitigation of the risk or rather the reduction of the conditions of risk. Moreover, we share the lines indicated by the European Commission within the Environment and Climate Programme which consist in (i) reducing the elements of damage with interventions to eliminate the causes and (ii) reducing the vulnerability with interventions of a technical nature which include the consolidation of the structures and the protection of the materials. Therefore, taking into account that the preservation of the architectonic structures is of fundamental interest for the economical, social, and educational aspects, our efforts are steered toward suitable technologies as integral part of the damage reduction policy and intervention which follow non-invasive criteria, designed to allow the availability of architectural structures and to preserve their artistic value (Fig. 2.12).

The Athens Symposium recalls today the original intuition to continue together to offer the findings of the interdisciplinary research on the rich and complex cultural reality of the Mediterranean Basin. According with my opinion, our work will remain in time as a spring of knowledge for the specialists and the young researchers who would like to share the multidisciplinary experience. This engagement must stimulate us to achieve the best results to reinforce the strategies to plan the conservation; besides, the international scenery suggests suitable proposals on the reconstruction of the monuments destroyed recently in Syria. This commitment is really in the wake to safeguard the identities and to preserve the memory of the past so that we can contribute to the spreading of the technological innovation in the field of the information and in that of the production.

Let me conclude addressing my esteem to the Organizing Committee, coordinated by Prof. Maria Koui, for the valuable competence to settle the venue and to plan tasks and works. I wish to turn all my consideration to the International Scientific Committee for the attendance to assess the

Fig. 2.12 Target of the International Group IGCMM

communications selected for the dissemination of the most recent findings in conservation. Finally, I thank heartily the participants who supplied the scientific works to support the commitment of our interdisciplinary activity, difficult to keep as promise but sustainable as challenge. Really in the challenge to continue our scientific mission, we have always found the motivation to enhance the activity of the International Group at conserving the memory of the past.

I wish to all the present a sound and rewarding work. Thank you.

Part II

Plenary Lectures

The Monument Stone: An Eternal Link of Past Civilizations

3

Fulvio Zezza

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3.1 Lecture

The topics on the historical, technological, and structural features of monuments penetrate the cultures of the Mediterranean belt down to their roots. Certainly, the remarkable scientific interest encourages research to further knowledge, bearing in mind that a holistic approach to conservation can make sense only when techniques, skills, environment, and beneficiaries are analyzed along with the properties, the behavior, and the value of building materials. Indeed, the use of monument stones reflects purposes, ideologies, and symbolisms referable to different traditions, thus determining the intrinsic value, both historical and cultural, of each monument.

The etymology of the word monument comes from the Latin *monere* which means to remember. Each monument whets the emotional component of memory (Fig. 3.1) and sends a message which exceeds the threshold of emotion: the use of the stone belongs to the history of civilizations, one after another influenced through the appealing and the assimilation. Besides the intrinsic value of the stone linked to the use cannot possibly be ignored, this element cannot be considered of secondary significance within a holistic approach to conservation.

The research has clarified the architectural devising of the past, its influence on the artistic language, as well as the relationship with ancient tradition. Nevertheless, some fundamental problems concerning the use tendencies in different historical periods, above all as regards ornamental stones, are still extant. The argument is too complex and requires systematic analyses of interdisciplinary character.

In time, stone has carried out both the role of building material and that of decoration. The stones employed in monuments are different in composition and variety. Their place of origin corresponds, almost always, with the site where a monument is located, but the ornamental stones come from far away (Fig. 3.2). In different sites the availability of building materials and the capability of craftsmen have favored constructions in harmony with their characteristic styles and traditions. In this regard, Vitruvio in his *De Architectura* (1st Book) wrote: "where square blocks are available, or flint, or cut stones, there will be the material to realize…." This statement has proved its worth throughout the centuries, if we consider the monumental heritage built both in the Eastern and in the Western Mediterranean using the local stone resources.

History tells us that, in ancient times, peculiar stones were selected for monument and transported from a long distance [1]: the white marble of Paros and Naxos, compact and pure, symbol of firmness and nobility in ancient Greece, and the granite of Siene (Aswan) red in color considered, in the ancient Egypt, right for the icon of the divine ancestry of the pharaohs descending from Ra, the god-sun creator of the world. However, the ancient monuments of the Greece reveal also that, above all, the white marble employed comes from the quarries quite near to the sites [2]. For instance, the Acropolis of Athens was built using the Pentelic marble quarried in the homonymous mountain at a distance of 20 Km, while the Temple of Poseidon, at Cape Sounion, was built using the Agrileza marble quarried 5 Km away. Moreover, the stones of other famous temples,

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