

Investigations methods to study corrosion of some ancient Islamic copper coins at Faculty of arts museum, Sohag university, Egypt

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Abstract

Through the time, copper affected by deterioration factors that interact with environment. Oxygen causes corrosion of copper artifacts and forms copper oxides, meanwhile it starts to mineralize and backs to its natural structure.

This research studied five Islamic copper coins at faculty of arts museum in Sohag University by Examination and Analytical methods to identify the corrosion nature and its effects on the coins.

The Experimental Techniques were used, such as Stereo microscope, X-Ray Radiography, SEM-EDX, and XRD.

Results show that coins have more cracks and different corrosion layers. The chemical study (EDX-XRD) shows that the main element in coins is copper with some other elements such as sulfur, chloride, calcium, magnesium, aluminum, and silicon which can be found in Egyptian soil composition or as blemish in metals compound.

The main compounds were copper oxides, Cuprite (Cu_2O), and Tenorite (CuO). Copper chlorides as Atacamite, Paratacamite ($\text{Cu}_2(\text{OH})_3\text{Cl}$) as result of Chloride Ions.

Key words: Copper Coins, SEM-EDX, XRD, Corrosion.

I. INTRODUCTION

Metals are one of the most materials which were used through ages in all life activities. The uses of metals in Egypt started from ancient Egyptian age, Christian age, Islamic age, and modern age, and the workers used copper, silver, gold, and some alloys like bronze, brass, billon to make their tools [1].

Numismatic are important evidence about the speared of the commercial and affairs ways, and some secrets from the ancient worlds. Most of Coins can survive in different environmental conditions that we can find many coins in excavations sites with different metals constitutes such as gold, Silver, copper, and some alloys. [2-4]

There are different factors which effect on the corrosion of metallic artifacts through the time for example: Metal Type, Structure, Surface and Thickness of Metal, Metal Resistance of Corrosion, burial Environment, pH value, the amount of Oxygen ions, chlorine, carbons, and others, and the present environment of the metals. Copper slowly oxidizes by oxygen to form Cuprite (Cu_2O) which changes to Tenorite (CuO). With the exists of chlorine ions it forms nantokite (CuCl), Atacamite, Paratacamite ($\text{Cu}_2(\text{OH})_3\text{Cl}$), and malachite $\text{CuCO}_3\text{Cu}(\text{OH})_2$. [4-6]

This research aims to identify the corrosion layers of five copper coins, which are stored in Faculty of arts museum, Sohag university, Egypt. These coins were registered as Islamic coins and Extracted from *Fustat* Excavations in Egypt. These coins suffered from bad storage without any treatments before storage to stop the corrosion process, so they are completely mineralized in their plastic bag. The dimension of these coins are about 1- 2.5 cm as there are missing parts of the coins and these parts attached to others so we can't measure the right dimension of the coins as can be seen in (figure 1)

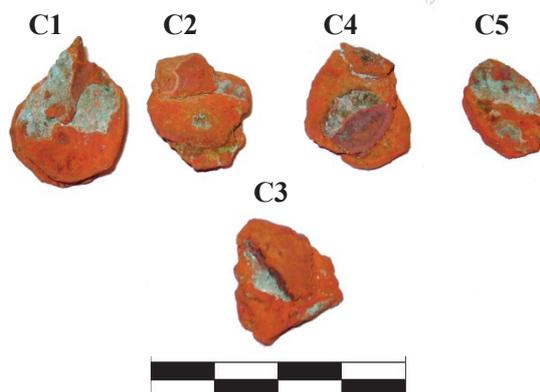


Fig. 1. The examined Coins

II. EXPERIMENTAL

Different methods for Examinations and analysis of these Coins were used.

Nondestructive X-Ray radiography [(Villa genius 500i) combined with computer and photo unit (Fuji computer Radiography CR-IR 359)]. The coins were exposed to X-Ray waves in order to give good photos of the coins' conditions and the corrosion layers [7,8].

SEM-EDX model [(JEOL-JSM 5300) attached with (Oxford) EDX unit] used to identify the elements and morphological structure of the coins [9, 10].

Finally, XRD [Phillips PW 1840 X-Ray Diffraction] was used to identify the coin's compositions and corrosion products [6, 11]. The operation conditions were as follows: Generator Tension {kV} 40, Generator Current {mA} 30, starting angle $2\theta^\circ= 4.025$, and ending angle $2\theta^\circ= 69.975$.

III. RESULTS AND DISCUSSION

X-ray Radiography images illustrated that all coins were fully transformed and mineralized, so the coins appear in white color without any dark areas in the coins (figures 2)

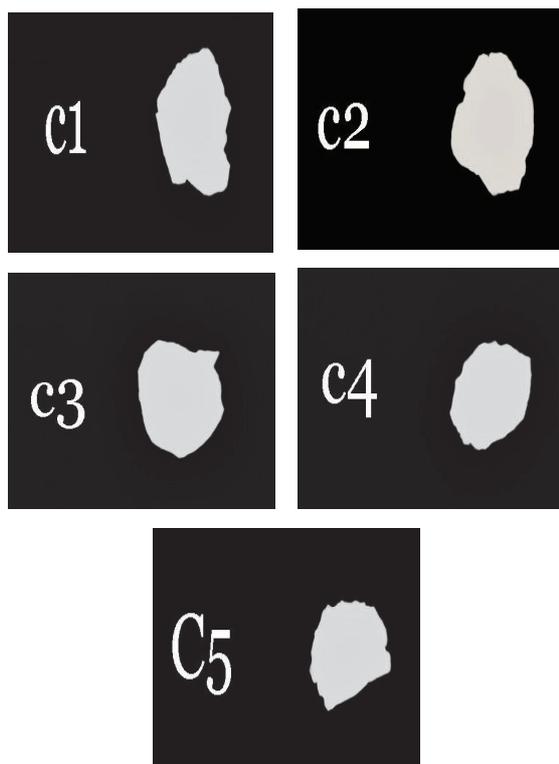


Fig. 2. X-Ray Radiography photos of the coins and these photo illustrated the full mineralized of all coins

I. STEREO MICROSCOPE

The investigation of the coins by using stereo Microscope, illustrated the condition of the coins in different colors. The cover of the coins is Cuprite(Cu_2O) which caused by the interaction of the coins with oxygen (figure 3-7), some black areas of Tenorite (CuO) resulted from the transformation of Cuprite when the

oxygen amount increased in the media. It can have observed that some coins attached with others and there are many cracks on the surface (figure 3A& B, 4A, 5A, 7B)

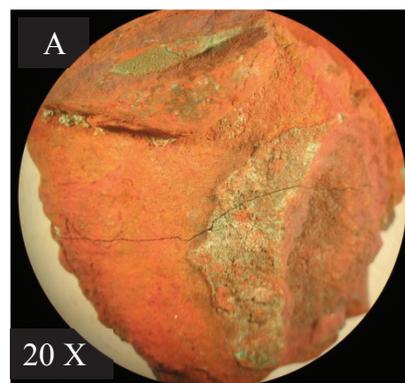


Fig. 3 (A) coin C1 covered with cuprite with some Tenorite and Atacamite

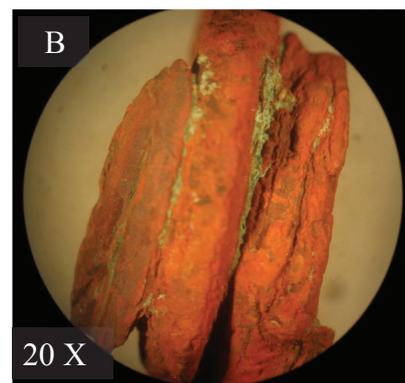


Fig. 3 (B) coin C1 with crakes and attached with some broken pieces

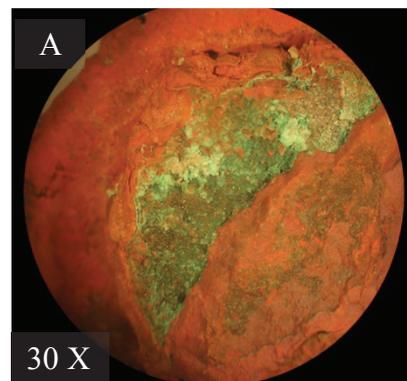


Fig. 4 (A) coin C2 covered of mixed cuprite with some Tenorite and Atacamite

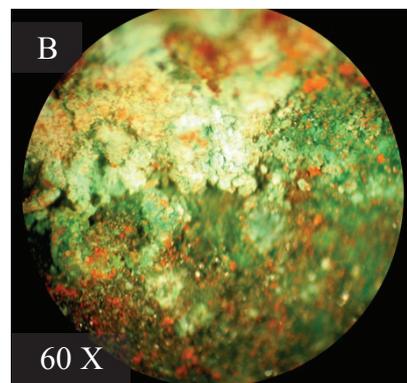


Fig. 4 (B) coin C2 illustrated the crystals of Cuprite, Atacamite, and Paratacamite

Fig. 5 (A)
coin C3
covered with
cuprite with
some
Tenorite and
Atacamite

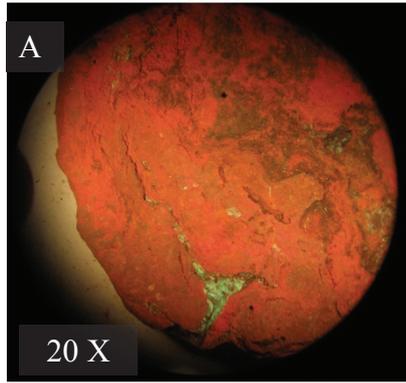
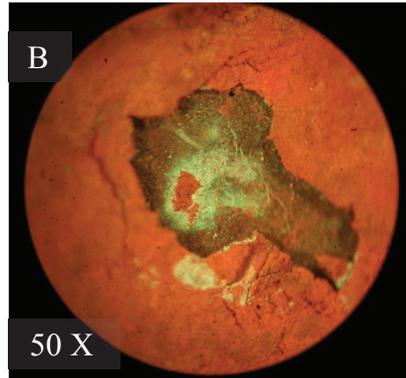


Fig. 5 (B)
coin C3
illustrated
the layer of
Atacamite
and



Paratacamite

Fig. 7(A) coin
C5, mixed of
Atacamite
and
Paratacamite
with Cupite

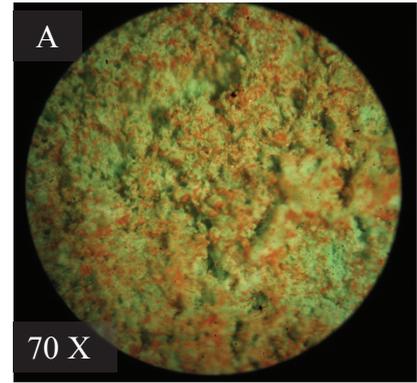


Fig. 7 (B)
coin C5,
cover of
Cuprite and
some
Atacamite &
Paratacamite
areas.
attached with
another
piece

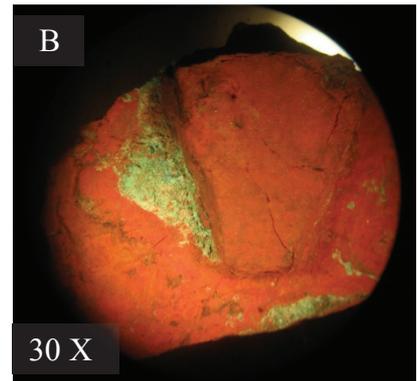


Fig. 6 (A)
coin C4
covered of
cuprite with
Atacamite
and
Paratacamite.

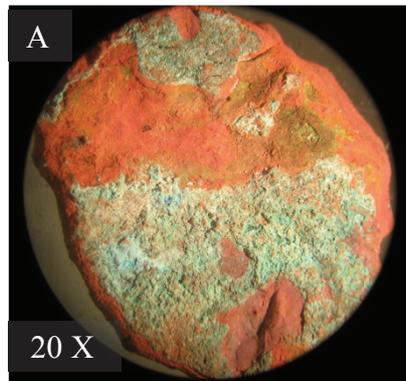
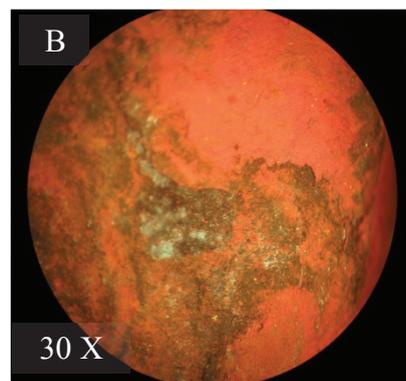


Fig. 6 (B)
coin C4,
mixed of
Tenorite and
Cuprite with
some
Atacamite
spots.



2. SEM-EDX

The electron microscopy which attached with EDX gives good information about the condition of the coins in a wide scale. EDX gives an indication about the coin's elements. The results confirm that all coins are consisting of copper which is the main element with some other elements related to soil elements and corrosion products [figure 8-12].



Fig. 8, SEM image of coin C1, shows a lot of cracks

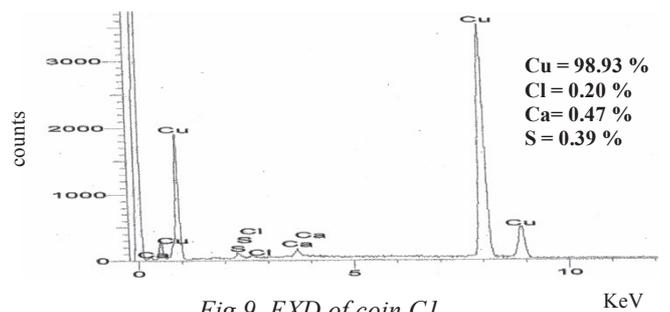


Fig 9. EXD of coin C1

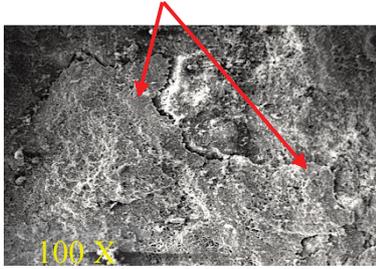


Fig. 10. SEM image of coin C2, Shows Atacamite layer on Cuprite

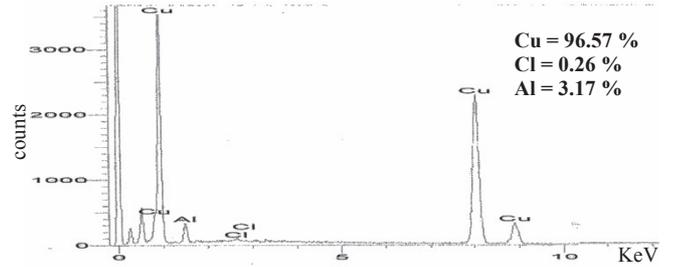


Fig. 15. EDX of coin C4

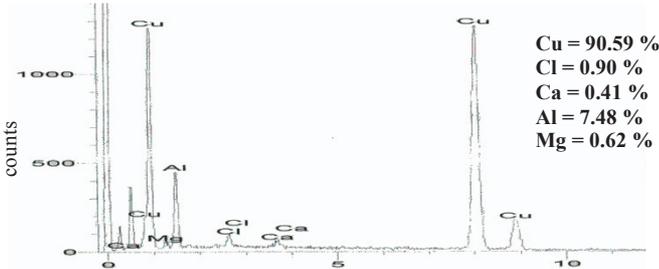


Fig. 11. EXD of coin C2 KeV

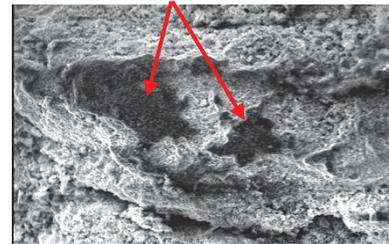


Fig. 16 SEM image of coin C5, illustrates Atacamite layer on Cuprite

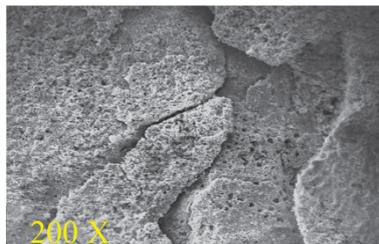


Fig. 12. SEM image of Coin 3 Illustrate the weakness of the corrosion layer as sponge shape on

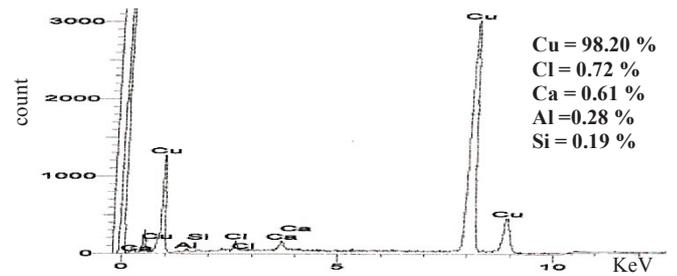


Fig. 17. EDX of coin C5

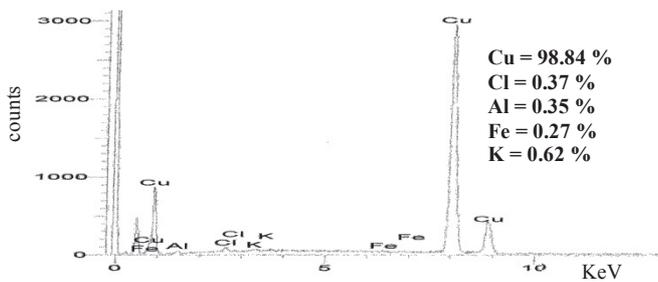


Fig. 13. EDX of coin C3

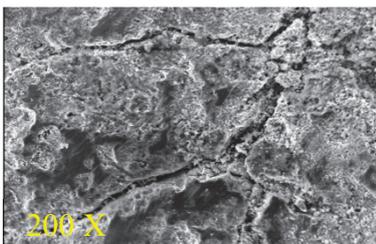


Fig. 14. SEM image of coin C4 illustrates a lot of cracks on the surface

3. XRD results

The results of XRD proved that all coins are fully transformed which related to the oxygen interaction with the copper as Cuprite and Tenorite compounds as major compounds. The existing of chlorine in the soil indicates that, Atacamite, Paratacamite, and Malacite are corrosion products. XRD patterns illustrated the composition of coins (figure 18-22)

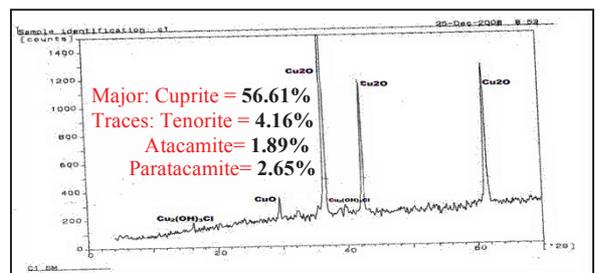


Fig. 18, XRD chart of Coin C1

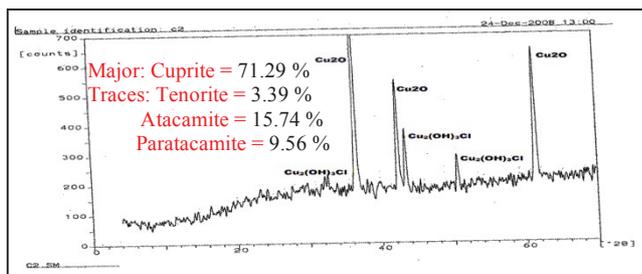


Fig. 19, XRD of coin C2

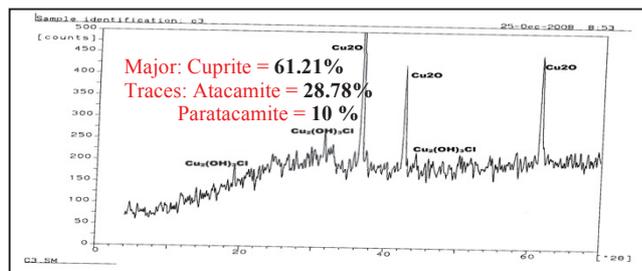


Fig. 20, XRD of coin C3

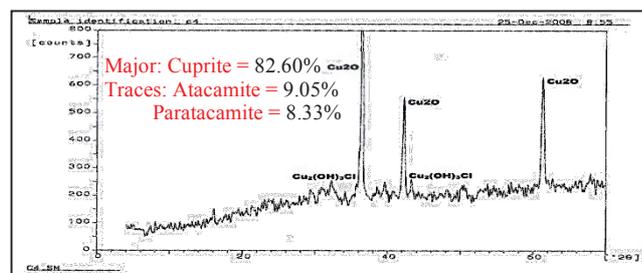


Fig. 21, XRD of Coin C4

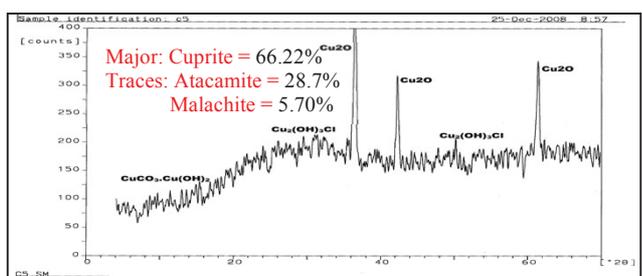


Fig. 22, XRD of coin C5

IV. CONCLUSION

The investigated coins suffered from different types of deterioration factors which mineralized and destroyed them completely. As the result of analysis, when copper contact with humid environment, the oxygen interacted with copper to form Cuprite Cu₂O. copper oxidize and transforms to Cu⁺ in aqueous environments. Cuprite forms Tenorite CuO when the oxygen concentration increased.

The Egyptian soil rich of sodium chloride which interacted with copper coins to form copper(II) chloride hydroxide with formula Cu₂Cl(OH)₃,

Atacamite, and Paratacamite. In addition, the bad storage way in the museum by placing these coins in plastic without any restoration and conservation process. These factors caused bad condition of the coins, and encourage the broken pieces to stuck together as can be seen in the microscopy photos.

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