Relating the damage assessment of outdoor bronze and copper monuments in Greece to the environment, techniques of construction, and past cleanings

V. Argyropoulos\textsuperscript{1*}, A. VOSSOU\textsuperscript{1}, M. GIANNOULAKI\textsuperscript{1}, D. CHARALAMBOUS\textsuperscript{1},
I. SIANOUDIS\textsuperscript{1}, K. POLIKRETI\textsuperscript{2}
A. KARYDAS\textsuperscript{3}, V. PERDIKATSIS\textsuperscript{4}, S. BITTNER\textsuperscript{5}, and M. MACH\textsuperscript{5}

1. Department of Conservation of Antiquities & Works of Art, T.E.I. of Athens, Ag. Spyridonos, Aigaleo, Greece 12210, 30210538549, bessie@teiath.gr

\textsuperscript{2}Hellenic Ministry of Culture and Tourism, Greece

\textsuperscript{3}Institute of Nuclear Physics, N.C.S.R Demokritos, Greece

\textsuperscript{4}Department of Mineral Sources, Technical University of Crete, Greece

\textsuperscript{5}Bayerisches Landesamt für Denkmalpflege, Zentrallabor, Munich, Germany
Kolokotronis in Nafplion and Athens
Objectives

• condition assessment for unique masterpiece monument located in Athens since 1927 “Theseus saves Hippodamea” constructed in 1908, artist Joh. Pfuhl, German manufacturer WMF in Geislingen
• Compare the types of corrosion products to past research carried out for the Kolokotronis monuments in Athens and Nafplio
• to better understand the techniques of fabrication, corrosion, and damages of this monument, in relation to its environment and past cleanings.
Theseus by Johannes Pfuhl in 1907

- Looks and sounds like cast bronze but copper
- 'Hollow type' expensive to make as opposed to 'Core type'
- Key is thickness of wall
- Good replication technique
Famous monuments in Poland and Germany

Perseus Monument in the catalogue of WMF (1910)

Perseus Monument on the roof of the “Theater des Westens”, Berlin
Electrotype technology
German WMF company founded an electrotype department in 1890

Voltaic power source in the laboratory of the chemist Sir Humphry Davy (1778-1829) made up of 200 copper-zinc galvanic elements

Schematic diagram of the "core type" process.
“Hollow Type” Process

- Graphite layer on mold (negative)
- Thin wire net in galvanic liquid (positive)
- Thicker walls than ‘Core type’ process
- No gypsum is required for core
Strap of the interior fitting at plinth stilts inside the plinth were fixed with narrow bands of electroplated copper.
Cracks - disequilibrating actions within the sculpture. The plinth is not able to absorb the complete weight of the overlying parts of the monument.
Examination of Iron Bars

Simple Magnet

Endoscopy and Digital Camera

OPEN AIR METAL OUTDOOR METALLIC SCULPTURE FROM THE XIXTH TO THE BEGINNING OF THE XXTH CENTURY
Visual Examination with an endoscopic and a digital camera

- The plinth inside is stabilised by an afloat base-ring made up of pig iron
- On this base-ring there are 5 tubes mounted vertically to stabilise the upper parts of the plinth
The iron base-ring is heavily corroded partially consisting of layered rust and partially already vanished.
Iron Stilts

• The iron stilts, which were covered by a galvanic coating, are corroded, too.

• As a consequence, the stilts lost the ability to bear the weight of the sculpture.

• The stilts caved in and the galvanic coating burst off.
Expected (magnet) and detected (endoscopy) iron bars inside the monument.
Hind Leg of the Centaur

• This burst fissure is a clear indication for a transversal and lateral shift of the upper part of the monument.
• If this process will proceed, it can be expected that the complete sculpture will lose its integrity and will break down some day.
Sampling Locations

OPEN AIR METAL OUTDOOR METALLIC SCULPTURE FROM THE XIXTH TO THE BEGINNING OF THE XXTH CENTURY
Documentation and Sampling Plan

- Monument’s construction technique (materials, structure, morphology)
- Surface characterization (surface inclination, surface texture, orientation, colour, texture, coverage, adhesion, crust types, patina, presence of fillers, coatings or other materials) (surface area in terms of orientation)
- Cracks and other types of physical damages
- Preliminary assessment of environmental/climatic and microclimatic data in relation to monument
- (rain/sun sheltered, exposed to wind/water/sun, in direct contact with wind/water, rain/water flow etc),
Portable XRF right hand of lying lady
Join and crack: Centaur’s right back leg and thigh
Kolokotronis

Nafplio

Athens

Open Air Metal Outdoor Metallic Sculpture From the XIXth to the Beginning of the XXth Century
Nafplion – Pitting Corrosion
SO2 and RH

Figure 1. Mean Annual SO$_2$ concentrations in Athens and Nafplion

Figure 2. Mean Relative Humidity for Athens and Nafplion
Sampling Plan
Portable XRF

Athens

Nafplion

OPEN AIR METAL OUTDOOR METALLIC SCULPTURE FROM THE XIXTH TO THE BEGINNING OF THE XXTH CENTURY
XRD in 2001 and 2006

• Siemens D500, X-Ray Diffraction system
• less then 20mg and zero Background (Si) sample holders were used to minimize the background
• DIFFRACPlus software (Brucker AXS) and JCPDS Powder Diffraction File
• In 2006, quantitative phase analysis was carried out using the Rietveld Method (TOPAS software, Brucker)
• relative percentages of the crystalline phases normalized to sum to 100%.
XRD in 2006

- Quantitative Analysis was carried out Nafplio
- The quantity and crystallization of corrosion products is larger in Nafplio than in Athens due to conditions
- Larger the quantity of crystalline phases in the sample, the better statistics we have when we measure the counts for each phase, so the quantitative analysis is easier.
- Athens, the sample more amorphous or at least less well crystallised phases, which do not result in well shaped peaks
- This creates problems to the fitting process and consequently to the quantification potential of the software
XRD Analysis
Variations in colour – Cuprite and green patina
Thanks

Conservators
Eleni Kapatou
Thanasis Karabotsos
Maria Mertzani
Maria Petrou
Christos Stefanidis
Dimitris Tsipotas
Amalia Siatou

TEI of Athens
Prof. Nobilakis
Prof. Rokkos
Prof. Labropoulos
Mr. Tzanolinos

Demokritos
Ch. Zarkadas

IGME
Dr. Oikonomou

Municipality of Athens and Nauplio

Eleni Drakaki

Funding by EC program Culture 2000 and Archimedes- Education and Initial Vocational Training Program are gratefully acknowledged