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CONSERVATION AND RESTORATION OF THE ACADEMY OF ATHENS – GREECE

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THE BRONZE STATUE OF EVANGELOS AVEROF – TOSSITSAS IN METSOVO - GREECE. CORROSION PATTERNS AND CONSERVATION PROCEDURES

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Περίληψη

Το κτίριο - μνημείο της Ακαδημίας Αθηνών κτίστηκε με χορηγία του εύπορου Βορειοηπειρώτη Σίμωνος Σίνα που ζούσε στη Βιέννη, μεταξύ των ετών 1858 και 1889 και το βασικό του δομικό υλικό ήταν πεντελικό μάρμαρο, όπως και τα περισσότερα μνημεία της Αθήνας κατά την αρχαιότητα. Σχεδιάστηκε από τον Δανό αρχιτέκτονα T. Hansen και με κίονες Ιωνικού ρυθμού και στοιχεία από τη διακόσμηση του Ερεχθείου της Ακρόπολης. Τα μαρμάρινα γλυπτά στο μπροστινό αέτωμα με την γέννηση της θεάς Αθηνάς στην πρόσοψη της Αθηνάς και του Απόλλωνα και στην είσοδο του Σωκράτη και του Πλάτωνα φιλοτεχνήθηκαν από τον γλύπτη Λ. Δρόση και τα κεραμικά γλυπτά στα υπόλοιπα αετώματα από τον F. Meltzinski.

Το κτίριο αποτελείται από την κεντρική αίθουσα των συνεδρίων και δύο μέρη αριστερά και δεξιά. Η κεντρική αίθουσα διακοσμείται από ζωγραφικά έργα του C.

Griepenkerl (1839 - 1916) σπουδαστή του K. Rahl (1812 - 1865), επηρεασμένα από μεγάλους δημιουργούς του 16ου αιώνα, ειδικά του Michelangelo και εμπλουτισμένα από το Baroque, με σκηνές από την ελληνική μυθολογία.

Στην παρούσα μελέτη εξετάζονται οι περιβαλλοντικές συνθήκες του μνημείου, όπως υγρασία, θερμοκρασία, ακτινοβολίες και ατμοσφαιρική ρύπανση και διαπιστώνεται η κατάσταση διατήρησής του. Στη συνέχεια παρατίθενται οι διαδικασίες συντήρησής του που πραγματοποιήθηκαν μεταξύ των ετών 2004 και 2008.

HISTORICAL DATA

The Academy of Athens is situated in Panepistimiou Street at the center of Athens, and was built after sponsoring by Simon Sinas, who was a wealthy nobleman living in Vienna - Austria, between 1858 and 1889. The structural material of the Neoclassical Monument is Pentelic marble and the whole construction finished in 1889 under the supervision of the Architect T. Hansen, who came from Denmark. In designing it, Hansen was largely inspired by the Ionic style decorative elements, whereas for the ground plan he drew his inspiration from the Erechtheum in Acropolis. The exterior of the building is decorated with sculptures, of which the composition on the façade pediment, representing the birth of the goddess Minerva, is a work by the sculptor L. Drossis (fig. 2). Those on the eight pediments of the side wings were made in terracotta by F. Meltzinski. The two statues of Apollo and Minerva which stand on tall Ionic style columns flanking the entrance, together with the two seated statues of Socrates and Plato in front of the building, were also created by L. Drossis. They symbolize the Academy's contribution to the revival of the ancient spirit as personified by the gods and the philosophers (fig. 3).

The Monument mainly consists of the central hall for the sessions, and two wings on the right and the left side. The Assembly Hall of the Academy is decorated inside with eight painted panels on the long sides and two large compositions over the front and back doors. They were painted on canvas by C. Griepenkerl (1839 - 1916), a student of K. Rahl (1812 - 1865), who began in 1878 working mainly on designs made by Hansen himself. The paintings were conceived and executed in the grandiose classical manner of the time, reminiscent of the great masters of the sixteenth century - especially Michelangelo - but enriched with features borrowed from the Baroque. The multicolored compositions are carefully balanced, the figures are idealized, the gestures are eloquent if somewhat exaggerated and the effect on the whole is monumental. They were meant to convey the 19th century perception of the Academies as the depositories of wisdom and enlightenment. To illustrate this, the myth of Prometheus was chosen, the Titan who re-created the human race after Deukalion's flood and provided men with fire and light, the prerequisites of civilization (fig.1).

Fig. 1. The Academy of Athens by T. Hansen.

INTRODUCTION

The difficult task of the conservation of this significant historic monument was carried out by a team of conservers from the Department of Conservation of Antiquities and Works of Art of the Technological Educational Institution of Athens under the supervision of Professor Dr V. Lampropoulos. The conservation began in 2004 and finished in 2008.

The damages on the marble sculptures, which we discovered as we first approached the Monument - building of the Academy of Athens, were so extensive that conservatory interventions were immediately carried out. The interferences are divided in the following two basic categories: the anaglyphs of the interior of the building, and those of the exterior ground. The sculptures which were treated inside the building are: the small sculptures on the doors of the central hall and in the other lecture halls, and the sculpture of Simon Sinas on the right-hand side behind the main entrance. The open air anaglyphs which were treated are located in the front and back enclosures, in the left and right-hand side of the main entrance, and finally the ornaments of Propylon in front of the entrance stairs. Apart from the marble architectonic material, the drawing panels inside the central area will be analyzed in the next section.

To sum up, two different conservatory plans have been accomplished for these two categories in order to make the laboratory work between the conservators of each field easier.

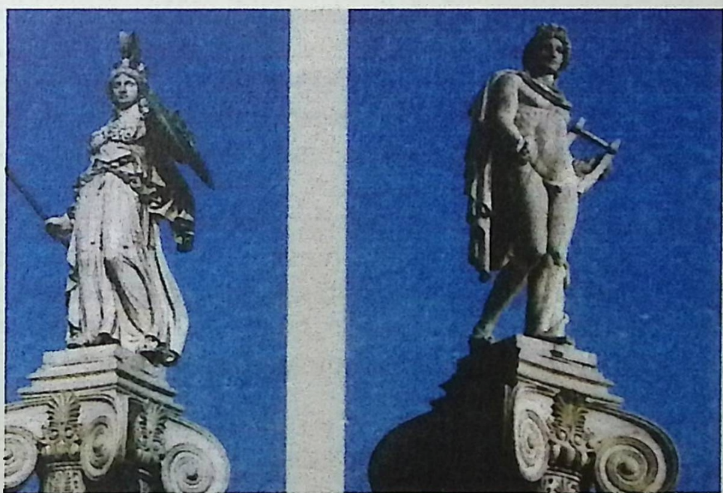


Fig. 2. The statues of Athena and Apollo on each side of the main entrance of the Academy of Athens.

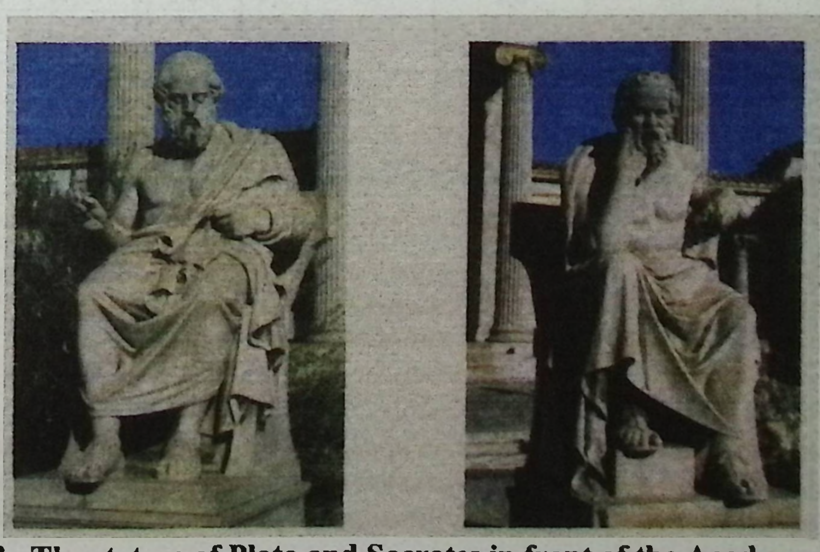


Fig. 3. The statues of Plato and Socrates in front of the Academy of Athens.

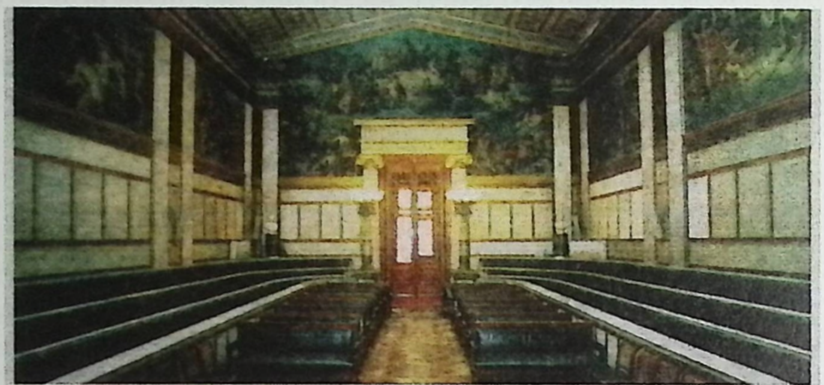


Fig. 4. The Ceremonial hall of the Academy of Athens.

EXPOSURE ENVIRONMENT

Based on the environmental findings, we can explain the corrosion types, especially the black patina found on the Monument, by two critical factors: the presence of gaseous air-pollutants, and the high values of relative humidity (RH).

ATMOSPHERIC POLLUTION

The main characteristic of the urban atmosphere in Athens is the high sulphur dioxide (SO_2) and nitrogen oxides (NO_x) concentration. As for the precipitation, it is highly acidic (50% of the rain shows pH values around 4,5). The concentration of atmospheric pollutants has been diminished during the last few years thanks to the change of old cars with others of new technology. The counts of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and smoke density are higher during the winter months and this is based on the use of central heating. What is more, during the winter season there is high rainfall and humidity, so acidity penetrates the Monument's healthy and corroded parts (Table 1).

	Sample	Porosity (%)	Water absorption (%)	Cd ($\mu S/cm^2$)	pH	Ca^{2+} (ppm)	HCO_3^- (ppm)	SO_4^{2-} (ppm)	NO_3^- (ppm)	Cl^- (ppm)
Healthy	1	0,2	0,11	98	5,9	11,1	17,1	25,6	3,0	12,6
	2	0,1	0,1	90	5,7	10,6	16,3	22,2	2,8	10,4
	3	0,4	0,1	93	5,4	10,2	15,7	23,0	,2	9,2
	4	0,1	0,12	89	5,7	9,8	15,2	21,9	1,4	10,8
	5	0,2	0,11	86	5,8	10,1	15,6	20,8	1,6	8,9
Corroded	6	1,2	0,9	66	6,0	4,5	6,9	12,1	0,8	9,6
	7	1,2	0,9	68	5,9	3,3	5,1	11,5	1,1	11,1
	8	1,3	1,0	61	6,1	3,1	4,8	10,2	1,5	11,3
	9	1,1	1,1	63	6,0	3,7	5,7	9,6	1,3	10,5
	10	1,1	1,0	58	6,2	3,4	5,2	11,2	1,1	9,4

Table 1: The table shows the analysis of the results of acid rain and the difference between the corroded and the healthier (uncorroded) parts of the Monument.

TEMPERATURE

Many fluctuations and variations appear in the temperature of Athens throughout the year, and due to this phenomenon expansion-contraction of the marble causes the mechanical distress of the tectonic material. Additionally, the phenomenon of frost is not observed on the

Monument, due to the combination of its low porous marble and the climatologic conditions of Athens.

WINDS

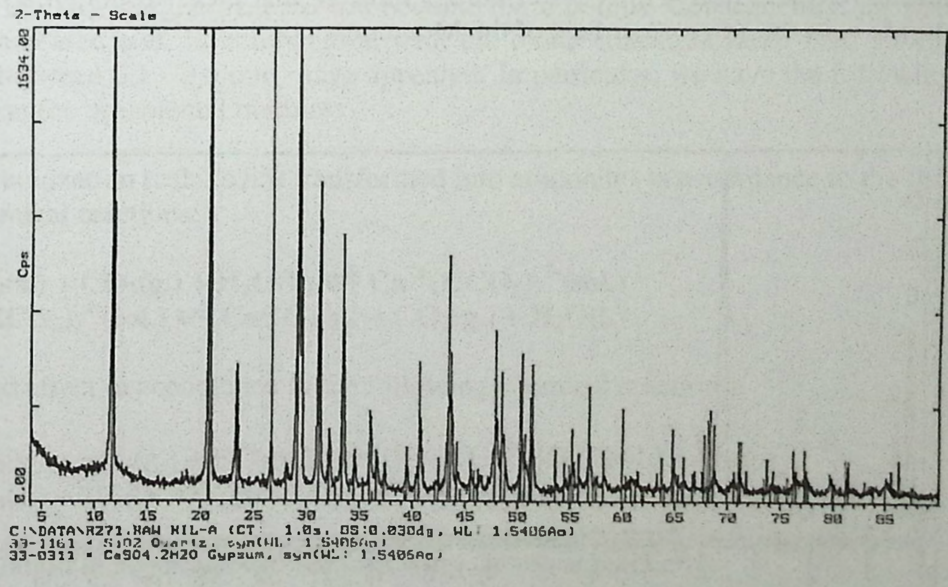
The most forceful winds are northern and this causes the diminishing of the minor amounts of corrosion products in the Academy of Athens. On the contrary, southern winds help the concentration of atmospheric pollution due to the physical phenomenon of the temperature inversion.

ANALYSIS OF STRUCTURAL MATERIAL

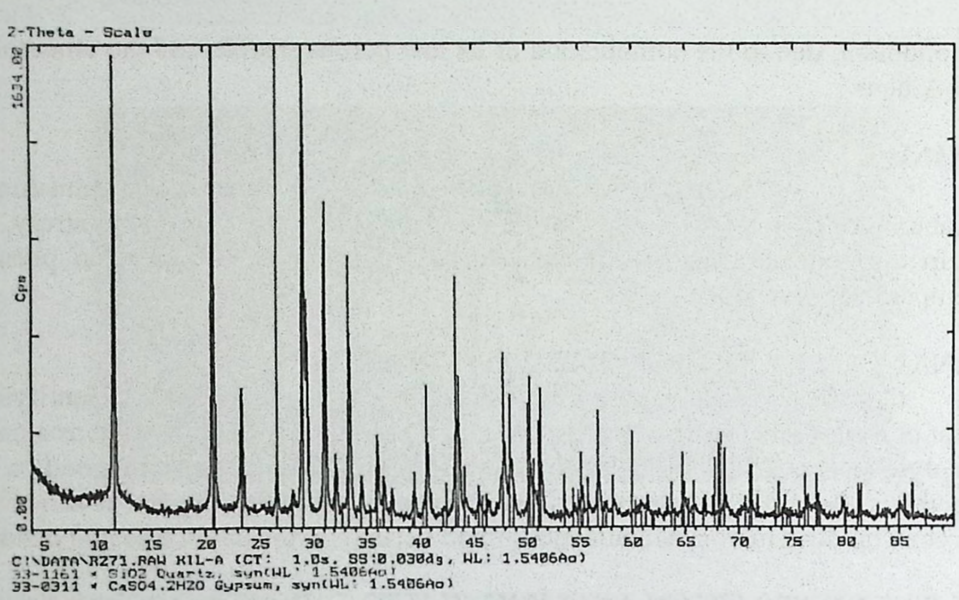
Our scientific approach proposes a complete methodology for identifying the materials that constitute the Monument and monitoring the condition of their corrosion. The work and analyses were carried out in the laboratory and not in situ; and were based on non-destructive methods (0,1 - 0,5 g of the material). The results show that the conservation strategy used to protect outdoor marble Monuments should depend on the environmental conditions.

X-RAY DIFFRACTION ANALYSIS (X-R.D.)

For the analytical petrology, morphology and chemical composition of the structural material, samples of corrosion products were taken from various areas of marble sculptures (10 samples). Before treatment, the first five samples were taken from healthy material, while the others were taken from areas with heavy corrosion products. In the first five samples we observed calcite ($CaCO_3$), and quartz (SiO_2), whereas the other samples were found to contain additionally major or minor amounts of gypsum ($CaSO_4.2H_2O$) and quartz (SiO_2). We were then able to compare the results between these two categories, the healthy and the infected material (Table 1).



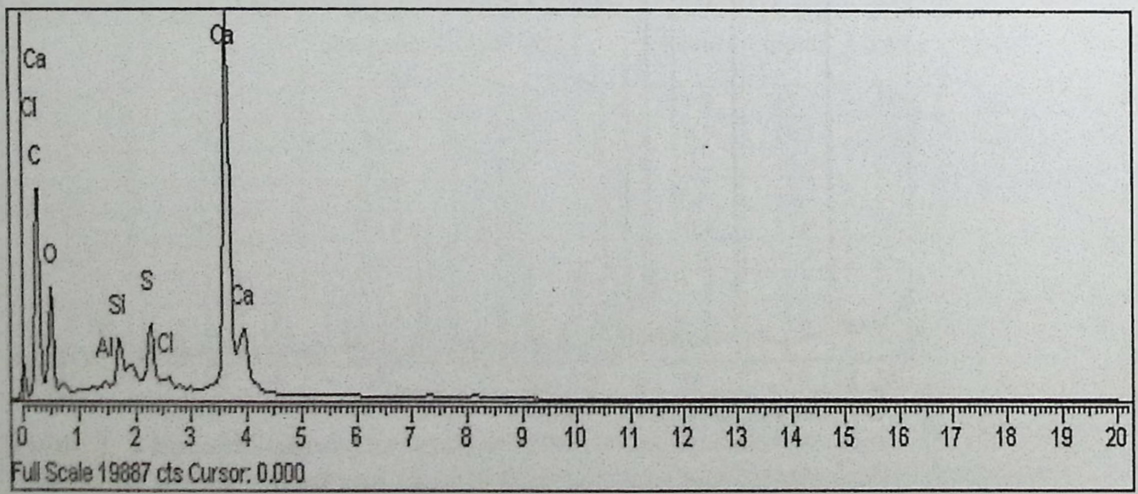
X-R.D. analysis diagram. Presence of gypsum.



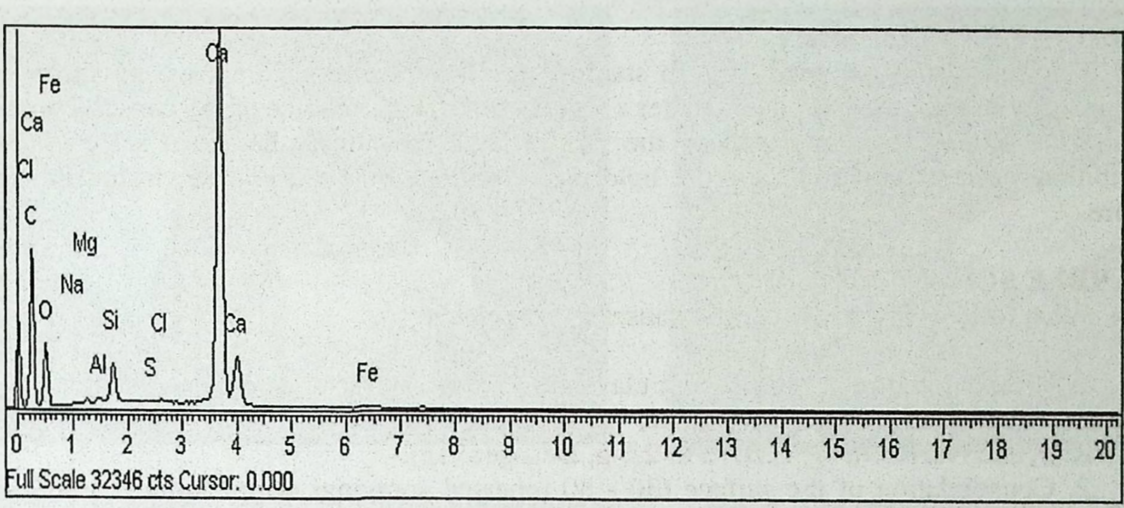
X-R.D. analysis diagram. Presence of gypsum.

SCANNING ELECTRON MICROSCOPY ANALYSIS (S.E.M.)

For the elementary analysis of the structural material and the corrosion effect, we analyzed the same ten samples as in the X-ray diffraction analysis. In the first five (healthy material), we observed the appearance of calcium (Ca), carbon (C), oxygen (O), silicon (Si), aluminum (Al), and magnesium (Mg). For the second five samples, we found high concentration of calcium (Ca), carbon (C), oxygen (O), sulfur (S), silicon (Si) sodium (Na), chlorine (Cl) and iron (Fe). These findings indicate that there are minor amounts of sodium chloride onto the external surface of the Monument.



S.E.M. analysis diagram. Presence of sulfur (S).



S.E.M. analysis diagram. Presence of sulfur (S).

CORROSION PRODUCTS

The interior and the exterior of the Monument of the Academy of Athens have suffered great damages due to its age, the atmospheric pollution and the recent earthquakes. The earthquakes have not caused serious problems to the walls that bear the weight of the building. However, they have seriously affected the roof, which has allowed water and humidity to pass inside the building. A shifting of the marble statues and the interior marbles (e.g. stairs), have occurred as well. These damages will cause a non-reversible deterioration, if they are not faced very soon. The earthquakes' direct results are an augmentation of the crevices and the fact that the material has become more porous. Consequently, the plastering degree has increased and, in combination with the oxide attack, surfaces with strong black crust (depth between 0,1 - 0,6 mm) have appeared. In particular, we have the following types of corrosion on the ornamental marbles:

1. Carbonization (calcite has transformed into aragonite) in accordance to the following chemical reactions:

$$\mathbf{CaCO_3(s.) + CO_2(g.) + H_2O(l.) \rightleftharpoons Ca^{2+}(HCO_3)_2^{2-}(sol.)}$$
$$\mathbf{Ca^{2+}(HCO_3)_2^{2-}(sol.) \rightleftharpoons CaCO_3(s.) + CO_2(g.) + H_2O(l.)}$$

2. Acid effect in accordance to the following chemical reactions:

$$\mathbf{CaCO_3(s.) + SO_2(g.) + \tfrac{1}{2}O_2(g.) + aq(l.) \rightarrow Ca^{2+}SO_4^{2-}(sol.) + O_2(g.)}$$
$$\mathbf{CaCO_3(s.) + 2H_3O^{+}NO_3^{-}(sol.) \rightarrow Ca^{2+}(NO_3)_2^{2-}(sol.) + CO_2(g.) + 3H_2O(l.)}$$

3. Sulfation in accordance to the following chemical reaction:

$$\mathbf{CaCO_3(s.) + SO_2(g.) + \tfrac{1}{2}O_2(g.) + 2H_2O(g.) \rightarrow CaSO_4.2H_2O(s.) + CO_2(g.)}$$

Finally, due to the earthquakes, a shifting of the statues has taken place and a material removal of the connection areas because of the increased volume of the oxide metallic links. Due to the pollution, an extra reduction of the hardness and the resistance of the marble surface have occurred.

LABORATORY CONSERVATION

The aim of the treatment was to stabilize the Monument and improve its appearance through minimum intervention and under a strict schedule. The choice of the conservation and restoration procedures was based on the fact that the Monument has been selected as an exhibition space and should therefore hold the conditions of a museum environment in the future.

MARBLE SCULPTURE

What follows is a review of the conservation project:

1. Cleaning and repair (absorbent clays, non - ionic surfactants, organic solvents, Mora pulp, laser tools, ultrasound tools). The main components of pulp Mora are: H_2O: 100cc, NH_4HCO_3 and $NaHCO_3$: 6g, E.D.T.A.: 2,5 g, Desogen: 1g).
2. Consolidation of the surface (30 - 80 repeated sprayings with saturated solution of calcium hydroxide $Ca(OH)_2$) in according to the chemical reaction:

$$\mathbf{Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O}$$

3. Gap filling, loss compensation (fluid quick-setting plaster with white cement Portland and powder of marble).
4. Removal and change of rusty conjunctions.
5. Copy of authentic material of ceramic anaglyphs at the edges of the roof.

In particular, the stage of cleaning and repair was carried out with non-ionic water and surfactants, paste of Mora and adsorbent clay, in order to clean and remove the resilient crust of the surface. The result was the desirable one, as we measured the pH and the specific electrical conductivity of the washed areas, and we confirmed the removal of all the oxide and alkaline reactivity.

The consolidation of the rickety, shaky areas of the surfaces was accomplished with the aid of saturated $Ca(OH)_2$. The method was carried out by spraying the cleaned surface more than two times per day. This method was repeated eighty (80) times in each consolidation.

In the area where the structural material was missing, we managed to fill and close the clefts. We used compatible plaster with considerable workability and we added inert matter to create colours that were close to the authentic ones.

In order to conserve the sculptures at the edges of the roof, we transferred them (due to the height) to the laboratory. After the restoration, we put them back again agglutinating-connecting the basis surface with plaster and a central interior metallic bar. The statues of Minerva and Apollo were not transferred to the laboratories, due to their heavy weight. However, the idea of transferring them to the laboratories is under discussion, in order to conserve, duplicate or replicate them, and finally replace the authentic statues with their copies.

Fig. 5. The marble statue of Simon Sinas during the conservation procedure (cleaning by use of absorbent clays - sepiolite).

Fig. 6. The marble statue of Simon Sinas during the conservation procedure (cleaning by use of absorbent clays - sepiolite).

Fig. 7. Marble statue of light column before the conservation procedure (presence of black crust due to the atmospheric pollution).

Fig. 8. Marble statue of light column after the conservation procedure.

Fig. 9. Marble statue of light column before the conservation procedure (cleaning by use of absorbent clays - sepiolite).

Fig. 10. Marble statue of light column after the conservation procedure.

Fig. 11. The bronze statue of Medusa on the statue of Minerva during the conservation procedure (cleaning by use of mechanical methods).

Fig. 12. The bronze statue of Medusa on the statue of Minerva during the conservation procedure.

Fig. 13. The marble statue of Apollo during the conservation procedure (presence of acid rain effect).

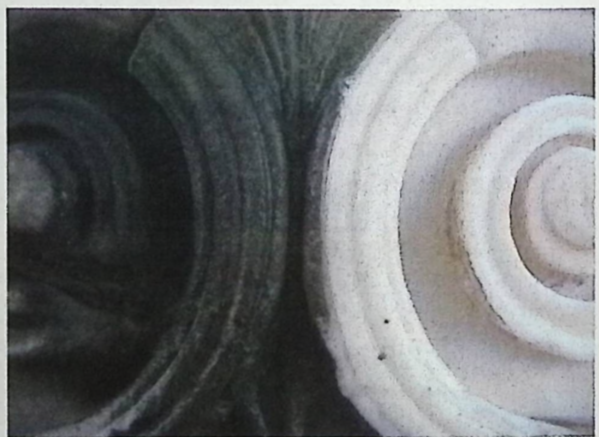


Fig. 14. The marble statue of Apollo during the conservation procedure (presence of black crust due to atmospheric pollution).

Fig. 15. The marble statue of Minerva during the conservation procedure.

Fig. 16. The marble statue of Minerva during the conservation procedure.

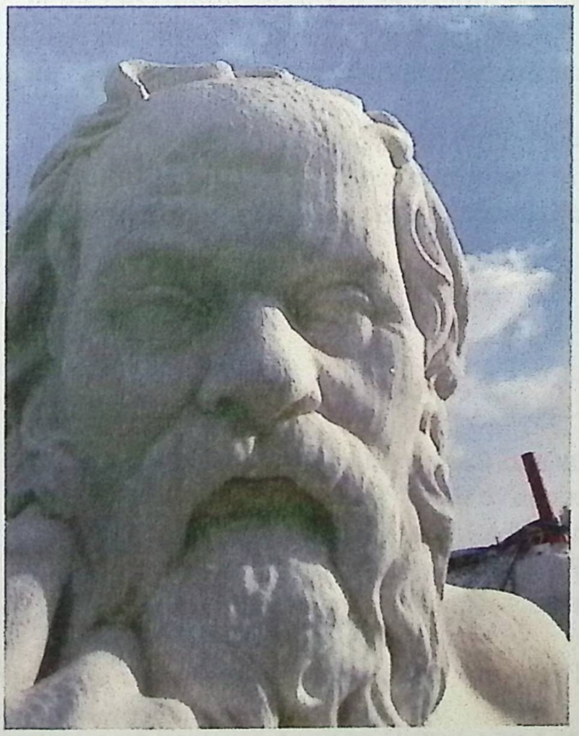


Fig. 17. The marble statue of Socrates during the conservation procedure (presence of carbonization and acid rain effect).

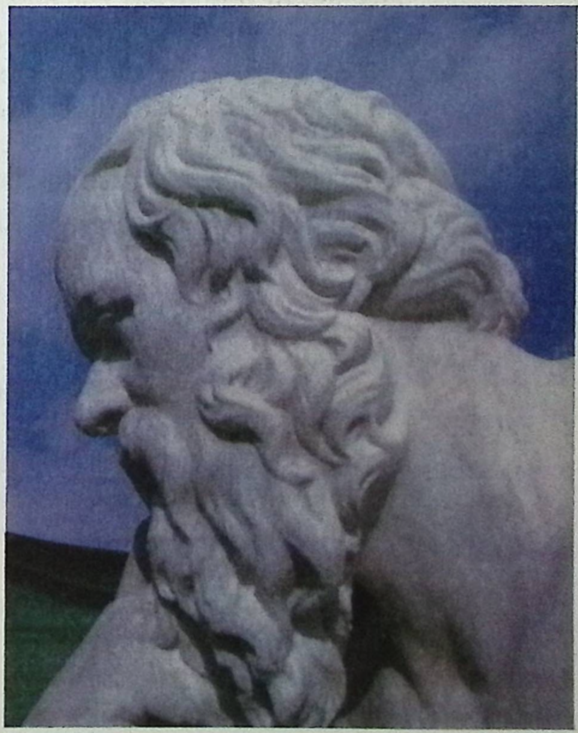


Fig. 18. The marble statue of Socrates during the conservation procedure.

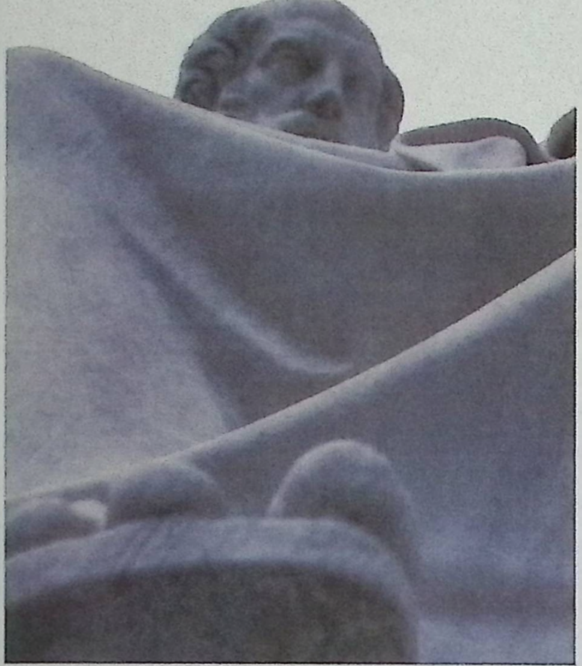


Fig. 19. The marble statue of Plato during the conservation procedure.

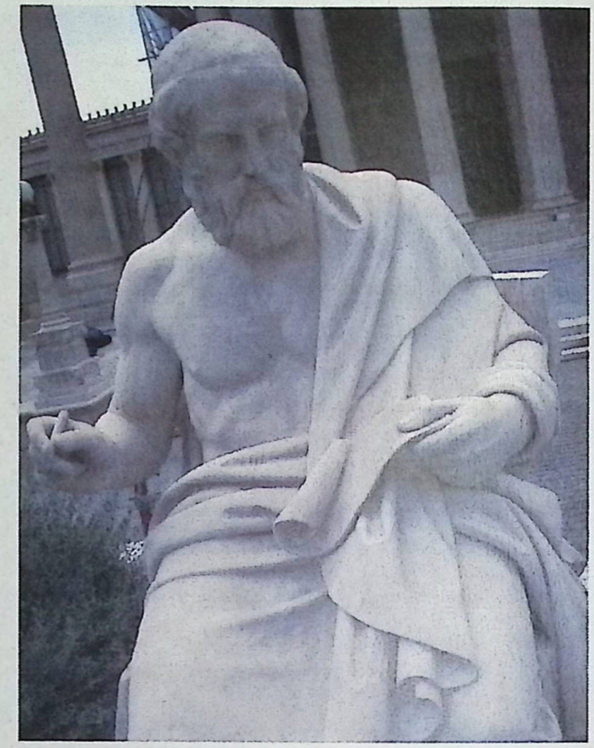


Fig. 20. The marble statue of Plato during the conservation procedure (presence of carbonization and acid rain effect).

CONCLUSIONS

The aim of this report has been to outline the processes involved in the conservation of the Academy of Athens and the historic items it contains. The main conclusions are as follow:

1. The methods that were applied in the conservation process resulted from the chemical analyses of the structural material.
2. Conservation techniques have been based on the test results.

During the last six years since the beginning of the conservation, the initial methods and the techniques we have developed have proven satisfactory in the medium to long-term, without destroying the authentic materials.

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THE BRONZE STATUE OF EVANGELOS AVEROF - TOSSITSAS IN METSOVO - GREECE. CORROSION PATTERNS AND CONSERVATION PROCEDURES

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Περίληψη

Ο Ευάγγελος Αβέρωφ - Τοσίτσας (1908 - 1990) ήταν μια εξέχουσα πολιτική φυσιογνωμία της νεότερης Ελλάδας, διανοούμενος και με υψηλή μόρφωση και σημαντική φιγούρα του προσώπου της Ελλάδας στο εξωτερικό. Γεννήθηκε στο Μέτσοβο της Ηπείρου το 1908 και έδειξε πολύ μεγάλο ενδιαφέρον για την ανάπτυξη της ιδιαίτερης πατρίδας του. Πέθανε στην Αθήνα το 1990 και το μπρούτζινο άγαλμά του φιλοτέχνησε ο γλύπτης, ακαδημαϊκός και καθηγητής της Ανωτάτης Σχολής Καλών Τεχνών, Ι. Παππάς τα έτη 1990 - 91.

Στην παρούσα μελέτη εξετάζονται οι συνθήκες περιβάλλοντος του γλυπτού όπως υγρασία, θερμοκρασία κ.λπ. και διαπιστώνεται η κατάσταση διατήρησής του. Στη συνέχεια προτείνονται διαδικασίες συντήρησης και αποκατάστασής του.

Introduction

Evangelos Averof - Tossitsas (1908-1990) was a distinguished Greek politician, intellectual and literary man, an eminent figure in the public affairs of modern Greece and an important national benefactor who contributed to the development of his hometown of Metsovo, in Epirus. He died in Athens in 1990. His bronze statue in Metsovo was created by the sculptor I. Pappas in 1990-91.

This paper discusses the most common corrosion factors of the Province of Epirus such as high humidity, frost, biological depositions and temperature variations. Climatic conditions around the monument and their effects are examined. Information about the most appropriate conservation treatment of the statue is also included.

The man Evangelos Averof - Tossitsas

Fig. 1. Evangelos Averof-Tossitsas.

Evangelos Averof - Tossitsas was born in 1908 in Trikala of Thessaly, where he lived for the first ten years of his life. He studied law and economics in Lausanne. His great interest in public affairs began early on and he played a leading role in the political life of Greece for nearly half a century. In particular, he served his country as Prefect, Parliamentarian, Deputy Minister and Minister of Supply, Finance and Agriculture. From 1956 to 1963 he held the post of Minister of Foreign Affairs and he also participated in one of the foremost acts of resistance against the regime during the military dictatorship of 1967-1974. He was arrested as an "instigator" for his activities but after the restoration of democracy he was appointed Minister of National Defense (1974-1981). Later he served as Vice President of the Government, Leader of the Official Opposition and in 1984 was proclaimed Honorary Chairman of the New Democracy party.

Evangelos Averof-Tossitsas was also a prominent author of political and historical works, such as "Customs Union in the Balkans" (1933), "Fire and Axe, 1944-1949" (1974) and "A History of Missed Opportunities: The Cypriot Problem 1956-1963" (1981). In particular, he successfully managed to leave a rich literary corpus of novels, short stories and plays which have been translated in many languages and have received international recognition and awards, such as the Gold Medal of the French Academy (1974) and the Acropolis literary prize (1978).

Furthermore, Averof was a man who engaged in wide ranging social and economic activities of public benefit in his village of origin, Metsovo. For example, he was the driving force of the Baron Michael Tossitsas Foundation and supervised the construction of more than a hundred schools in the prefecture of Ioannina. He also founded a Students' Hall of Residence in Athens where university students from the district of Epirus stay free of charge, a museum of folk art in Metsovo (Tossitsas Museum), a ski centre, a model cheese-making industry, a wood working factory and a centre for the sale of folk art and handicrafts. However, ''Katogi Wine'' was the only one of his activities in Metsovo which had the form of an enterprise and did not operate on a non-profit basis. Today, Katogi Averof S.A. is firmly established as a dynamic young company with solid foundations and high-quality products.

Fig. 2. Tossitsas Museum.

Towards the end of his life, he created the public service institution Evangelos Averof - Tossitsas Foundation to which the Art Gallery belongs. It is a three-storey building which houses Averof's valuable personal collection of 250 works by Greek artists of the 19th and 20th centuries. Today, the Museum attracts 15.000 visitors a year from all over Greece because of its temporary exhibitions and its significant cultural events.

Fig. 3. Averof Gallery.

Evangelos Averof - Tossitsas died on 2 January 1990 in Athens. His bronze statue in Metsovo was created by sculptor I. Pappas in 1990-91.

Fig. 4. The city of Metsovo.

Climatic conditions

Fig. 5. Map of Ioannina Prefecture.

The bronze outdoor sculpture is situated in Metsovo, which is one of the most picturesque and traditional towns of Ioannina Prefecture. The capital of Ioannina Prefecture and of Epirus is Ioannina. Metsovo is built like an amphitheatre at an altitude of 1.156 m., on one of the highest peaks of the Pindos mountain range at the junction of Epirus, Thessaly and Western Macedonia. Its geographical place and its topographic configuration play a decisive role in its climatic conditions.

Typical climatic elements of the region are the relatively high humidity, the abundant rains, the intense snowfalls, the frosts and the temperature variations which are also the most common corrosion factors of the Province. Such an environment is of course very unfriendly to outdoor bronzes. Consequently, it is evident that there is a significant relationship between climatic parameters and corrosion damage. The infiltration of rainwater at the interior of a monument in conjunction with exterior moisture promotes rapid corrosion on its metal surface.

For this reason, by checking the environment, we control at the same time the process of corrosion; and therefore it can be possible to limit the causes of deterioration.

**Fig. 6. The bronze statue of
Evangelos Averof-Tossitsas in Metsovo.**

The basic climatic parameters of Ioannina Prefecture and region of Metsovo - such as wind speed and direction, solar radiation, air temperature and relative humidity, dew point temperature and rainfall - are given in the tables, graphs and climatic diagrams below.

According to table one of the climatic parameters of Ioannina Prefecture (period 1956 - 2001), we are led to the following conclusions: The climatic conditions of the area are those of a transient zone (between Mediterranean and Continental). This means that the average monthly temperature ranges from 5 °C (January) to 25 °C (July); and the average monthly relative humidity fluctuates between 52% (July) and 82% (December). Additionally, the absolute maximum temperature ever recorded was 42.4 °C, while the absolute minimum temperature ever recorded was -13 °C. Summers are also characterized by moderate precipitation.

HELLENIC NATIONAL METEOROGICAL SERVICE
DIRECTION OF CLIMATOLOGY
SECTION OF STATISTICAL CLIMATOLOGY

CLIMATOLOGICAL DATA BASE — IDATCLIMI

STATION 642
LATITUDE 39φ 42' N LONGITUDE 20φ 49' E ALTITUDE OF BAROMETER 484.0 METERS

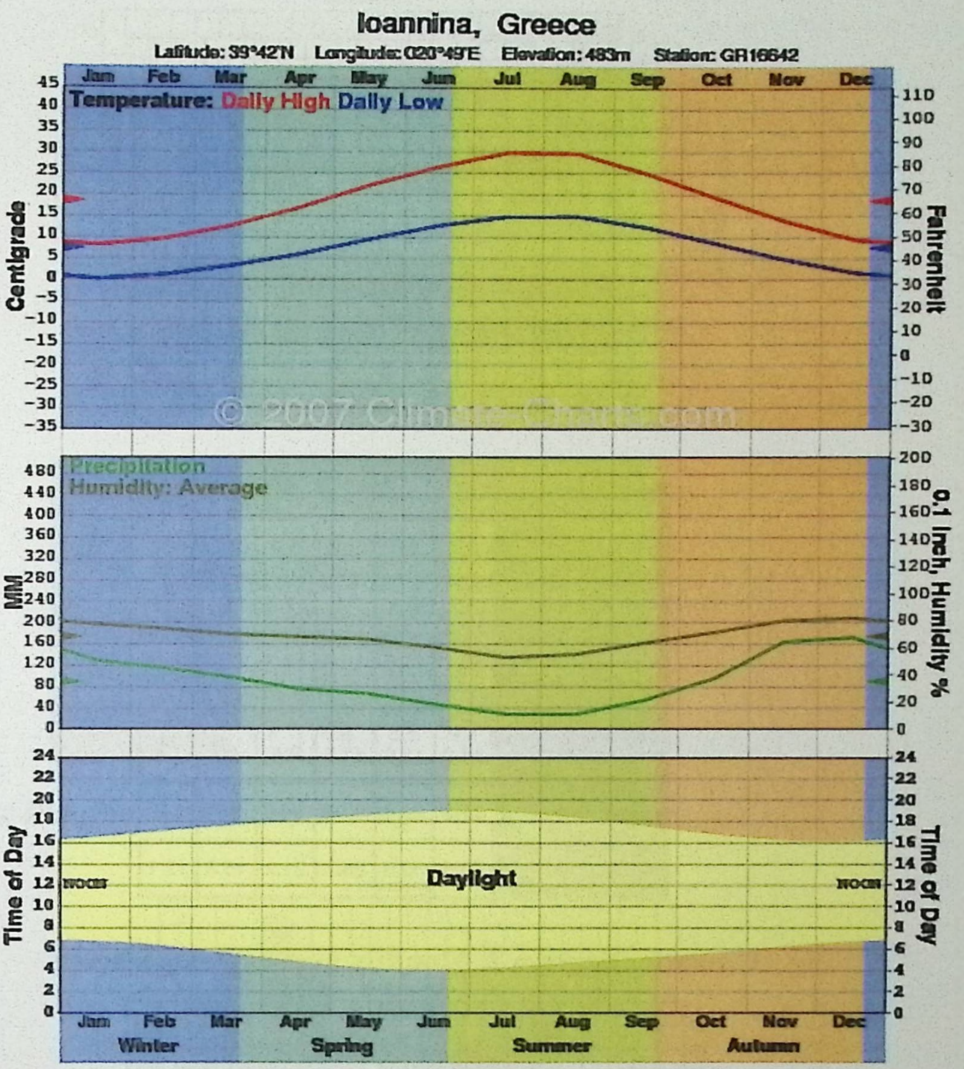
PERIOD 1956-2001

MONTH	PRESS(M.S.L.)	TEMPERATURE MEAN	AV.MAX	AV.MIN	ABS MAX	ABS MIN	REL HUM.	AV.CLOUD.	PRECIPITATION(IN MM) TOTAL	MAX 24H	PREV.WIND
JANUARY	1019.5	4.7	10.0	.2	20.0	-13.0	77.2	4.6	118.7	89.7	SE
FEBRUARY	1018.0	6.0	11.4	1.0	23.6	-10.2	73.9	4.7	110.4	56.6	SE
MARCH	1016.5	8.8	14.4	3.2	29.2	-8.2	69.4	4.7	92.2	58.8	SE
APRIL	1014.3	12.4	17.7	6.0	28.2	-3.0	68.1	4.9	78.1	67.3	SE
MAY	1015.0	17.5	23.1	9.7	34.2	-.5	65.8	4.2	67.5	45.4	W
JUNE	1014.5	22.0	27.7	12.8	38.8	5.2	58.8	3.0	41.8	55.3	W
JULY	1013.3	24.9	30.9	15.0	42.4	7.4	52.1	2.0	30.4	53.2	W
AUGUST	1013.8	24.5	31.0	15.1	40.5	7.0	54.1	1.9	30.6	72.0	NW
SEPTEMBER	1016.8	20.1	26.6	12.2	37.3	3.0	63.9	2.7	53.5	64.5	W
OCTOBER	1018.9	15.0	21.3	8.5	32.2	-3.0	71.1	3.6	97.8	111.6	SE
NOVEMBER	1019.2	9.7	15.4	4.8	24.4	-8.4	80.0	4.7	170.3	94.0	SE
DECEMBER	1018.8	5.8	10.9	1.7	19.0	-11.0	81.8	5.0	175.0	86.6	SE

NUMBER OF DAYS WITH

MONTH	CLOUDINES (0 - 8/8) 0-1.5	1.6-6.4	6.5-8.0	PREC.	RAIN	SNOW	THUND	HAIL	ST GND	FOG	DEW	H.FROST	TEMPERATURE MIN LE 0.0	MAX LE 0.0	WI ND GE 6B	GE 8B
JANUARY	7.1	12.9	10.9	13.0	12.1	1.9	1.9	.0	.8	5.5	.7	4.7	15.1	.1	1.5	.3
FEBRUARY	6.2	11.8	10.2	12.5	11.5	2.2	2.1	.2	1.0	3.2	.5	2.8	11.7	.1	1.5	.3
MARCH	5.9	15.9	9.2	12.6	12.0	1.2	2.2	.2	.6	2.5	1.5	1.3	6.0	.0	1.6	.3
APRIL	4.0	18.0	8.0	12.7	12.7	.0	2.8	.2	.0	1.7	2.6	.1	.8	.0	.7	.0
MAY	5.8	20.8	4.4	11.0	10.8	.0	5.1	.2	.0	1.6	3.1	.0	.0	.0	.3	.0
JUNE	10.1	18.7	1.3	6.8	6.7	.0	5.2	.1	.0	.8	2.5	.0	.0	.0	.1	.0
JULY	17.8	12.7	.4	4.7	4.7	.0	4.8	.1	.0	.3	1.1	.0	.0	.0	.2	.0
AUGUST	17.8	12.9	.3	4.8	4.7	.0	4.7	.1	.0	.2	.7	.0	.0	.0	.3	.0
SEPTEMBER	13.3	15.0	1.7	6.8	6.7	.0	3.8	.1	.0	1.6	2.2	.0	.0	.0	.3	.0
OCTOBER	10.2	16.0	4.8	9.8	9.7	.0	3.3	.0	.0	5.0	3.5	.2	.5	.0	1.0	.2
NOVEMBER	6.0	14.5	9.5	13.8	13.7	.2	4.0	.1	.0	7.2	2.7	1.9	4.8	.0	.5	.0
DECEMBER	6.0	12.7	12.3	15.2	14.5	1.1	2.5	.2	.5	6.6	1.1	4.6	11.5	.1	.8	.2

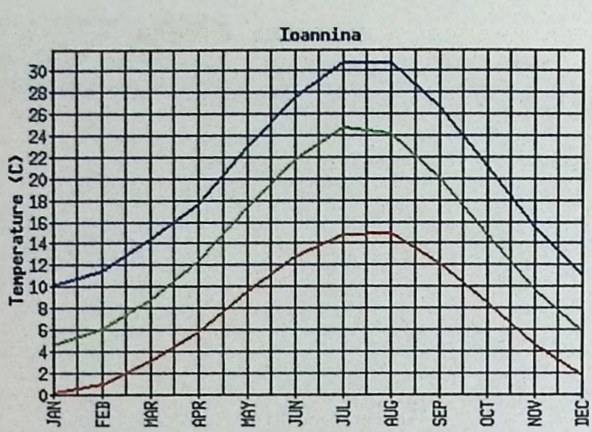
Table 1. Climatological data base of period 1956-2001.



Climatic Diagram 1. Ioannina Greece Yearly Climate Temperature and Precipitation. Ioannina: Longitude 20°49'1" / Latitude 39°42'0"/ Alt 483m.

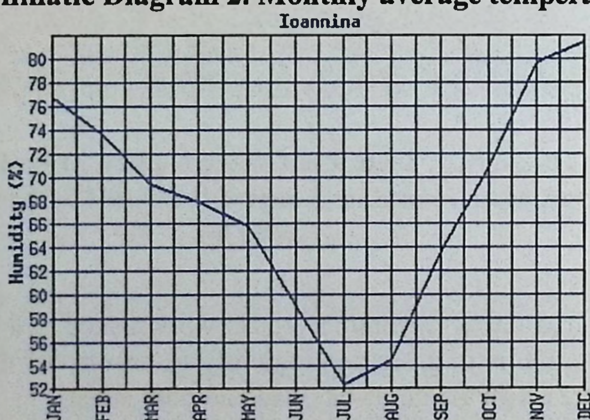
At the top section, high and low temperatures are shown with red and blue lines respectively. In the middle section, precipitation is in green and humidity in brown. At the bottom section, daylight is shown by the yellow area with a time-of-day scale on both sides.

Additionally, according to the above climatic diagrams it is obvious that the climate is humid and rainy with cold, long and dry winters and warm summers with few local rains. Particularly, intense snowfalls are marked from December to March and frosts are observed from November until April. It is marked that January is the coldest month of the year while the hottest is July.



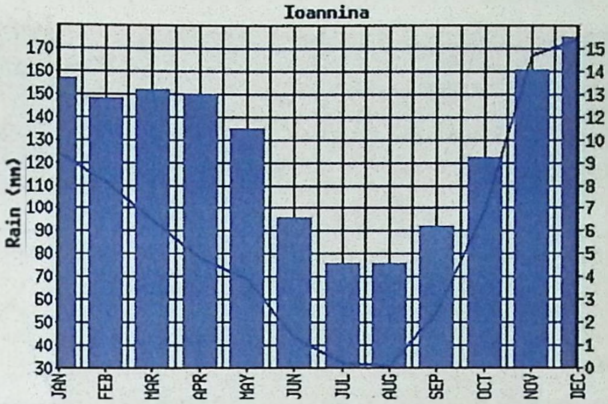
1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Min Temperature	0.2	1.0	3.2	5.9	9.6	12.8
Monthly Average Temperature	4.7	6.1	8.8	12.4	17.4	21.9
Monthly Max Temperature	10.1	11.5	14.4	17.7	23.0	27.6
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Min Temperature	14.9	15.0	12.2	8.5	4.7	1.8
Monthly Average Temperature	24.8	24.3	20.1	14.9	9.7	5.9
Monthly Max Temperature	30.8	30.9	26.7	21.2	15.5	11.1

Climatic Diagram 2. Monthly average temperature.



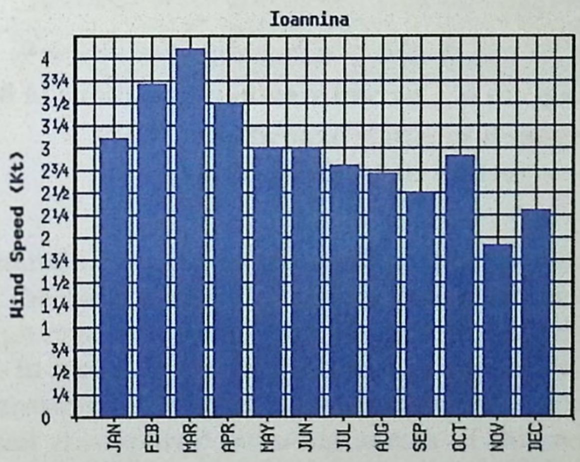
1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Humidity	76.9	73.7	69.5	67.9	65.9	59.1
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Humidity	52.4	54.4	63.6	70.8	79.8	81.5

Climatic Diagram 3. Monthly average humidity.



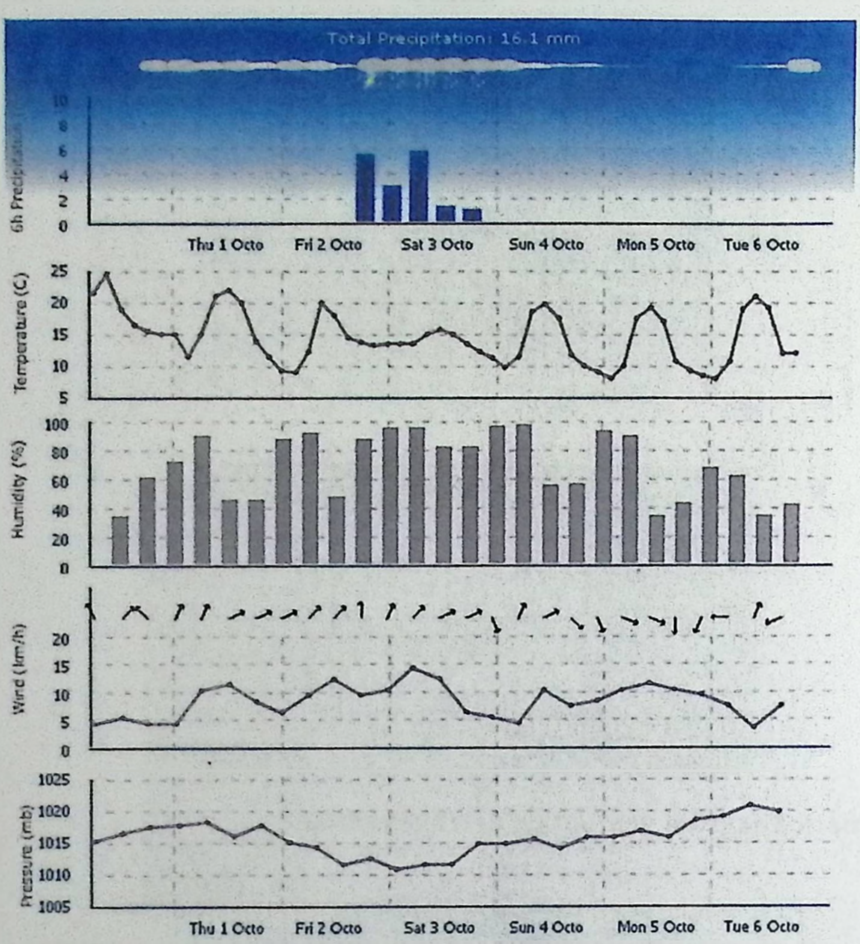
1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Rainfall	124.2	111.6	95.4	78.0	69.3	43.5
Total days of Rain	13.3	12.4	12.8	12.6	11.0	6.9
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Rainfall	32.0	31.2	54.0	99.5	167.9	174.9
Total days of Rain	4.8	4.8	6.5	9.7	13.7	15.2

Climatic Diagram 4. Monthly average rainfall.



1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Wind Direction	SE	SE	SE	NW	NW	NW
Monthly Average Wind Speed	3.1	3.7	4.1	3.5	3.0	3.0
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Wind Direction	W	NW	W	SE	SE	SE
Monthly Average Wind Speed	2.8	2.7	2.5	2.9	1.9	2.3

Climatic diagram 5: Monthly average wind direction and wind speed.



Climatic Diagram 6. Current weather conditions in Metsovo.

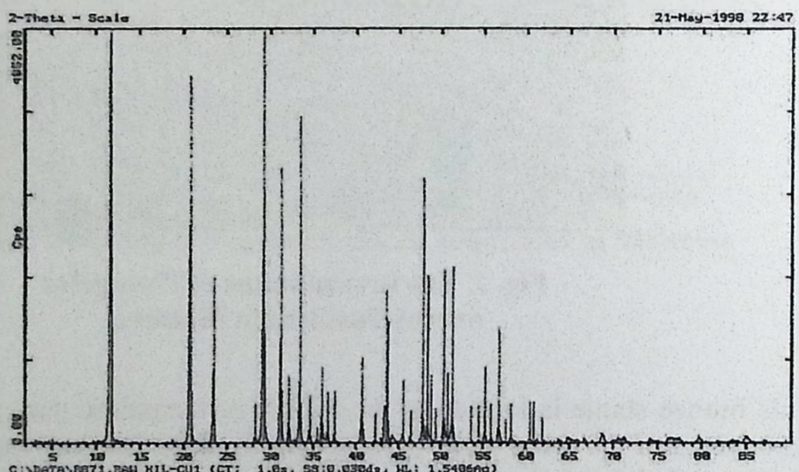
Corrosion problems

Fig. 7. The bronze statue of Evangelos Averof-Tossitsas in Metsovo.

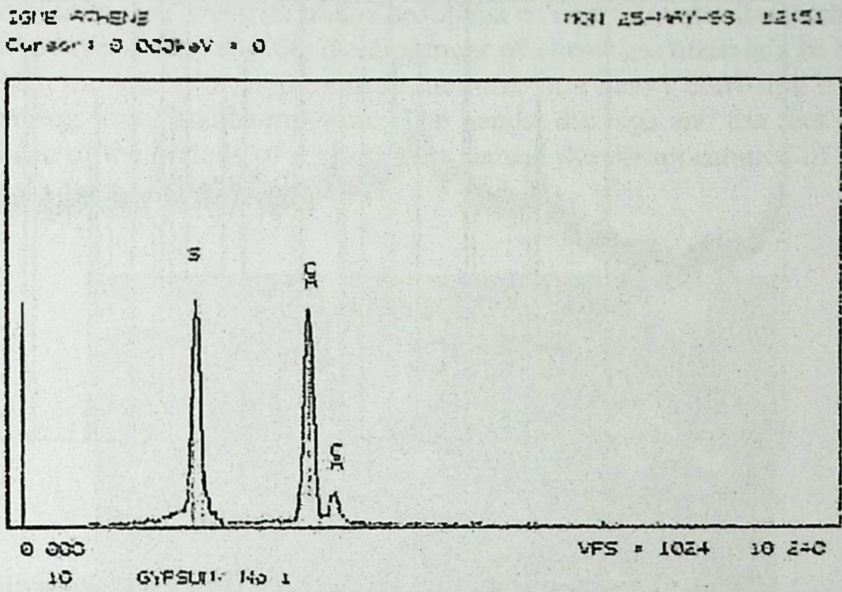
This bronze statue is located in the middle of the public park in Metsovo. Given the rapid adjustment of the metal surface to the temperature of the surrounding air, the factors of precipitation and high relative humidity are the fundamental elements that accelerate electrochemical corrosion. In regard to the electrochemical aspects, climate certainly has a decisive influence on the corrosion of the bronze. Fundamentally, it must be said that humidity, temperature and different atmospheric polluting agents of this region constitute its "macroclimate", whereas the "microclimate" is the specific condition surrounding the object, depending surely on the sculpture's morphology. Copper and bronze objects or elements of construction, such as sculptures, are affected by the atmospheric environment. Thus, the surface of a bronze statue is covered with corrosion products, dirt and biological contamination.

Samples from this sculpture mainly contained copper corrosion and patina compounds. A mineral analysis with the use of X-rays diffraction (X.R.D.) and Scanning Electron Microscope (S.E.M.) has been performed in order to estimate the corrosion materials and the depositions. Gypsum ($CaSO_4.2H_2O$) and Descoloizite ($Pb(Zn,Cu)VO_4(OH)$) have been formed on the base of its surface as confirmed by X-Ray Diffraction (X.R.D.)analysis. The more abundant corrosion products identified on the whole surface are Rozazite of zinc ($(Cu,Zn)_2CO_3(OH)_2$), Rozazite ($Cu,Zn(CO_3(OH)_2)$), Cuprite (Cu_2O), Moganite (SiO_2), Paratacamite ($Cu_2Cl(OH)_3$), Clinochlore ($CuPb_2Cl_2(OH)_4$).

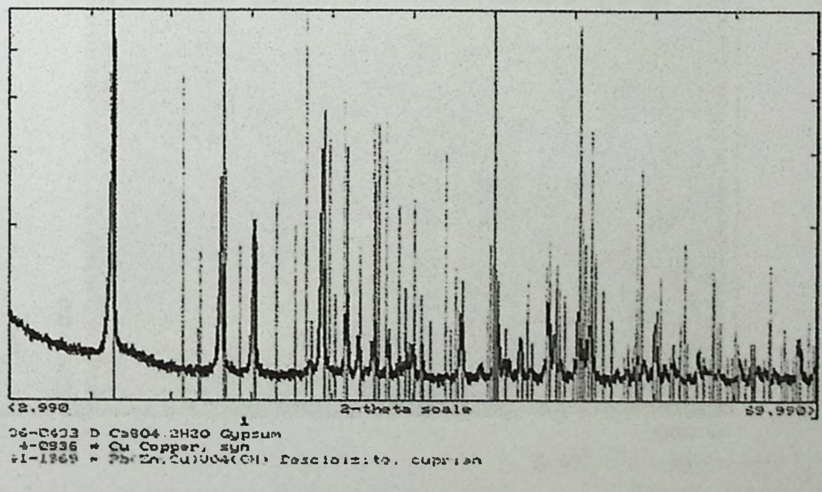
Fig. 8. The base of the statue.



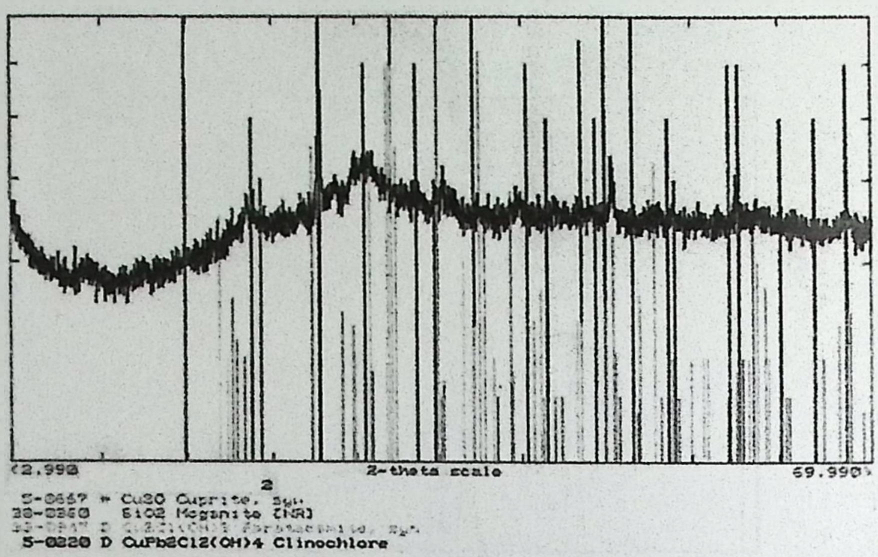
Graph. 1. X-ray diffraction (X-R.D.). Presence of Gypsum ($CaSO_4$. $2H_2O$) and Copper (Cu).



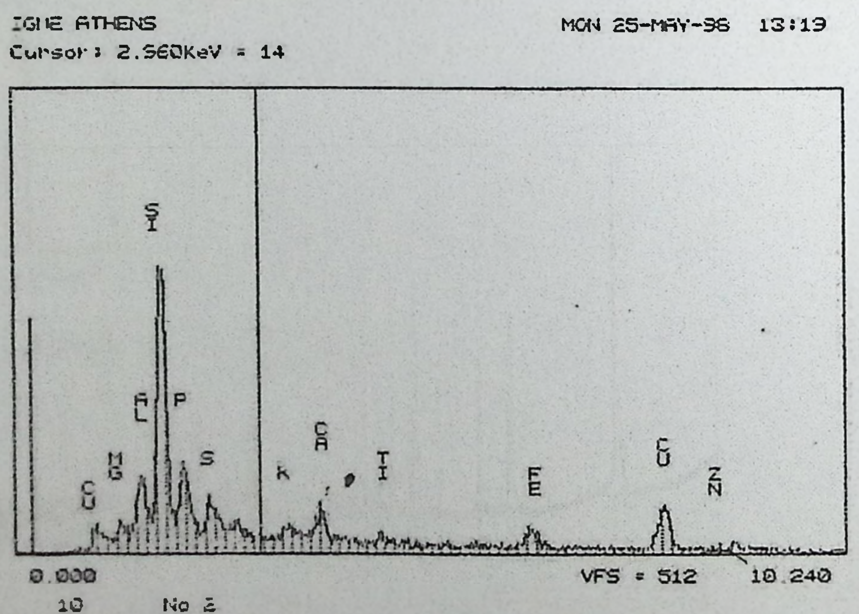
Graph. 2. Scanning Electron Microscope (S.E.M.). Presence of Sulfur (S) and Copper (Cu).



Graph. 3. X-ray diffraction (X-R.D.) Presence of Gypsum ($CaSO_4.2H_2O$), Copper (Cu) and Descoloizite (Pb (Zn,Cu)VO_4(OH)).



Graph. 4. X-ray diffraction (X-R.D.). Presence of Rozazite of zinc $(Cu,Zn)_2CO_3(OH)_2$), Rozazite $(Cu,Zn(CO_3(OH)_2)$, Cuprite (Cu_2O), Moganite (SiO_2), Paratacamite ($Cu_2Cl(OH)_3$), Clinochlore ($CuPb_2Cl_2(OH)_4$).



Graph. 5. X-ray diffraction(X-R.D.). Presence of Rozazite of zinc $(Cu,Zn)_2CO_3(OH)_2$), Rozazite $(Cu,Zn(CO_3(OH)_2)$, Cuprite (Cu_2O), Moganite (SiO_2), Paratacamite ($Cu_2Cl(OH)_3$), Clinochlore ($CuPb_2Cl_2(OH)_4$).

The sculpture also suffered a natural alteration due to the instability of bronze in outdoor conditions. In fact, it presents major problems of natural corrosion such as the removal of the protective layer (wax) and the development of corrosion materials in specific areas of its surface. Thus, the alteration is present in the form of a heavy corrosion on the surface exposed to streaming water and to moisture. The hands, the legs and the feet of the statue are corroded because of the actions of visitors that caused the disappearance of the original patina.

Fig. 9. Removal of "patina" on feet of the statue.

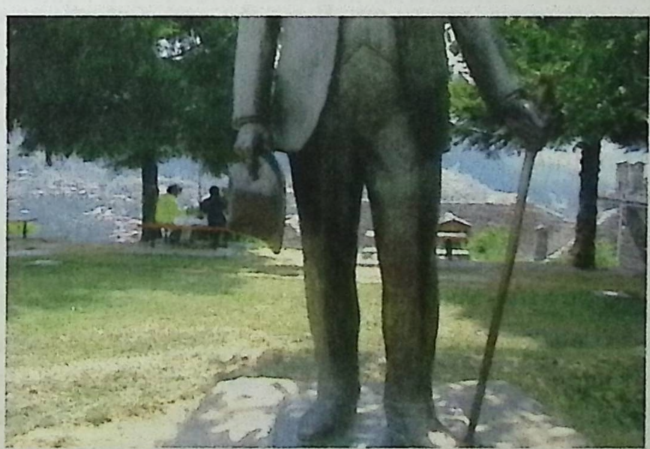


Fig. 10. Removal of the protective layer (wax) and appearance of corrosion materials.

Fig. 11. Presence of graffiti on the surface of the statue.

Consequently, this outdoor bronze has lost its original artificial patina and its surface coating. The surface of the bronze has developed a natural, green patina with heavy black copper sulphide because of the lack of maintenance. On the whole surface of this statue there is also a thin green layer of mineral "malachite" as a result of the corrosive environment. Furthermore, there is "graffiti" in the form of symbols and various figures at the back of the statue.

Overall, the monument is dirty with green corrosion, containing chlorides, speckled with large black corrosion areas, many small cracks and distortions of form throughout the sculpture.

Its popularity as a tourist attraction also leads to significant wear to the accessible areas of the sculpture, and to the attention of graffiti artists. As a result, the surface of the bronze sculpture is in poor condition, mainly because of surface dirt and discolouration. It deteriorates over time and also loses its characteristic brightness.

Conservation treatment

All interventions for the conservation on the sculpture, the choice of methods and products, were made by professors of the Department of Conservation of Antiquities and Works of Art of T.E.I. of Athens and by specialist Conservators of Antiquities and Works of Art. The products that were used were stable for the outdoor environment. Additionally, the conservation treatment was conducted in situ.

The best way of preserving a statue is a systematic scientific approach. Conservation is achieved by arresting deterioration through understanding its mechanisms and applying scientifically-investigated treatment and preventive measures. To prevent further loss of the surface, it is necessary to remove the corrosion products and thus inhibit further corrosion. For this reason, it is necessary to acquire a detailed knowledge of the structure of the statue and the chemical and physical deterioration mechanisms it is likely to undergo given its atmospheric environment and the various other factors to which it is exposed.

The most appropriate methods used in conservation for the cleaning of statuary are laser cleaning, abrasive cleaning, chemical cleaning and steam cleaning. In practice, the surface of the statue was cleaned with a mixture of organic solvents which were very active on the paint without any influence on the patina, in the cases of corroded wax and graffiti. In addition, deionized water, chelated agents (E.D.T.A.) and mechanical methods were used for the cases of biological depositions and corrosion materials. Using high pressure water technology in order to treat the whole surface, it is possible to maintain colour continuity. After this cleaning, no significant areas of active corrosion were found. It is certain that all these cleaning treatments make the monument more aesthetically pleasing and at the same time can reveal some unresolved conservation problems.

Moreover, a total chemical repatination - consisting of potassium sulphide and a mixture of special wax and UV absorber - was applied in order to protect the whole surface. This wax contributes to the prevention of paint vandalism and makes cleaning easier. Obviously, localised repatination was carried out in order to unify the colour of all bronze elements to a dark black and to keep the sculpture in a more balanced and stable state. Fundamentally, the most effective way of preserving the natural or artificial patina is using the coating layers in conjunction with regular cleaning and annual waxing with a special wax formulated for outdoor conditions.

In fact, this sculpture is in some ways a living object and will always be touched. This reflects the fact that new graffiti will reappear. The metal surface can be protected by the wax and in that case the graffiti should be easily eliminated. As a general rule, we recommend a new application of wax every two or five years in order to keep its efficiency and also to clean the freshly made graffiti. Similarly, given the need to seal the surface from moisture, it is necessary to apply an impermeable arrangement of coatings. The key to the long-term protection for bronzes is regular maintenance and the renewal of protective coatings of lacquer or waxes. Actually, the high resistance of copper to atmospheric corrosion and the characteristic layers of corrosion products (patina) contribute to greater stability of objects in the atmospheric environment.

Conclusions

The conservation must consist of the following steps: examination, recording, diagnosis, action and care. The objective of conservation is the safeguarding and preservation of material cultural heritage within an ethical framework which ensures that the physical, historic and intrinsic nature of the monument is not altered.

Weather conditions can never be changed or eliminated. Deterioration can be retarded but not completely arrested. In fact, the damage that it causes can never be completely repaired but it can be reduced by controlling its causes.

Finally, it is generally believed that multiple strategies, including technical measures, conservation treatment and monument management, are more likely to preserve the statue intact for future generations.

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