Chemical Analysis of 1794 & 1795 U. S. Silver Coins – Part 2

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1. Introduction

This is the second article of a multi-part series. Part 1 was published in the September 23, 2018 *John Reich Newsletter*. It can also be downloaded from the *Newman Numismatic Portal* (https://nnp.wustl.edu/).

Part 1 provided the historical overview of events that laid the foundation for this project. Based on letters written to President Washington by Mint Directors Henry William de Saussure and Elias Boudinot, it has been postulated that the Mint attempted to strike some, most, or all of the 1794 and 1795 dated silver coins to a standard of 90% silver and 10% copper. If true, this was a violation of the Mint and Coinage Act of April 2, 1792.

The authors decided that chemical analysis of 1794 and 1795 dated silver coins was required to confirm whether the Mint attempted to strike any of these coins to a 90% silver and 10% copper standard. The approach taken was to first determine the chemical compositions of the silver coins. Then, using statistical analyses, ascertain whether the Mint's refining targets were most likely 89.24278% or 89.24+% silver and 10.75722% or 10.76-% copper alloy, or 90% silver and 10% copper.

This article reviews the technologies available today to perform chemical analysis, the issues analyzing a silver-copper alloyed coin, and the goals of this project.

2. XRF Analysis

X-ray Fluorescence (XRF) is a non-destructive analytical technique used to determine the elemental composition of materials. XRF is based on the principle that individual atoms, when excited by an external energy source, emit X-ray photons of a characteristic energy or wavelength. By counting the number of photons of each energy emitted from a sample, the elements present may be identified and quantitated.

Analysis of coins using XRF technology can be performed, however there are issues:

1. XRF analysis of a coin is restricted to the extreme surface. A silver half dollar is 2.15 mm or 2,150 microns thick. An XRF analyzer will penetrate approximately 10 microns into the surface.

2. During normal circulation, surfaces of coins get contaminated with other elements. An element that is detected on the surface of a coin may not be present below the surface.

3. Copper is more corrosive than silver. Over time, copper will leach off the surface when exposed to oxygen and liquids. This results in artificially higher silver and lower copper percentages on the surface.

These issues render XRF as an unreliable method for basing any conclusions about the true chemical composition of the coin(s) in question.

3. ICP-AES Analysis

In order to determine the true composition of an early U. S. silver coin, analysis below the surface of the coin is essential. Since the elements below the surface would not have been subjected to environmental contamination or copper leaching, the elements and their percentages would be as they were on the day the bullion deposit was melted and refined at the Mint.

Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) was selected as the method for analyzing the chemical composition of the coins. ICP-AES is a destructive analysis. A brief overview of the ICP-AES process is as follows:

- The sample being analyzed is first diluted in nitric acid; a highly corrosive acid.
- A plasma torch then vaporizes fine droplets of the sample at a temperature of approximately 12,000 degrees Fahrenheit.
- The atoms of the sample generate wavelengths that are measured by an array of semiconductor photodetectors.
- For some elements, ICP-AES is accurate to parts per trillion.

In order to prepare each sample for ICP-AES analysis, each coin would first be cut into three pieces. The surfaces and edges of the center piece would be ground away and polished, thus eliminating any areas containing environmental contamination and/or copper leaching. The center piece would then be sent for ICP-AES analysis, leaving two pieces in reserve for future testing.

4. Selecting Coins To Analyze

Initially, this was a self-funded project. Not only did the coins have to be thick enough to support surface removal as previously described, they had to be cheap. The Half Dollar was easily selected as the denomination for testing:

- 1794 and 1795 Half Dismes were too thin. Once the surfaces of a Half Disme were ground down, there would be nothing left to test.
- Dismes and Quarters were first struck in 1796, and were therefore not considered since the scope of this project is for 1794 and 1795 silver coins.
- Who would donate a 1794 Dollar to be sliced into three pieces, then have the surfaces of the center piece ground down?
- Although holed and/or damaged 1795 Dollars could be purchased, the cost for purchasing one damaged 1795 Dollar was equivalent to the cost for purchasing three or four damaged 1795 Half Dollars.
- Holed and/or damaged 1795 Half Dollars were more available than holed and/or damaged 1795 Dollars. They were also affordable.
- Holed and/or damaged 1794 Half Dollars were expensive. Analyzing at least one 1794 Half Dollar was crucial to the project. Obtaining a coin could possibly take some time.

5. Multiple Half Dollars Had To Be Analyzed

Since no one had previously attempted to determine the true chemical composition of an 18th century United States silver coin, certain assumptions were made before the first coin was analyzed. The quantities of Half Dollars that were transferred from the custody of Chief Coiner Henry Voigt to the custody of Treasurer of the Mint Dr. Nicholas Way during calendar year 1795 were as follows:

- February 4, 1795: 18,164
- March 3 and 30, 1795: 107,468
- April 11 and 30, 1795: 93,833
- May 6 and 16, 1795: 95,312
- June 5, 1795: 3,067

The author's assumptions were as follows:

1. Whereas the silver bullion for the coins from the early part of the 1795 Half Dollar emission order sequence was most likely refined on or prior to February 4, 1795,

the silver bullion for the coins from the later part of the emission order sequence was most likely refined during May and/or early June, 1795.

2. If die marriages from the early, middle and later parts of the 1795 Half Dollar emission order sequence were analyzed, then the silver in the coins analyzed was most likely refined at different times.

3. If the analysis of multiple 1795 Half Dollars exhibited statistically similar results, the confidence levels would increase that the *rule* was analyzed, and not the *exception*.

4. The greater the number of 1795 Half Dollars being analyzed, the greater the confidence level that the statistical analyses were determining whether the Mint refined the metals in one or more of the coins to an 89.24+% silver and 10.76-% copper standard, or to a 90% silver and 10% copper standard.

6. Each Refining Heat Would Produce Different Results

Each silver bullion deposit was refined by the Mint in multiple manageable batches or heats. Each refined heat was weighed, and using pencil and paper, the math was performed to calculate the appropriate amount of copper to add to the silver. The silver and copper was then melted, and poured into one or more ingots. Although this step in the Mint's workflow is referred to as Melting & Refining, it is actually Refining & Melting.

Even if today's advanced chemical, metallurgical, electrical, pyrometrical and computer technologies were used to refine and melt a silver bullion deposit, no two heats would produce the exact same chemical results. Likewise, in 1795, no two heats produced the exact same chemistry. Several factors played a role in the final chemistry of a silver-copper alloyed coin:

1. Was the silver bullion and copper refined properly?
2. Was the amount of copper to be added to the refined silver calculated correctly?
3. Was the refined silver and copper weighed correctly?
4. Were there any other elements in the refined silver?
5. Were there any other elements in the copper?
6. If trace (a relatively low amount) and/or residual (a relatively high amount) elements were identified in the coins analyzed, what were their origins?

7. Third Party Funding Was Obtained From EPN-NES

This was going to be a very complex project. ICP-AES analysis had to be performed on 1795 Half Dollars, 1794 and 1795 Half Cents and Large Cents, and hopefully one 1794 Half Dollar. The authors needed to understand what elements were in 1794 and 1795

copper coins, what elements were in 1794 and 1795 Half Dollars that were alloyed with copper, and hypothesize what elements were originally in the refined silver.

1794 and 1795 Half Cents, Large Cents, and Half Dollars had to be purchased. Not only were the coins going to be expensive, the ICP-AES analyses were going to be expensive. Third party funding was needed.

Thanks to the efforts of Andy Newman and Stuart Levine, funding was obtained in January, 2018 from the Eric P. Newman Numismatic Education Society (EPN-NES) for the purchase of coins and the cost of the ICP-AES analyses.

8. Project Goals

The authors did not want to waste EPN-NES's money. Realistic goals had to be set. Eight goals were identified, and were stated as questions. It was assumed that the results would identify a need for a follow on project, so the initial project was named Phase 1 and the follow on project was named Phase 2.

The Phase 1 goals were as follows:

1. What was the chemical composition of (a) 1794 and 1795 dated Half Dollars, as well as (b) post 1795 dated silver coins?

2. Did the Mint attempt to produce any of the 1794 and 1795 silver coins to an 89.24+% silver and 10.76-% copper standard as required by the Mint & Coinage Act of April 2, 1792?

3. Did the Mint attempt to produce any of the 1794 and 1795 silver coins to a 90% silver and 10% copper standard, thus violating the Mint & Coinage Act of April 2, 1792?

4. Were the copper coins of 1794 and 1795 pure copper per the Mint & Coinage Act of April 2, 1792?

5. Is it even conceivable that the knowledge base and technology of 18th century chemistry and metallurgy allowed Mint personnel to differentiate between 90% silver and 10% copper .vs. 89.24+% silver and 10.76-% copper?

6. Did the Mint attempt to produce silver coins to the legal standard of 89.24+% silver and 10.76-% copper after 1795 and prior to the Act Supplementary to the Mint Act of January 18, 1837 (that changed the standard to 90% silver)?

7. Are there trace and/or residual elements in the silver coins that will identify the silver refining method employed by the Mint (i.e., the lead fire refining method

and/or the saltpeter [potassium nitrate] fire refining method)?

8. Are there trace and/or residual elements in the copper coins that will identify the copper refining method employed by the Mint (i.e., the silica fire refining method)?

9. Seven 1795 Half Dollars Were Analyzed Via ICP-AES

Seven holed and/or damaged 1795 Half Dollars were purchased for the Phase 1 project. Each was a different Overton die marriage (see Figure 1). The die marriages in Figure 1 are ordered by the 1795 Half Dollar emission order sequence per *Early United States Half Dollars, Volume 1, 1794 – 1807* by Steve Tompkins. Arrows identify the seven die marriages of the Half Dollars that were analyzed via ICP-AES.

Since die marriages from the early, middle, and late parts of the 1795 Half Dollar emission order sequence were analyzed, the ICP-AES analysis results would most likely identify whether the Mint:

1. targeted all 1795 Half Dollars to a 90% silver and 10% copper standard, or

2. initially targeted the 1795 Half Dollars to an 89.24+% silver and 10.76-% copper standard, then changed the standard to 90% silver and 10% copper.

10. Preparing The Half Dollars For ICP-AES Analysis

Refer to Figures 2, 3 and 4 for images of the 1795 O-109, 1795 O-115 and 1795 O-116 Half Dollars that were analyzed via ICP-AES. Using a marker, each coin was marked for cutting (Figure 5). Using a diamond cutter, each coin was sliced into three pieces (Figure 6). The surfaces of the center piece were then ground away and polished (Figures 7 and 8) to completely remove trace element surface contamination and the effects of copper leaching.

One of the sliced and polished end pieces of the 1795 O-105 Half Dollar was mounted in Bakelite (Figure 9). This sample would be passed out at presentations.

[Note: The chemical composition of this end piece was analyzed via XRF and compared to the chemical composition of the corresponding center piece that was analyzed via ICP-AES. This end piece is now the standard for verifying that an XRF analyzer is correctly calibrated prior to analyzing a future sample for any project.]

11. 1794 Half Dollar Donated By The Terry Brand Estate

Thanks to the efforts of Jim Halperin and Jim Stoutjesdyk of Heritage Auctions, the Terry Brand Estate donated a 1794 Half Dollar in June, 2018 for ICP-AES analysis (see Figure 10). Although the coin was severely corroded and barely discernable, enough details were present to attribute the die marriage. On the obverse, the date and LIBERTY were visible, as were parts of the chin, mouth and bust. On the reverse, UN, STATES, OF and the leaves below OF were visible. The Half Dollar was definitively attributed as the 1794 Overton 105 die marriage.

Refer to Figure 11 for the 1794 Half Dollar emission order sequence per *Early United States Half Dollars, Volume 1, 1794 – 1807* by Steve Tompkins. The arrow identifies the 1794 O-105 Half Dollar die marriage. This die marriage was struck after the 1794 O-109 and 1794 O-111 die marriages. There are three known 1794 O-109 Half Dollars and the 1794 O-111 is presently unique. It is therefore logical to assume that the 1794 O-105 Half Dollar was most likely the first mass produced 1794 Half Dollar die marriage. Since 5,300 1794 Half Dollars were transferred from the custody of Chief Coiner Henry Voigt to Treasurer of the Mint Dr. Nicholas Way on December 1, 1794, it is also logical to assume that the 1794 O-105 Half Dollars were most likely struck around this time.

12. 1794 And 1795 Copper Coins Were Analyzed Via ICP-AES

Refer to Figures 12 for the images of the 1794 Large Cent and 1795 Half Cent that were analyzed via ICP-AES.

13. Next Steps

In July, 2018, the ground and polished center pieces of one 1794 Large Cent, one 1795 Half Cent, one 1794 Half Dollar and seven 1795 Half Dollars were sent to an independent and accredited laboratory for ICP-AES analysis. In addition, the ground and polished center pieces of one 1806 Quarter, one 1807 Quarter, one 1807 Capped Bust Half Dollar, and one 1855-O Seated Half Dollar were also sent for ICP-AES analysis.

The ICP-AES results were obtained in August, 2018.

To be continued…

1795 Half Dollar Emission Order Sequence (Tompkins)

1.	1795 O-119	17.	1795 O-108
2.	1795 O-121	18.	1795 O-128
3.	1795 O-117 ←	19.	1795 O-111
4.	1795 O-120	20.	1795 O-112
5.	1795 O-122 ←	21.	1795 O-110 ←
6.	1795 O-123	22.	1795 O-126
7.	1795 O-129	23.	1795 O-127
8.	1795 O-130	24.	1795 O-104
9.	1795 O-131	25.	1795 O-105 ←
10.	1795 O-115 ←	26.	1795 O-102
11.	1795 O-116 ←	27.	1795 O-132
12.	1795 O-124	28.	1795 O-101
13.	1795 O-125	29.	1795 O-103
14.	1795 O-113	30.	1795 O-106
15.	1795 O-114	31.	1795 O-107
16.	1795 O-109 ←		

Figure 1 – The (7) 1795 Half Dollars Analyzed Via ICP-AES

Figure 2 – 1795 O-109 Half Dollar

Figure 3 – 1795 O-115 Half Dollar

Figure 4 – 1795 O-116 Half Dollar

Figure 5 – 1795 O-116 Marked For Cutting

Figure 6 – 1795 O-116 After Being Sliced Into 3 Pieces

Figure 7 – 1795 O-116 Center Piece After Grinding

Figure 8 – 1795 O-105 Center Piece After Polishing

Figure 9 – 1795 O-105 End Piece Mounted In Bakelite

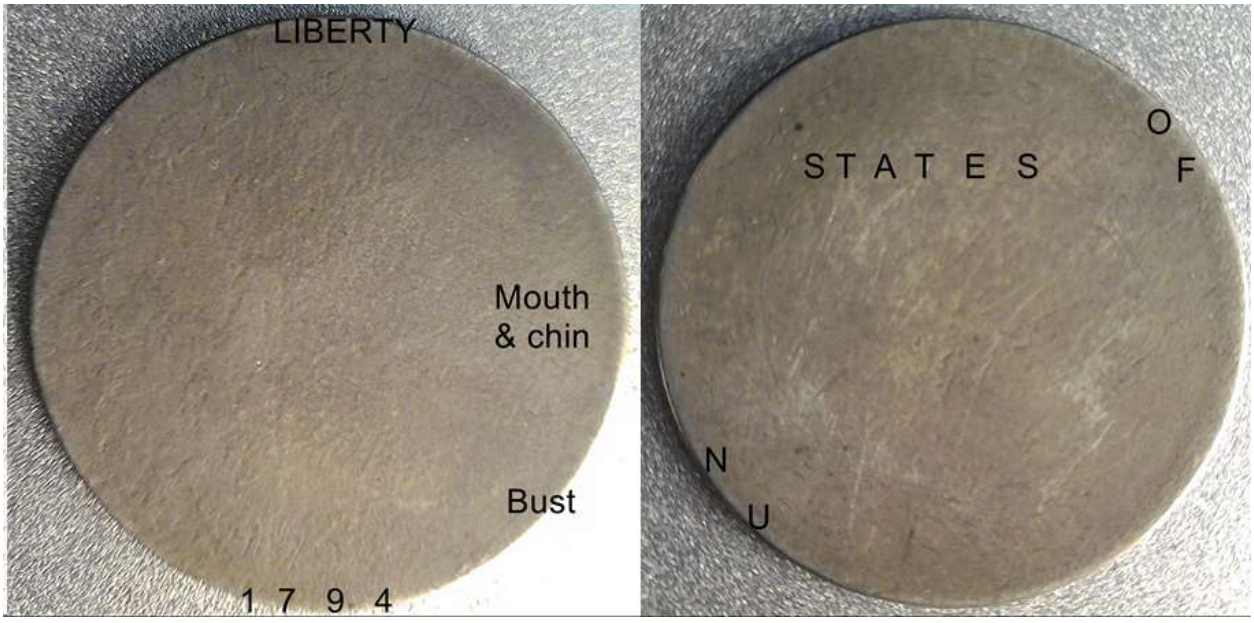

Figure 10 – 1794 O-105 Half Dollar

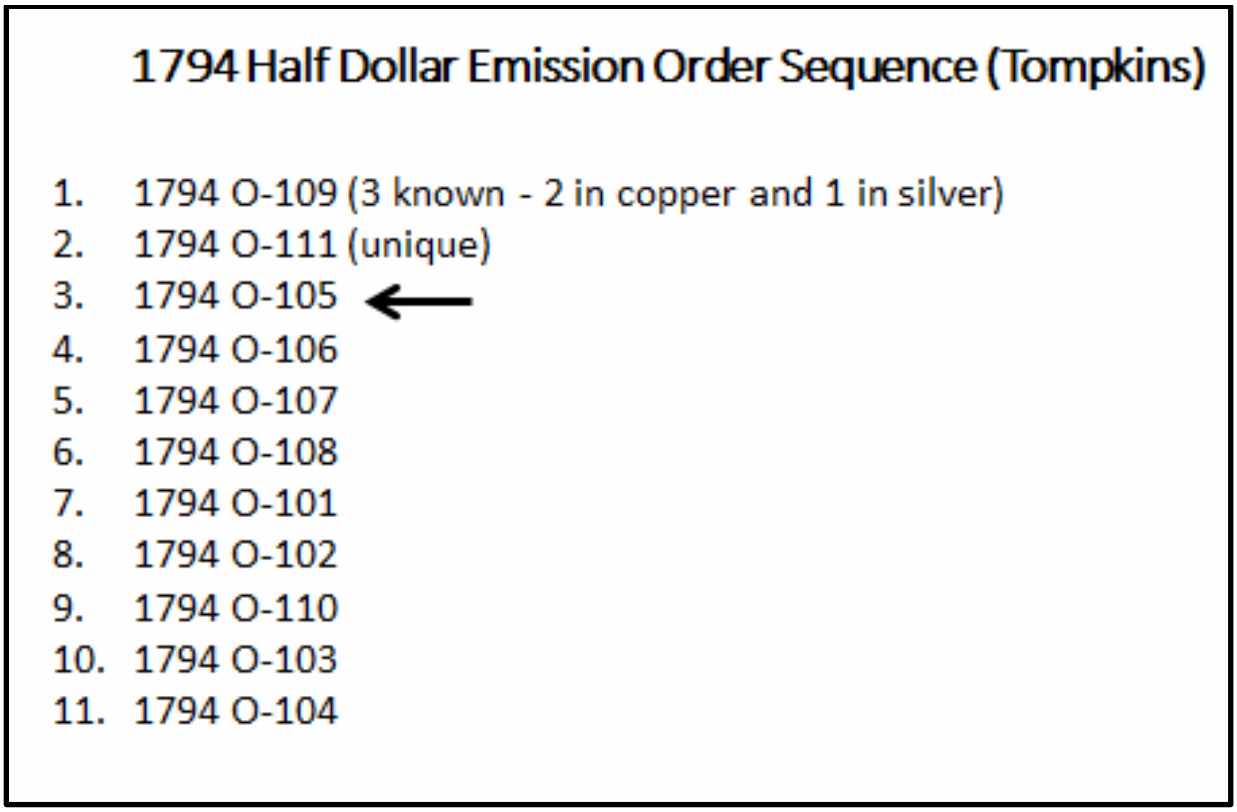

Figure 11 – The 1794 O-105 Half Dollar Analyzed Via ICP-AES

Figure 12 – 1794 Large Cent & 1795 Half Cent