NASA FELLOWSHIP

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Title: Identifying Coin Corrosion on Silver Quarters & Carbon-based Wheat Pennies using X-Ray Techniques

Background

When examining older artifacts, especially currency, its imperative to use non-invasive and non-destructive technologies, such as X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and also scanning electron microscopy (SEM). Overall determination of surface corrosion layers, as well as coin composition is important when identifying compounds that form from different alloy[1]. X-Ray Fluorescence is widespread across many laboratories for its easy-to-use capabilities, including its fast, sensitive, and simultaneous multi-elemental analysis that ensures no artifacts will be destroyed upon examination[2]. XRF spectrometry is useful to preform elemental analyses of various materials, where it compromises a low power/freq generator, along with an x-ray detector, a multichannel analyzer, and a computer; which for every photon detected on a material, provides a pulse of amplitude that is proportional to its energy[3]. An electron can get ejected from atomic orbital by absorption of a light wave, or photon, due to a sufficient amount of energy[5] where this energy must be higher than which the energy formed between the electron and the nucleus. The florescent light produced is called the characteristic X-Ray of the elements discovered.

XRD & XRF[6]:

Advantages	Disadvantages
• Surface Analysis	• Sometimes incongruous quantification for elemental gatherings
• Determination of Minor Elemental Composition (XRF) and Crystalline Structures (XRD)	• Limited Information of element Distributions in coin material (i.e. Ag rich/Cu rich surface layer)
• Non-Destructive	• Restricted selection of analyzed area
• Inexpensive Equipment	• Can't be used to determine Beryllium content
• Easy-to-use	

Personal Collection:

Tables 1 & 2 were generated by my personal collection of old coins

Table 1 (upper right hand corner) includes Four Pre-1964 quarters (1935-1952), all with corrosion marks and location of type of corrosion and its respective location. While archeological pieces with high silver concentration often held surface enrichment of Ag[2], quarters minted before 1964 had an overall elemental composition that was near or about 90% Ag. Although the causes of these enrichments to silver composition can be altered to cleaning agents, all coins in the table had not previously been cleaned and kept in their original conditions. When preforming non-destructive techniques on coins with high Ag content, such as XRF, quantitative results are most often obtained with known elemental composition, which can help explain circulation of money for older coins, and coins of whose dates had been worn down[4].

Table 2 (Under table 1, upper right) includes 9 wheat pennies (1934-1956), all with a detailed location of corrosion site on the surface of the coins. The wheat penny is said to be a "Classic iconic early 21st century American Coin"[6] that were minting began in 1909 and lasted until 1956. Known by collectors as the Wheat Cent, it has a composition primarily made out of copper, while steel versions (zinc plated steel) were issued during WW2, due to war efforts needing high amounts of copper to create ammunition, shell casings, equipment, ect. Prior research involving copper coins have been examined upon more frequently, due to their commonality to be located easier in excavation sites than gold or silver, and are more adaptive to acquiring corrosion on their surface layer[7]. The best known corrosion on copper based objects is the formation of a patina, where the alloys are kept in a damp oxygenated environment[8].

*Patina = a compact and often aesthetically very attractive layer which develops on Copper alloys, consists normally of green malachite, basic Cu(II) carbonate or, in drier environment (less commonly) blue azurite, a different basic Cu(II) carbonate[8].

H&M Analytical Services, Inc:

Located in Cream Ridge NJ, H&M Analytical Services is a full-service testing lab (X-Ray) which also includes an open range towards other testing and material characterization services.

Material science engineering & Analytic testing's for:

- X-Ray techniques
- Chemical analysis
- Particle size analysis
- High resolution imaging
- Thermal analysis
- Reverse engineering
- Competitive analysis
- R&D work
- Failure analysis
- Quality control testing

H&M provides detailed reports on customer samples and provides correct analysis promptly without effecting quality.

https://h-and-m-analytical.com/wp/

Table 1: Four (4) pre-1964 quarters minted with a 90% silver content, corrosion indication

Year	Front	Back	Corrosion Location on Coin
1953-D			**Front**: Under ear, Around head region **Back**: Around body of bird
1935			**Front**: N/A **Back**: Around body of bird
1952-D			**Front**: Back of head **Back**: Inscription, around body of bird
1940			**Front**: Around head regions, all sides **Back**: Inscription, surrounding wings, & body

Table 2: Nine (9) Wheat Pennies, dated 1934-1956. High Copper mintage (90-95%), corrosion marks w/ coloration locations

Year	Side w/ corrosiveness	Corrosion Location/ Coloration	Year	Side w/ corrosiveness	Corrosion Location/ Coloration
1935		Dark brown & greenish spots, right side (front)	1948		Dark spots throughout "in god," date, & underneath shirt (front)
1944		Heavy discoloration, green & teal Majority of face (front)	1941		Large brown splotch underneath shirt (front)
1950-D		Dark spots around edges, underneath shirt, date (front)	1956		Dark green spot under chin, edges under "liberty" (front)
1934		Brown discoloration in head region & edges around (front)	1945-D		Heavy discoloration, dark green & teal Majority of face/right side (front)
1946		Dark spot, brown color on top edge above head (front)			

Purpose of Study/Research:

- Independently, I gathered 9 wheat pennies along with 4 pre-1964 quarters, all with corrosion marks, in attempt to look at them under a non-destructive method, such as XRF, XRD, and SEM at H&M Analytical Center. Established in 1997, H&M offers services (Georgian Court University has a cooperative agreement) for us to inspect corrosion marks on coins, and determine their elemental composition. Under chemical analysis, it would have shown types of different elements that have been captured over time and remained on the surface of coin; also, if they had changed the composition of the coin itself. Pre-1964 quarters have a supposable 90% Ag content, but corrodes can impair that number. Corrosion on coins can also alter the 88% Cu-based wheat pennies, for which these analytical methods could determine their current configuration.

Unfortunately, due to COVID-19, all testing centers were closed, including H&M, and the tests could never be preformed

(Absence of Conclusions & Results)

- I conducted a literature search and compiled a review of nearly a dozen scholarly articles, which were used to generate summary background data, table configurations, and pros and cons of the proposed methods. Data from past researchers in this group were reviewed. There are no set future plan

- This study was funded by NASA NJ Space Grant. NASA has one if its directorates "fundamental research" and corrosion on metals is of interest. Coins are unique in that they are exchanged in currency for long periods of time, may rust, be worn down, and be exposed to, for example, cleaning and other products that linger on their surfaces.

References:

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