Elemental Analysis of the Alleged Grapeshot that Killed Count Casimir Pulaski and Some Other Southern Revolutionary War-era Cast Iron Ordnance

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By Daniel T. Elliott

The LAMAR Institute, Inc.
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I. Introduction

This monograph presents the findings from an elemental analysis of selected Revolutionary War-era cast iron ordnance. This project began with a request from a colleague, Lisa Powell, for assistance in the investigation of a very cold case—the death of Brigadier General Count Casimir Pulaski in mid-October, 1779, after being mortally wounded by an artillery blast on the western defenses of Savannah on October 9, 1779.

Contemporary accounts of Pulaski’s final disposition differ. Captain Paul Bentolou, a senior officer in Pulaski’s Independent Legion and aide-de-camp to Brigadier General Pulaski, later wrote that Pulaski, who was taken aboard the privateer brig Wasp along with the wounded Bentolou following the October 9 battle, died and was buried at sea. Bentolou described, “Just as the Wasp got out of the [Savannah] river, Pulaski breathed his last, and the corpse immediately became so offensive, that his officer [Bentalou] was compelled, though reluctantly, to consign to a watery grave all than now left upon earth of his beloved and honoured commander (Bentalou 1824:30; Sparks 1825:388). Bentolou also noted that Pulaski, “received a swivel shot in the upper part of his right thigh” It should be noted that Bentolou’s recollection dates 43 years after the actual event, when Bentolou was 69 years of age.

Bentalou’s account of Pulaski’s burial at sea is corroborated by Mrs. Martha Phillips, widow of Eleazer Phillips who served as a mariner aboard the brig Wasp when the wounded Pulaski was taken aboard. She recounted, “that the gallant Pulaski being wounded at Savannah in October 1779, He was put on board said Brig where he died, and was buried in the ocean between North and South Edisto” (Phillips 1838). Phillip Moore, attested in 1841 at the age of 80 years, that he heard Eleazer Phillips speak of his services in the revolution, including, “that Eleaser Phillips was at the siege of Savannah as a mariner on board a vessel and that he made the coffin for Count Pulaski”.

The burial at sea scenario is further supported by an 1854 letter to the editor by James Lynah, grandson of Dr. James Lynah. The younger Lynah stated, “My grandfather, Dr. James Lynah, of Charleston, S.C., who lived to a very advanced age, has frequently told me that he extracted the bullet that gave Pulaski his death-wound. He performed the operation on the field, in view of the lines of Savannah, assisted by my father, who, as a youth, was acting with him as surgeon’s mate, and a faithful negro, named Guy. The ball is an iron grape shot, (now in my possession,) and was supposed to have come from the fire of the English galleys, which assisted in the defence of the town. The ball entered the groin, and was removed with great difficulty, Pulaski bearing the operation with inconceivable
fortitude... Rather than this [face capture and return to Russia], he said he should prefer death, and take the chance of a cure in the French fleet, commanded by D'Estaing. Accordingly, he was carried on shipboard, died on the passage round to Charleston, and his body buried in the sea.” (Lynah 1854:2).

A drastically different account of Pulaski’s final disposition places his burial at Greenwich plantation at Thunderbolt, Georgia. This version is suggested in a letter from Samuel Bulfinch, Captain of the privateer *brig Wasp*, to Major General Benjamin Lincoln, dated October 15, 1779, which places the burial of the remains of an American soldier who had died that day aboard the *brig Wasp* at Thunderbolt (Figure 1; Bulfinch 1779; Pinkowski 1997). While Bulfinch’s letter does not specifically identify the “American” soldier who was buried, Pinkowski concluded that he was referring to Pulaski. Subsequent writings, which have appeared in official U.S. government publications, have misquoted Bulfinch, stating, “He said that Pulaski died on board his ship on October 15” (Congressional Record 2007). Congressional Record- Extensions of Remarks, March 6, 2007:3475.

A third version of history places the final disposition of Pulaski’s remains in South Carolina. Interestingly, the Charleston Museum holds in its collection an iron grapeshot purported to be associated with Casimir Pulaski (Stello 2013). Bentalou (1824:30) described, “the most splendid funeral honours” conducted in Charleston to commemorate General Pulaski were conducted upon the arrival of the Wasp in Charleston harbour. This ceremony was a funeral procession, which included a pall, “carried by three American and three French officers of the highest grade…” Felix Molski identified a mystery pertaining to the grapeshot that killed Pulaski. He wrote:

“Wiki had an account of Pulaski’s life and illustrated the text with a photo of the grapeshot that killed Pulaski that was extracted by Dr. James Lynah. Wiki went on to state that the grapeshot is on exhibit in the Powder Museum of Charleston, South Carolina. Being in Savannah recently to view the Pulaski monument in Monterey Square I was only 2 hours drive away from the Powder Museum. Not wanting to go on a wild goose chase, I rang to be sure I would have something to see. They replied 'Yes, we have it on display'. I asked if visitors are allowed to photograph it. The reply: 'Yes they can'. I did the two hour drive there the next day, but the grapeshot I viewed on display is mounted differently, not on the expensive looking silver candlestick holder shown in Wiki, the one on display at the Powder Museum sits on a cheap plastic tube. The curator assured me that the research had been done, and indeed it was the grapeshot taken from Pulaski’s thigh.”
Figure 1. Letter to Major General Benjamin Lincoln from Samuel Bullfinch (Bullfinch 1779).
“The next day, back in Savannah, I visited the Georgia Historical Society and saw the very grapeshot pictured in Wiki. The provenance for this exhibit is more certain as it is on loan to the Society from descendants of Dr. James Lynah, the doctor who extracted the grapeshot from Pulaski's thigh. Letters documenting this fact are part of the Societies exhibit. When I told the Society of the Wiki reference to the Powder Museum and the fact that they too have grapeshot on display purportedly extracted from Pulaski. The officials at the Society were shocked because they were totally unaware of the Wiki reference or the fact there is grapeshot on exhibition in another museum anywhere. This immediately set the balls rolling for action to change the Wiki entry and the questioning of the provenance of the Powder Museum grapeshot exhibit. Only a few days after interacting with officials of the Georgia Historical Society I notice the Wiki entry has been corrected.” (Molski 2012).

An artifact label at the Powder Magazine Museum in Charleston, S.C., states, “Iron grapeshot reportedly removed from the right thigh of Kazimierz Pulaski, the ‘Father of the American Cavalry’ on October 9th, 1779 after the Battle of Savannah” (Figure 2).

![Figure 2. Iron Grapeshot on Display, Powder Magazine, Charleston, South Carolina.](image)
Fascination with the death of Pulaski was strong in Savannah among the mid-nineteenth-century elite class. Historian Merton Coulter stated that the cornerstone for a monument to Pulaski was donated by the Marquis de Lafayette when he visited Savannah in 1825 (Coulter 1964:105-106). Plans for a monument in Monterey Square in 1853 culminated in the monument’s dedication on January 9, 1855 (Knight 1914, Volume I:104-105). Included with the monument were the bones of a body alleged to be Pulaski and a time capsule. These bones are purported to have been exhumed from a grave on the former Greenwich plantation in Thunderbolt, Georgia by then-property owner W. P. Bowen (Loudon Free Press 1854:1).

Restoration work on the Pulaski monument in 1995 led to a renewed interest in the mystery of Pulaski’s death and final disposition of his remains. Workmen who were dismantling the monument in 1996 discovered a metal box at the base of the monument that contained human remains. The metal box also contained an engraved silver plate that identified the remains as “Brigadier General Cassimer Pulaski”. City authorities took possession of the remains and Dr. James Metts, Jr., Chatham County coroner, was appointed to head an investigation into the remains. Dr. Metts was assisted by Dr. Karen Burns, a forensic anthropologist. That investigation included DNA analysis of the remains, which were compared with the remains of Pulaski’s grandniece, who had been buried in Poland in 1834 (Powell 2006).

The surgeon who attended to Pulaski’s wounds was Dr. James Lynah, who was a surgeon in Charleston, South Carolina and Chief Surgeon in Colonel Daniel Horry’s South Carolina Regiment of Light Dragoons at the Siege of Savannah. The Georgia Historical Society holds in its collections an iron grapeshot mounted on a silver candlestick that bears an engraving made by one of Dr. Lynah’s descendants attesting to this particular grapeshot being removed from Pulaski by Dr. Lynah. This object (GHS Catalog Number A-0509-002 [Box 52]) was the initial subject of study in this elemental analysis. According to GHS records, this grapeshot is part of the James Lynah Papers collection (Georgia Historical Society MS 509), which also includes fragments of the cloth vest that Pulaski wore when he was shot. The fabric from the vest was made into a satchel where the grapeshot was kept. The James Lynah papers were donated to GHS by Mrs. James Lynah in 1957.

The GHS grapeshot is nearly spherical and measures 27.57 mm by 28.49 mm. As it is mounted in a silver candlestick and could not be removed, its weight was not determined. It displays a casting line that runs vertically, indicating it was
cast in a two-piece mold. It has the exterior appearance of iron and is heavily pitted. It possesses no other visible marks. The GHS grapeshot is mounted in a silver candlestick and the grapeshot is secured by a silver wire. An inscription at the base of the candlestick (Figure 3) reads, “Grapeshot which mortally wounded Count Casimir Pulaski October 9, 1779 extracted from his body by Dr. James T. Lynah, ancestor of the present owner, James Lynah, Esquire.”

Figure 3. Inscription on Candlestick Mounting for GHS Grapeshot.

As this brief historical review indicates, the facts surrounding Pulaski’s final days remain controversial. This controversy bleeds over into the archaeological record. Two museums both claim to have the grapeshot that was extracted from Pulaski. Unless Pulaski had two grapeshot removed from his body, both museum claims cannot be correct. The GHS specimen appears to have the stronger provenance. Regardless, many unanswered questions about the Pulaski story remain.
II. Background

Very few published studies have been conducted on the elemental composition of early historic military cast iron ordnance. None have specifically explored Revolutionary War-era cast iron ammunition. Relevant studies are summarized below.

Caporaso and her colleagues examined 21 cast iron shell and case shot artillery fragments recovered by Doug Scott and his colleagues from the Civil War battles of Pea Ridge, Arkansas and Wilson’s Creek, Missouri (Caporaso et al. 2008). The sample included both Confederate and Federal artillery examples. These samples were submitted to Chicago Spectro Service Laboratory, Inc. for a determination of their exact chemical composition. This chemical analysis identified Carbon (C), Manganese (Mn), Phosphorus (P), Sulfur (S), Silicon (Si), Nickel (Ni), Chromium (Cr), Molybdenum (Mo) and Copper (Cu) (Caporaso et al. 2008:20, Table 3).

Lees (2009) examined soils on a Civil War battlefield in Florida, where he hoped to identify elements associated with lead and cast iron ammunition. He used an Innov-X Omega pXRF system. Soils were sampled at each location for 60 seconds. Samples were He examined 274 samples searching for 21 elements, which included: Copper (Cu), Titanium (Ti), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Zinc (Zn), Arsenic (As), Selenium (Se), Rubidium (Rb), Strontium (Sr), Zirconium (Zr), Molybdenum (Mo), Silver (Ag), Cadmium (Cd), Antimony (Sn), Barium (Ba), Mercury (Hg) and Lead (Pb). Lees identified 14 elements in the soils, which included: Barium (Ba), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Rubidium (Rb), Strontium (Sr), Tin (Sn), Titanium (Ti), Zinc (Zn) and Zirconium (Zr). Of these only Barium (Ba), Iron (Fe), Manganese (Mn), Titanium (Ti), Zinc (Zn) and Zirconium (Zr) were identified in levels above 100 ppm. While Lees did not actually sample any cast iron ordnance, he addresses their likely presence in his discussion of the battlefield environment.

Sloto and Helmke examined the elemental composition of domestic cast iron objects in the museum collections at the Hopewell Furnace National Historic site in Pennsylvania (Sloto and Helmke 2011). These included cast iron stoves, cookware and kettles. These objects were manufactured over a wide span of time from about 1772 to 1840. This study examined 23 elements. Data was collected using an Innov-X Avenger pXRF handheld system. Data on each sample was collected for one minute or less, with settlings ranging from 10-40 kV voltage and 5-50 µA current. This system uses a silicon pin detector. Elements that were detected in Sloto and Helmke’s study included: Arsenic (As), Copper (Cu), Zinc (Zn), Cobalt (Co), Bromine (Br), Cadmium (Cd), Gold (Au), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Rubidium (Rb), Selenium (Se), Strontium (Sr) and Zirconium (Zr). Of these, only Arsenic (As), Zinc (Zn), Cobalt (Co),
Bromine (Br), Gold (Au), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Rubidium (Rb) and Strontium (Sr) were detected in levels above 100 ppm in some samples. No traces were identified in their study for the following elements: Antimony (Sb), Barium (Ba), Chromium (Cr), Mercury (Hg), Nickel (Ni), Silver (Ag), Tin (Sn) or Titanium (Ti) (Sloto and Helmke 2011: 52, Table 1).

Scarr and her colleagues (Scarr et al. 2012) studied 43 cast iron cauldron fragments from archaeological sites in northern Delaware using a Bruker Tracer III-SD handheld device. These artifacts date to the eighteenth and nineteenth centuries. The voltage was set at 35 kV and the current was set at 10 µA. The researchers examined the photon values for Arsenic (As), Rubidium (Rb), Strontium (Sr), Yttrium (Y) and Zirconium (Zr). Of these, Zirconium and, to a lesser extent, Rubidium were identified as potentially meaningful elements for differentiation the cauldrons sampled in the study.

Mentovich and his colleagues (Mentovich et al. 2010:2520-2528; Askenazi et al. 2012:177-182; Cvikel et al. 2013) analyzed two cast iron cannonballs from the Akko 1 shipwreck, which was a Mediterranean naval auxiliary brig excavated in Akko harbor. The samples, a 9-pounder and a 24-pounder, were analyzed by XRF and other methods. The specific methods of the XRF analysis were not described by the authors. The XRF analysis revealed the compositions weight of each specimen to be similar containing 97.7 percent Iron (Fe), one percent Silicon (Si), 0.6 percent Manganese (Mn) and 0.7 percent Phosphorus (P) (Cvikel et al. 2013:113, Table 2). They linked the presence Manganese (Mn) in both balls as a deliberate alloy component that dated after 1839, following an 1839 patent issued involving the addition of manganese to cast iron to reduce gas porosity and blow holes. They concluded that the two cannonballs were likely associated with the 1840 Egyptian naval bombardment of Akko, Israel.

Revolutionary War period cast iron ordnance from several southeastern archaeological sites were analyzed by the author. Descriptions of this analysis appears for the first time in print herein. These include grapeshot from Kettle Creek (Wilkes County, Georgia) battlefield, a two-pounder cannonball from the Beaufort (S.C.) battlefield, four cannonballs from Redoubt 4 at New Ebenezer and the Purysburg (S.C.) battlefield. All of these ordnance are considered to be associated with American Patriot artillery. These samples were analyzed using the same Bruker Tracer equipment that was used to sample the GHS Pulaski grapeshot. All of these samples were collected for 180 seconds each, although different energy settings were used from that used in the present study.
III. Chemical Characterization of Cast Iron

Data Collection Methods

Data were collected for the GHS specimen with a Bruker Tracer III-V for 180 seconds, black filter (Ti/Al), 48 kV voltage, and 29 µA of current. The GHS grapeshot specimen was sampled four times on each of four quadrants of the object with this method. Next, the GHS specimen was sampled four times each for 180 seconds, using no filter, 48 KV voltage and 29 µA of current. A total of eight spectra were collected from this object. Figure 4 shows data collection in progress.

Potentially Important Elements for Study

The Bruker Tracer series is unable to identify elements with Atomic Numbers of 12 (Magnesium, Mg) or lower. Rhodium (Rh) and Palladium (Pd) are present in the Bruker Tracer hardware, so their presence in the spectral readings should be largely ignored. Elements that were recognized as potentially important in this study include: Arsenic (As), Barium (Ba), Bromine (Br), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Rubidium (Rb), Silver (Ag), Strontium (Sr), Tin (Sn), Zinc (Zn) and Zirconium (Zr). Iron (Fe) was, of course, expected to be the dominant element in the samples.

Figure 4. Lisa Powell and Daniel Elliott Collect Elemental Data from Pulaski Grapeshot (Courtesy of Georgia Historical Society).
Arsenic

Arsenic (As) is a metalloid with the atomic number 33. It rarely occurs as a pure crystal and, more commonly, in combination with sulfur and metals. It has a sublimation point (passing directly from a solid to a gas) of 1137°F. It has a value of 3.5 on Mohs hardness scale. Arsenic was used in the Bronze Age as a hardening allow in bronze (Greenwood and Earnshaw 1997).

Barium

Barium (Ba) is a soft, silvery alkaline metal with atomic number 56. It does not occur in nature as a free element. It was first identified in 1774 but not isolated as a metal until 1808. It has a melting point of 1341°F. It has a value of 1.25 on Mohs hardness scale (Greenwood and Earnshaw 1997).

Bromine

Bromine (Br) is a halogen with the atomic number 35. It does not occur freely in nature but it is found in halide salts. It was first isolated in 1825. It has a melting point of 19°F (Greenwood and Earnshaw 1997).

Copper

Copper (Cu) is a malleable reddish-gold metal with the atomic number 29 (Doebrich 2009:1-4). Copper has a very high melting point (1984°F). It has a value of 3 on Mohs hardness scale. Copper has been mined since ancient times.

Iron

Iron (Fe) is a metal with the atomic number 26. It is very common in the Earth’s crust. It occurs in metallic form and a wide range of oxidized states. It has a melting point of 2800°F. It has a value of 4 on Mohs hardness scale. Iron has been mined since ancient times (Schubert 1957).

Manganese

Manganese (Mn) is a silver-gray metal with the atomic number 25. It does not occur as a free element but is often found in combination with iron. It was first isolated in 1774. It has a melting point of 2275°F. It has a value of 6.0 on Mohs hardness scale (Greenwood and Earnshaw 1997).

Molybdenum

Molybdenum (Mo) has the atomic number 42. It is a silvery metal that does not occur naturally as a free metal but it does occur in various oxides. It has a very high melting point (4753°F) and is used to harden steel alloys. It has a value of 5.5
on Mohs hardness scale. The element was discovered in 1778 and isolated in 1781. It was not mined commercially until 1885 (Kropschot 2010).

**Nickel**

Nickel (Ni) is a silvery-white lustrous metal with the atomic number 28 (Nickel Institute 2017). Nickel has a very high melting point (2646°F). It has a value of 4.0 on Mohs hardness scale.

**Rubidium**

Rubidium (Rb) is a soft, silvery-white alkali metal with the atomic number 37. It was discovered in 1861. It has a low melting point (102.74°F). It has a value of 0.3 on Mohs hardness scale (Butterman and Reese 2004).

**Silver**

Silver (Ag) is a precious silver metal with the atomic number 47 (Butterman and Hilliard 2004). Silver has a high melting point (1761°F). It has a value of 2.5 on Mohs hardness scale. Silver has been mined since ancient times.

**Strontium**

Strontium (Sr) is a soft, silver-white yellowish alkaline metal with the atomic number 38. The element commonly occurs in nature. It was discovered in 1790 and first isolated in 1808. It has a melting point of 1431°F. It has a value of 1.5 on Mohs hardness scale (Greenwood and Earnshaw 1997).

**Tin**

Tin (Sn) is a soft, white metal with the atomic number 50 (Calvert 2002). It occurs with lead ores. Tin has a melting point of 449°F. It has a value of 1.5 on Mohs hardness scale. Tin has been mined since ancient times.

**Zinc**

Zinc (Zn) is a lustrous metal with the atomic number 30 (Bleiwas and diFrancesco 2010; International Zinc Association 2017). Zinc has a high melting point (787°F). Zinc has a value of 2.5-3 on Mohs hardness scale. Zinc has been mined since ancient times.

**Zirconium**

Zirconium (Zr) is a lustrous, grey-white strong transition metal with the atomic number 40. It has a melting point of 3371°F. It has a value of 5.0 on Mohs hardness scale (Greenwood and Earnshaw 1997).
IV. Study Samples

GHS Sample

The single grapeshot (or case shot) in the Georgia Historical Society collection (GHS Catalog Number A-0509-002 [Box 52]) was the initial subject of study in this elemental analysis. It is nearly spherical and measures 27.57 mm by 28.49 mm. As it is mounted with wire in a silver candlestick and could not be removed, its weight was not determined. An estimated weight of 3 ounces (85 g) was calculated using a chart provided by Muller (1768:12). It displays a casting line that runs vertically, indicating it was cast in a two-piece mold. It has the exterior appearance of iron and is heavily pitted. It possesses no other visible marks. The grapeshot was sampled eight times. The first four readings (Pulaski 1 through Pulaski 4) were made using the Black Filter. The latter four readings were made using no filter. Figure 5 shows a portion of the GHS spectra for Samples Pulaski 1 through Pulaski 4. Table 1 shows photon values for key elements in the GHS samples.

![Figure 5. Portion of GHS Spectra, Samples Pulaski 1-4, Black Filter.](image-url)
Table 1. Photon Values for GHS Specimen.

| Sample | Ag Kx1 | Ag Kx2 | Ar K | Ar L | As K | As L | Ba L1 | Ba L2 | Bi L1 | Bi L2 | B L | B MeV |
|---------|--------|--------|------|------|------|------|-------|-------|-------|-------|-----|-------|-------|
| pulaski1| 1527   | 156    | 197  | 158  | 5840 | 15   | 100   | 1120  | 135   | 97    | 647 | 28    | 65    |
| pulaski2| 511    | 215    | 198  | 192  | 3978 | 56   | 164   | 117448| 191   | 93    | 155  | 602   | 24    |
| pulaski3| 521    | 194    | 130  | 316  | 3716 | 7    | 130   | 123632| 267   | 105   | 121  | 604   | 35    |
| pulaski4| 521    | 130    | 130  | 3716 | 7    | 130   | 123632| 267   | 105   | 121   | 604  | 35    | 54    |
| Average | 119    | 51    | 117  | 188  | 3544 | 18    | 131   | 12027 | 316   | 130   | 130  | 130   |

**Charleston Museum Sample**

The cast iron grapeshot (or case shot) in the Charleston Museum collection (Accession Number 1978.1, Catalog Number MM99) was sampled. According to an old museum card, this object was removed from Count Casimir Pulaski upon being wounded at the Siege of Savannah in October 1779 by Dr. James Lynah of Charleston. The object was held by the History Department of the Charleston Museum before being transferred to the Archaeology Department. It measures from 34.8 mm to 35.4 mm in diameter, which is larger than the GHS specimen. It weighed 165.0 g (5.8 oz.). Figure 6 shows a portion of the spectra for the Charleston Museum’s Pulaski grapeshot.

![Figure 6. Portion of Charleston Museum Spectra, Sample MM99, Black Filter.](image)

**Kettle Creek Samples**

Archaeologists recovered two cast iron grapeshot (or case shot) from the Kettle Creek battlefield, where patriot Georgia and South Carolina militia engaged Loyalists and loyalist recruits on February 14, 1779. The battle, which was a patriot victory, lasted several hours. Documentary records from four days earlier indicate that the patriots had some artillery on hand. No records of any Loyalist artillery are mentioned in the accounts. The case shot from Kettle Creek were recovered
from two distinct parts of the battlefield. The first specimen, which is larger than the second, was recovered from the opposite side of Kettle Creek from the Kettle Creek monument. It measured 19.1 mm in diameter (0.75 caliber) and weighed 25 g (Elliott 2008: Appendix 1, LN524). The second example was recovered from the same ridge as the monument but on its lower slope (Patch 2016). Both specimens are suspected to be associated with Patriot artillery. Figure 7 shows a portion of the spectra for the Kettle Creek grapeshot specimens.

![Figure 7. Portion of Kettle Creek Samples Spectra, Black Filter.](image)

**Purysburg Sample**

Archaeologists recovered three cast iron grapeshot (or case shot) from the Purysburg battlefield. The three case shot came from a suspected redoubt location and were in relatively close proximity. Purysburg was a Patriot headquarters complex in early 1779. The British and Loyalists attacked the town on April 29, 1779, when the town was defended by only a skeleton force.

The first specimen (38JA158, Lot 191) measured 27 mm in diameter and weighed 59.5 g (2.1 oz.). The second specimen (38JA158, Lot 190) measured 28 mm in diameter and weighed 63.0 g (2.2 oz.). The third specimen (83JA158, Lot 219) measured 26 mm in diameter and weighed 57.0 g (2.0 oz.). All three specimens are suspected to be associated with Patriot artillery. Figure 8 shows a portion of the spectra for the Purysburg grapeshot specimens.
Aiken-Rhett Sample

One cast iron grapeshot (or case shot) was excavated by Zierden in 2002 from a Revolutionary War siege trench at the Aiken-Rhett property in Charleston, South Carolina. It was discovered in Zone 4 (N340 E155) and was given the designation FS142 and recorded in the Charleston Museum as Accession Number 2002.030, Catalogue Number ARL 27763.1. This specimen is suspected to be an American artillery projectile. It measures 33 mm in diameter and it weighed 137.8 g (4.9 oz.). It was analyzed with the Bruker Tracer. Figure 9 shows a portion of the spectra for the Aiken-Rhett Siege Trench grapeshot specimen.
Eutaw Springs Sample

One cast iron grapeshot (or case shot) was collected from the surface of Eutaw Springs Battlefield by Gene Waddell. It is recorded in the Charleston Museum as Accession Number 1964.45.3, Catalogue Number ARL 3899). It measured 38.3 mm (1.5 in) in diameter and it was dented on one side. It was analyzed with the Bruker Tracer. Figure 10 shows a portion of the spectra for the Eutaw Springs grapeshot specimen.
**Beaufort Cannonball Sample**

One cast iron cannonball recently recovered from the February 1779 Battle of Beaufort/Grays Hill in Beaufort County, South Carolina. Archaeologist Daniel Battle indicates that this projectile was fired by British artillery at the American artillery position. It bears no identifying marks, although it is heavily dented on one side. It weighed 467.2 g (1.03 lbs.) and was 50.8 mm (2 in) in diameter. This specimen was analyzed with the Bruker Tracer. Figure 11 shows a portion of the spectra for the Battle of Beaufort cannonball specimen.

![Figure 11. Portion of Beaufort Cannonball Sample Spectra, Black Filter.](image)

**Ebenezer Cannonball Sample**

Four cast iron cannonballs recently recovered from Redoubt Number 4 at New Ebenezer, Georgia (9EF28) were analyzed with the Bruker Tracer. Figure 12 shows a portion of the spectra for the Ebenezer cannonball specimens. These objects were analyzed in their pre-cleaned condition with a thin crust of rust and rusty sand. Metrics for these cannonballs were: Lot 67—1,694 g (3.74 lbs.) and 77 mm in diameter; Lot 68—1,819 g (4.01 lbs.) and 77 mm in diameter; Lot 69—1,809 g (3.99 lbs.) and 79 mm in diameter, and Lot 70—1,909 g (4.21 lbs.) and 80 mm in diameter. The weights for these specimens suggest that all were intended for a four-pounder gun. These four specimens likely date between 1779 and 1782, which is the period of occupation for Redoubt Number 4. What is less clear is their military affiliation, as both British and Patriots used this earthworks. Redoubt 4 was never bombarded with artillery, so it is a reasonable conclusion that these four cannonballs were never fired from a cannon.
Figure 12. Portion of Ebenezer Cannonball Samples Spectra, Black Filter.

**Stono Settlement Cannonball Sample**

One cast iron cannonball was recovered by Ron Anthony from the Stono Settlement (38CH851). He suggests that it dates to the period of the British military camp there, but it remains unclear which army it is associated with. It measured 77 mm in diameter and was heavily dented on one side. It weighed 1,650.8 g (3.64 lb.). The weight suggests that this ball was intended for a four-pounder gun. This object was conserved by Anthony and it was treated with Tannic and Phosphoric Acid; and was electrolyzed using a stainless steel sacrificial anode. The ball was coated with microcrystalline wax. This specimen was analyzed with the Bruker Tracer. Figure 13 shows a portion of the spectra for the Stono Settlement cannonball specimen.
One cast iron cannonball was recovered by Carl Steen from his (then) residence at 65 Vanderhorst Street in Charleston. This specimen was conserved using identical methods to those described above for the Stono Settlement cannonball. It measured 72 mm in diameter and weighed 1,274.8 g (2.8 lbs.). It was analyzed with the Bruker Tracer. Figure 14 shows a portion of the spectra for the Vanderhorst Street cannonball specimen.
**Legare Street Cannonball Sample**

One cast iron cannonball was recovered from excavations at 14 Legare Street in Charleston. It was excavated by Zierden from Feature 168 (N30 E75, FS 567). It is recorded in the Charleston Museum as Accession Number 1998.046, Catalogue Number ARL 43677.1. This specimen had not been electrolyzed or otherwise treated. It was analyzed with the Bruker Tracer. Figure 15 shows a portion of the spectra for the Legare Street cannonball specimen.

![Figure 15. Portion of Legare Street Cannonball Sample Spectra, Black Filter.](image)

**Legare Street Bar Shot Sample**

Excavations by the Charleston Museum at 14 Legare Street unearthed one cast iron bar shot. It weighed 3,452.4 g (7.6 lbs.) and was a maximum of 89.7 mm (3.5 in) in diameter. It was likely intended for use with an eight-pounder gun. This specimen was analyzed with the Bruker Tracer. Figure 16 shows a portion of the spectra for the Legare Street bar shot specimen.
Figure 16. Portion of Legare Street Bar Shot Sample Spectra, Black Filter.
V. Discussion

Our research identified two grapeshot specimens both of whom have similar provenance linking them to Brigadier General Count Casimir Pulaski and Dr. James Lynah. Unless the good general had two cast iron projectiles removed from his body by the good doctor, at least one of these claims is inaccurate. Elemental analysis alone cannot solve this riddle. It can provide details about the two objects, as well as other contemporary grapeshot and cannonballs, that can add to this important American historical drama. Let us begin by comparing the physical facts about the two grapeshot. This will be followed by consideration of the other grapeshot and cannonballs included in this study. Table 2 contains a summary of the photon values for key elements in the study.

Table 2. Photon Values for Study Samples.

<table>
<thead>
<tr>
<th>Type</th>
<th>Location Sample</th>
<th>Ag 121</th>
<th>As 121</th>
<th>Bi 121</th>
<th>Br 121</th>
<th>Ca 121</th>
<th>Co 121</th>
<th>Cu 121</th>
<th>Fe 121</th>
<th>Mn 121</th>
<th>Fe 121</th>
<th>Mn 121</th>
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<th>Fe 121</th>
<th>Mn 121</th>
<th>Fe 121</th>
<th>Mn 121</th>
<th>Fe 121</th>
<th>Mn 121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charleston</td>
<td>Pulaski Specimen</td>
<td>105</td>
<td>102</td>
<td>100</td>
<td>97</td>
<td>94</td>
<td>90</td>
<td>86</td>
<td>83</td>
<td>80</td>
<td>77</td>
<td>74</td>
<td>71</td>
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<td>62</td>
<td>59</td>
<td>56</td>
<td>53</td>
<td>50</td>
<td>48</td>
<td>46</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

The GHS Pulaski grapeshot is smaller in diameter and weighs less than the Charleston Museum Pulaski grapeshot. Both are within the size and weight ranges of other Revolutionary War grapeshot.

The GHS Pulaski grapeshot yielded the highest photon readings for Silver (Ag) and Arsenic (As) and the lowest photon reading for Palladium (Pd) of the 15 samples included in this study.

The high silver values are substantially higher than all other 14 objects included in this study. This can be explained by three possible scenarios. First, and least likely, the GHS specimen was originally manufactured with the silver content. Second, the GHS specimen had an intentional silver wash or silver plating added to it. While this seems like a reasonable explanation, the GHS specimen exhibits
no visible signs of any silver plating or silver wash. Third, over the century or more that the GHS specimen was mounted in the silver candlestick and secured by the silver wire some silver content was, by some electro-chemical process, transferred from the silver source to the cast iron ball.

The Charleston Museum Pulaski grapeshot yielded the lowest photon readings for Copper (Cu), Rubidium (Rb) and Strontium (Sr) and was tied with other samples for lowest photon readings for Nickel (Ni) and Zinc (Zn).

In stark contrast to the GHS specimen, the Charleston Museum specimen displays very low silver content (only 84 photons for the Charleston Museum specimen versus an average of 3,769 photons for the GHS specimen).

The Silver (Ag) to Iron (Fe) ratios, or Ag/Fe for the sample set was calculated in an attempt to smooth out variations in the instrument readings (Table 3). The GHS samples ranged from a low of 0.0181 to a high of 0.0669. The GHS average displays a ratio of 0.0325, or more than 30 times higher than the Charleston Museum specimen. The other 13 specimens in the study all yielded ratio values far lower than the GHS specimen. These data indicate that silver is an uncommon element in the composition of cast iron ordnance in the Revolutionary War era. The substantially higher frequency of silver observed in the GHS sample may indicate that the silver content was added to the object after its initial manufacture.

Table 3. Iron Ratios for Key Elements in the Study.
The presence of manganese (Mn), either accidentally or intentionally has implications in the elemental analysis. Improvements in metal technology from the years 1799 to 1839 indicate important chronological markers for the intentional addition of manganese to cast iron. Consequently, one should be able to distinguish through elemental analysis some cast iron objects dating prior to this period from those produced afterwards.

A United States patent was issued to William Hancock in 1799 for an improved method of casting iron (Elsworth 1840:62). Unfortunately, the details of this patent are unknown as a result of a catastrophic fire at the U.S. Patent Office in 1839. Also in 1799, William Reynolds was issued a patent in Great Britain for “Preparing iron for the conversion ‘thereof into steel’”, in which, “Oxide of manganese, or manganese, is to be mixed either with the materials for making the pig or cast iron; or with the cast iron to be converted into malleable iron in the finery, bloomery, puddling furnace, or otherwise” (Lack 1883:29; Bessemer 1905).

In 1808 a patent in Great Britain was issued to John Wilkinson for “Making pig or cast metal from the ore, for manufacture into bar iron equal to Russian or Swedish”, and that Wilkinson’s invention consisted of using “manganese, or ores containing manganese, in addition to ironstone and other materials now used in making iron” (Lack 1883:33).

In 1839 a patent was issued in Great Britain to Josiah Marshall Heath for the manufacture of iron and steel, which included the addition of manganese (Mn) in cast iron to make it more malleable. Heath wrote, “To obtain malleable iron of better quality, from 1 to 5 per cent of pure oxide of manganese may be added (without other substances) to molten metal under treatment in the puddling furnace”, and he added, “Carburet of manganese may be used in any process for the conversion of iron into cast steel” (Lack 1883:73; Bessemer 1905:258).

Manganese counts for the samples in this study range from 1 photon (bar shot at 14 Legare Street) to 2,373 photons (9EF28, Lot 67-cannonball). Manganese to Iron ratios, or Mn/Fe were calculated for the study samples. These ranged from a high of 0.1388 (9EF28, Lot 67) to a low of (14 Legare St., Bar shot). Ratios for grapeshot ranged from a high of 0.0053 (Charleston Museum, MM99) to 0.0005 (Purysburg, Lot 191).

We compared the elemental composition of the two candidates for Pulaski’s fatal grapeshot. The GHS average sample contains the highest photon values for silver (Ag) and the lowest palladium values. It should be noted, however, that
some palladium photon values are generated by the Bruker Tracer device and are not indicative of the sample.

The GHS sample contains less manganese than the Charleston Museum sample (251 vs. 409 photons, respectively). The GHS sample had an average Mn/Fe ratio of about 0.4 compared to over 2.4 for the Charleston Museum sample. The Charleston Museum specimen also had the highest Mn/Fe ratio of all study samples.

The Charleston Museum specimen contains the lowest copper (Cu), rubidium (Rb) and strontium (Sr) photon values in the study and was tied for lowest in nickel (Ni) and zinc (Zn) photons. (Tables 2 and 3 and Figure 17).

The GHS sample averaged 3,769 photons of silver, compared to only 84 for the Charleston Museum sample. Ag/Fe ratios were 30.04 and 0.03 for the GHS and Charleston Museum samples, respectively. The GHS ratio is more than 900 times that of the Charleston Museum.

The GHS sample averaged 174 photons of arsenic, compared to 106 for the Charleston Museum sample. As/Fe ratios were 0.0015 and 0.0012 for the GHS and Charleston Museum samples, respectively. The Charleston Museum and GHS ratios are nearly equal.

The GHS sample averaged 3,420 photons of cobalt, compared to 949 for the Charleston Museum sample. Co/Fe ratios were 0.0295 and 0.0122 for the GHS and Charleston Museum samples, respectively. The GHS ratio is more than 2 times that of the Charleston Museum specimen.

The GHS sample averaged 22 photons of chromium, compared to 10 for the Charleston Museum sample. Cr/Fe ratios were 0.0002 and 0.0001 for the GHS and Charleston Museum samples, respectively. The GHS ratio is twice that of the Charleston Museum specimen.

The GHS sample averaged 131 photons of copper, compared to 43 for the Charleston Museum sample. Cu/Fe ratios were 0.0011 and 0.0006 for the GHS and Charleston Museum samples, respectively. The GHS ratio is slightly less than twice that of the Charleston Museum specimen.

The GHS sample averaged 98 photons of molybdenum, compared to 32 for the Charleston Museum sample. Mo/Fe ratios were 0.0008 and 0.0004 for the GHS and Charleston Museum samples, respectively. The GHS ratio is twice that of the Charleston Museum specimen.

The GHS sample averaged 102 photons of nickel, compared to only 25 for the Charleston Museum sample. Ni/Fe ratios were 0.0009 and 0.0003 for the GHS
and Charleston Museum samples, respectively. The GHS ratio is 3 times that of the Charleston Museum specimen.

The GHS sample averaged 644 photons of lead, compared to 426 for the Charleston Museum sample. Pb/Fe ratios were 0.0056 and 0.0055 (nearly equal) for the GHS and Charleston Museum samples, respectively.

The GHS sample averaged 44 photons of rubidium, compared to 13 for the Charleston Museum sample. Rb/Fe ratios were 0.0004 for both the GHS and Charleston Museum samples.

The GHS sample averaged 692 photons of tin, compared to 197 for the Charleston Museum sample. Sn/Fe ratios were 0.0060 and 0.0025 for the GHS and Charleston Museum samples, respectively. The GHS ratio is more than twice that of the Charleston Museum specimen.

The GHS sample averaged 101 photons of strontium, compared to only 9 for the Charleston Museum sample. Sr/Fe ratios were 0.0009 and 0.0001 for the GHS and Charleston Museum samples, respectively. The GHS ratio is 9 times that of the Charleston Museum specimen.

The GHS sample averaged 139 photons of zinc, compared to only 21 for the Charleston Museum sample. Zn/Fe ratios were 0.0012 and 0.0003 for the GHS and Charleston Museum samples, respectively. The GHS ratio is 4 times that of the Charleston Museum specimen.

The GHS sample averaged 154 photons of zirconium, compared to 33 for the Charleston Museum sample. Zr/Fe ratios were 0.0013 and 0.0004 for the GHS and Charleston Museum samples, respectively. The GHS ratio is more than 3 times that of the Charleston Museum specimen.

Table 4. Comparison of Key Element to Iron Ratios for the GHS and Charleston Museum “Pulaski” Grapeshot.

<table>
<thead>
<tr>
<th>Element</th>
<th>GHS/CM</th>
<th>CM/GHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn/Fe</td>
<td>2.434</td>
<td>0.411</td>
</tr>
<tr>
<td>Ag/Fe</td>
<td>0.033</td>
<td>30.040</td>
</tr>
<tr>
<td>As/Fe</td>
<td>0.827</td>
<td>1.210</td>
</tr>
<tr>
<td>Co/Fe</td>
<td>0.414</td>
<td>2.413</td>
</tr>
<tr>
<td>Cr/Fe</td>
<td>0.687</td>
<td>1.456</td>
</tr>
<tr>
<td>Cu/Fe</td>
<td>0.490</td>
<td>2.040</td>
</tr>
<tr>
<td>Mo/Fe</td>
<td>0.489</td>
<td>2.045</td>
</tr>
<tr>
<td>Ni/Fe</td>
<td>0.368</td>
<td>2.718</td>
</tr>
<tr>
<td>Pb/Fe</td>
<td>0.989</td>
<td>1.011</td>
</tr>
<tr>
<td>Rb/Fe</td>
<td>0.953</td>
<td>1.049</td>
</tr>
<tr>
<td>Sn/Fe</td>
<td>0.426</td>
<td>2.350</td>
</tr>
<tr>
<td>Sr/Fe</td>
<td>0.134</td>
<td>4.439</td>
</tr>
<tr>
<td>Zn/Fe</td>
<td>0.225</td>
<td>7.476</td>
</tr>
<tr>
<td>Zr/Fe</td>
<td>0.321</td>
<td>3.114</td>
</tr>
</tbody>
</table>

This comparison shows that the elemental composition of the GHS and Charleston Museum samples are very different. This suggests that the two grapeshot were not cast from the same metal stock. The GHS specimen contains substantially more impurities (non-iron elements) relative to the Charleston Museum specimen, particularly cobalt, chromium, molybdenum, nickel, rubidium, tin, silver, strontium, zinc and zirconium. The Charleston Museum
specimen contains higher relative amounts of only one element—manganese. The two specimens contain nearly equal amounts of arsenic, lead and rubidium.

Figure 17. Iron Ratios for Selected Elements for GHS (Blue) and Charleston Museum (Orange) “Pulaski” Grapeshot.
VI. Summary

The elemental analysis of case shot described in the preceding report is an important stride in Revolutionary War conflict archaeology. It’s purpose in the beginning was the analysis and interpretation of a single piece of grapeshot with a fabled history—the shot that killed Casimir Pulaski. It quickly grew to be a pioneering effort to characterize the elemental composition of cast iron ammunition from the Revolutionary War era. As the study progressed and as the author searched the internet for comparable data, another grapeshot surfaced whose institutional records claimed was the shot that killed Pulaski. Both claims are not likely true, but the elemental analysis alone provided no solid answers as to which claim was more valid. The GHS and Charleston Museum “Pulaski” grapeshot have very different elemental compositions. The puzzle and mystery surrounding Pulaski’s death remains!
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Molski, Felix  

Muller, John  

Nickel Institute  

Patch, Shawn M.  

Pense, A.W.  

Phillips, Eleazer  

Pinkowski, Edward  

Powell, Charles E., editor  

Royal Society of Chemistry  

Scarr, Kristin, D., H.E. Krofft and D.S. Clarke  

Schubert, H.R.  

Shackley, M.S.  

Sloto, R.A., and M. F. Helmke  

Sparks, Jared  

Stefanescu, D.M.  
Stello, R. Alan, Jr.

Thornton, Iain, R. Rautiu, and S. Brush
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