



Fayoum University



Faculty of Archaeology
Conservation Department

**IMPACT OF WEATHERING ON THE CHEMICAL AND
MINERALOGICAL COMPOSITION OF ANCIENT EGYPTIAN
COPPER-BASED PIGMENTS
WITH APPLICATION ON TREATMENT AND CONSERVATION
OF SOME PAINTED ARCHAEOLOGICAL STELAE**

Submitted By

Seham Ramadan Mahmoud

Demonstrator at the Conservation Department, Faculty of Archaeology, Fayoum
University, Egypt

**A thesis submitted in partial fulfillment of the requirements for the
degree of Master in Conservation of Antiquities**

(Conservation Department- Faculty of Archaeology)

Supervised By

Prof. Dr. Gamal Mahgoub

Professor in Conservation

Conservation Department, Faculty of Archaeology, Fayoum University, Egypt

Dr. Abdelrazek Elnaggar

Associate Professor, Conservation Department, Faculty of Archaeology, Fayoum
University, Egypt\ Egypt-Japan University of Science and Technology (EJUST)

Dr. Austin Nevin

Senior Researcher – Institute for Photonics and Nanotechnologies,
National Research Council (CNR) -- Milan – Italy

FAYOUM UNIVERISTY

2019

Summary

The thesis addresses several points including the characterizing and study of the mineral and chemical composition of copper – based pigments whether natural pigments "Azurite – Malachite" or synthetic pigments "Egyptian blue – Egyptian green". The understanding and characterizing of the salt and biological weathering mechanisms of ancient Egyptian copper-based pigments that were mixed with different binding media are the main focus of this research.

Mural paintings and Stelae in the archaeological sites and museums confront large challenge either by their exposure to uncontrolled environmental conditions or by incompatible non-professional conservation interventions, also inappropriate storage methods to Stelae in museums from where un-controlled in temperature, relative humidity and lighting, that finally damage to the paint appearance of stelae. Either the physical and chemical change is finally because loss of cohesion cracks, flaking and complete loss of the paint layers. As a result of different effects of temperature, relative humidity, salts and microorganisms are responsible in change of the paint appearance have been occurred. The paints changes are produced from the chemical change in paint or binding media, a result of a reaction with surrounding environment or a reaction between paint material and binding media with surrounding environment.

The master includes three chapters, **Chapter One "History of Copper-Based Pigments in Ancient Egypt, Egyptian Funerary Stelae and Painting Technique"**. This chapter discussed the Egyptian funerary Stelae and how it was developed from simple shape to shape that gains its importance from the scenes and writings made on it and the pyramid top. The oldest paintings date goes back to the first pharaonic dynasty. Each tomb has two paintings. Also this chapter contained the painting techniques from Tempera technique where the technique of Stela (case study) is Tempera technique, and this chapter contained the study of copper based pigments that were used in decorate the tombs and temples from divided to natural pigments (azurite, malachite) and artificial pigments (Egyptian blue, Egyptian green) and how to prepared Egyptian blue and the studied the binding media that was used with copper-based pigments (animal glue, arabic gum and glair).

Chapter Two "Deterioration Mechanisms of Copper – Based Pigments". The chapter dealt with the effects of the salt and biological weathering on copper-based pigments. Also it included weathering, the patterns of weathering and the most important salts which attack archeological buildings and the effect of salt weathering (physical, chemical role) on the damage of pigments. This chapter also dealt with the degradation of azurite, malachite, and Egyptian blue and Egyptian green by salts as well as the color (blackening) darkening and copper chloride cancer). Biodeterioration of copper-based pigments and effect fungi, bacteria, algae and lichens have been studied.

Chapter Three "Materials and Methods" This chapter contained the results of the experimental and practical studies that were carried out to investigate the aspects of physical and chemical changes to Stelae (Egyptian Museum – El Tahrier – Egypt and Egyptian Museum – Turin - Italy), and the synthesis of Egyptian blue from natural materials to study the different effects on it. UV (artificial, natural), study the effect of salt weathering on copper-based pigments, biological weathering and the fungi effect on copper-based pigments, animal glue and prepared some nanomaterial to cleaning and consolidation of Stelae.

This chapter has been recognized the investigation and technique of the Stelae from structural composition and the use of the Fourier transform infrared to identify the binding media, and deterioration products with the aim of assessing its present state of conservation to finally justify the treatment procedures. The digital light microscope, stereomicroscope, scanning electron microscope were connected with dispersive energy, multispectral imaging, portable x-ray fluorescence, x-ray diffraction and colorimetric measurements were employed for the technical analysis and assessment of the present conservation state of the Stelae. The investigation of the Stela (Egyptian Museum-El Tahrier-Egypt) confirmed that the Stela was applied with the Tempera technique and The Stela from the age of Seti 1 to (Iy) that was discovered in 1904 in Fayoum – Kom Medinet Ghurab (Moeris). This Stela goes back to the new kingdom 19th dynasty. The Stela of Iy was found to serve in the Egyptian Museum – El Tahrier - Egypt by the number (SR 4\14199) (JE36850). The Stela was stored in the store 19 in the ground floor (Egyptian Museum-El Tahrier), and moved to the restoration laboratory. This is a rectangular with round edges. Analytical confirmation of Stela included, blue pigments (Egyptian blue), red pigment (Hematite), black pigment

(carbon black), support (limestone- calcite) and binding media (Animal glue) has been investigation. The study confirmed that the major reasons in darkening of Egyptian blue are the effect of the salts (NaCl-Na₂CO₃), microbial damage, and the unsuitable storage, where after discovering the Stela; it has been put in the store (Egyptian Museum-El Tahrier) in uncontrolled temperature and relative humidity. This work focused on the studying of physical and chemical changes of mural paintings and this study has been carried out on the copper-based pigments such as (Egyptian blue, Egyptian green, malachite and azurite) and the Egyptian blue (Synthesis). A microbiological study has been also done. This study included the isolation of fungi asoliated with Stelae, identifying them and investigating their effects on copper based pigments as well as the binder (animal glue). Moreover this study was subjected to the synthesis of nanomaterials and studing their antifungal activites.

As a part of the research, experimental samples were prepared with the same stratigraphy of the Stela and were subjected to UV (artificial, natural) and salt aging. Biological aging after the identifying of microorganisms in Stela. Microscopy, colorimetric measurements and multispectral imaging, FTIR and XRD were carried out to investigate the physical and chemical changes of paints before and after aging and preparation some nanomaterial to cleaning and consolidation the Stela, preparation of Nanogel, Nanolime and preparation of Nanosilver from *Aspergillus terreus*.