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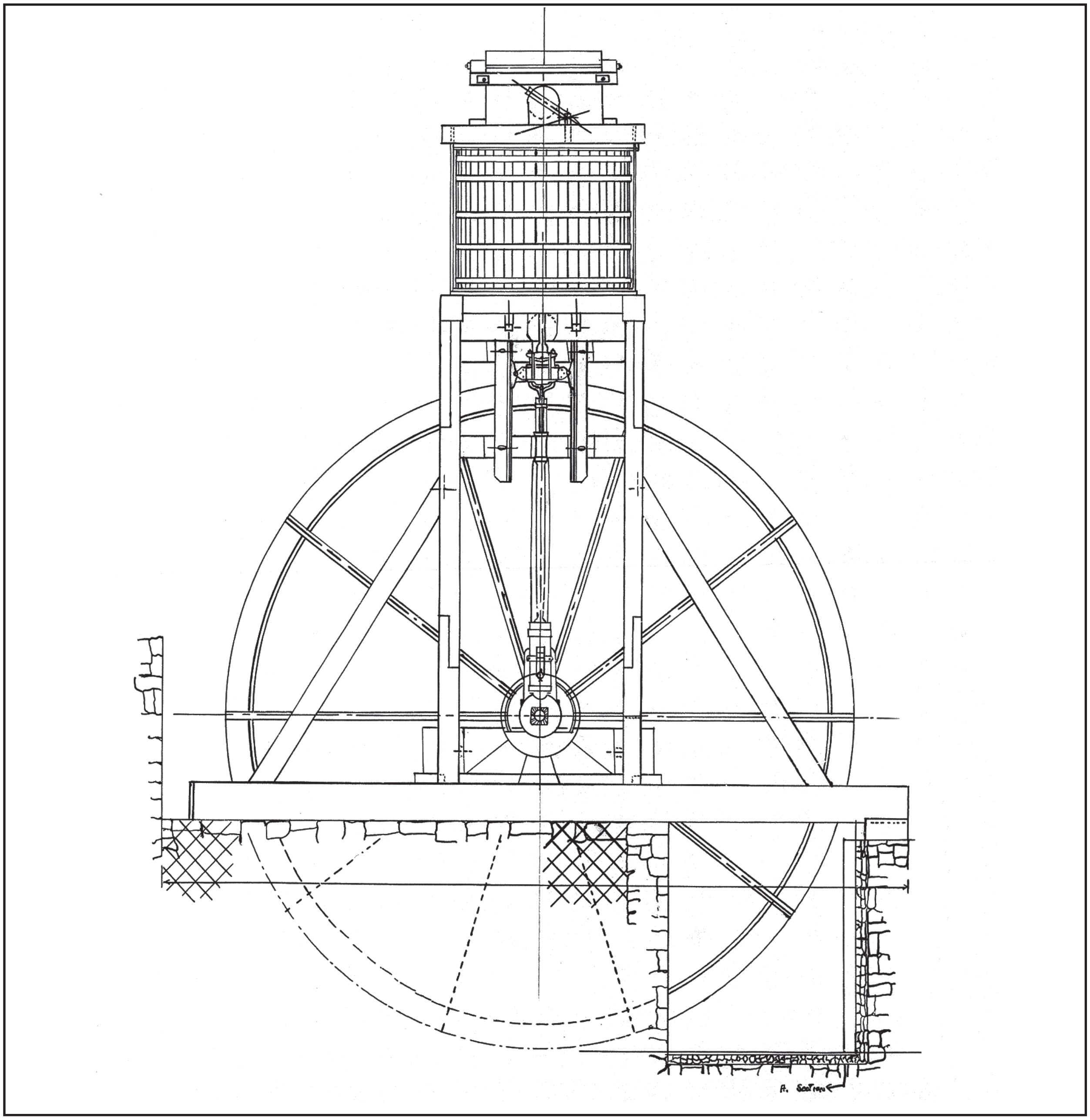

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Trace Element Time Markers as Proxies for the Calibration of Civil War-Era Sediment Accumulations at the West Point Foundry

Joel W. Grossman, Robert J. Taylor, and Eri Weinstein

Abstract

Between 1989 and 1995, Joel Grossman and his team were selected by the Environmental Protection Agency and Army Corps of Engineers to conduct the first major archaeological excavation of the contaminated Superfund and National Register site of the West Point Foundry in Cold Spring, New York. The project included both a terrestrial and a marine aspect. The team needed to determine the depth of the buried and submerged Civil War-era surface within the shoreline coves that were to be dredged to remove cadmium deposits deposited by a twentieth-century nickel-cadmium battery plant. The trace elements of copper (Cu), lead (Pb), and cadmium (Cd) were used to calibrate the depth of historic and modern marine sediments as part of the remediation process. We selected copper and lead because both metals represent industrial byproducts of military smelting. Six cores were successfully recovered from submerged Hudson River and marsh sediments. We used the depth of recorded increases in the levels of both metals to demarcate the onset of foundry operations in 1817. Increases in mid-level readings of Pb and Cu suggested a major increase in effluents during the Civil War. Twentieth-century fluctuations are tied to the advent and elimination of leaded gas.

Dating archaeological deposits can be difficult. The dating of submerged cultural, or anthropogenic, sediments can be even more so. This report will summarize the use of lead, copper, and cadmium (Pb, Cu, and Cd) concentration in core profiles to establish the depth of datable historic sediments in an important but contaminated archaeological site complex composed of riverine and terrestrial components. This dating method also proved useful in determining the relative depth of proposed dredging operations. In the early 1990s, metal concentrations served as chronological proxies to augment the 1950-era nuclear benchmarks from the first atomic bomb tests which were, until that time, one of the few sources for dating of twentieth-century sections from vertical core samples. These archaeological benchmarks augment the inventory of available time markers in the Hudson River sediments and provide archaeological proxies for three critical events in the local history: 1) the opening of West Point Foundry operations in 1817, 2) the peak of foundry production during the Civil War years (1858–1865),[1] and 3) the onset of discharge of cadmium into East Foundry Cove from the Marathon Battery Company in 1953.[2]

The U.S. Environmental Protection Agency and Army Corps of Engineers selected Grossman and his team to plan and direct the first federally mandated archaeological investigation of a contaminated Superfund site. This investigation took place between 1989 and 1995 in the context of a large-scale, multi-year archaeological sensitivity study and mitigation program required by Section 106 of the National Historic Preservation Act ahead of critical remediation work to remove cadmium from the shore and cove areas around Cold Spring, New York (figure 1).

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The clean-up area encompassed the Civil War-era iron manufacturing complex of the West Point Foundry, which specialized in cannon for the military, steam engines, and sugar production machinery, as well as general commercial iron products.[3] Cadmium deposits from a post-WWII battery factory built over the historic foundry needed to be removed, both on land and from the marshes bordering the river. Clean-up could not begin until the poorly defined historic site had been documented. The Superfund effort posed critical health and safety constraints, and there was a need to expedite the fieldwork under often adverse weather conditions. It also represented a logistical and scientific test case of the ability of archaeology, as a discipline, to meet federal preservation laws in contaminated and potentially dangerous contexts.[4]

Fieldwork along the shoreline of the foundry complex was completed in deep winter under heavy, custom-built steel-reinforced shelters covered with inflated, forced-air-insulated, plastic skins. Heavy pumps worked around the clock to lower the water table down to the level of the buried Civil War surface, five ft. below the 1990 grade. Large industrial heaters ducted hot air to the shelters to keep the artifacts and archaeologists thawed. All field and laboratory team members were HAZMAT-certified and medically monitored. A range of applied technology solutions was deployed to facilitate the safe and timely investigation and documentation of the site. Instead of using "statistically valid" random sampling, liability and health concerns necessitated a strategic shift to safer, non-random, target-specific geospatial and geophysical technologies to locate buried and submerged resources. Traditional "hands-on" manual recording was improved with remote, or non-contact, high-speed 3D laser transit and photogrammetric recording systems to limit exposure to potentially toxic deposits and artifacts. On-site concurrent computer and conservation systems provided real-time feedback and planning capabilities, reducing uncertainty over where sampling should occur and focusing project resources on only undisturbed, high integrity study areas.

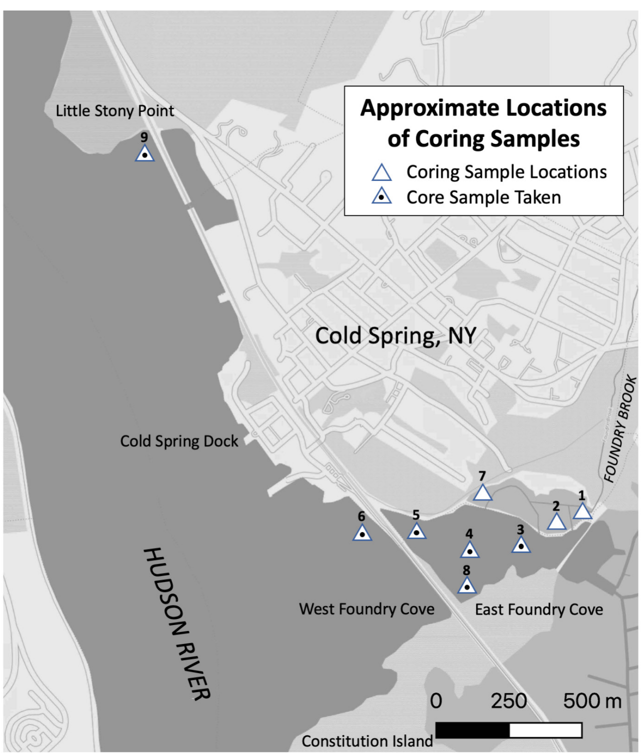

Figure 1. General location map of core samples from East and West Foundry Coves, Cold Spring, New York. Map by Steven A. Walton.

The five-year archaeological rescue effort resulted in major discoveries in Civil War military history. Intensive terrestrial geophysical surveying of a football-field-sized shoreline area targeted for cleanup and land reclamation resulted in the discovery and documentation of the preserved wooden and iron gun testing platform of Parrott's 30,000 lb. rifled cannon (figure 2). Recovered beside it were the remains of the cannon hoist tower for lifting this new class of heavy rifled ordnance. These archaeological materials were covered by a deposit of 3–5 ft. of cadmium-laced industrial fill. While these terrestrial discoveries have been extensively described, the riverine elements of the overall study have not.[5] This summary presents the use of trace elements as markers or proxies to document historic riverine and marsh sediment depths.

The marsh and riverine portions of the investigation combined scaled comparisons of historic bathymetric surveys, geophysical (magnetometer) marine surveys and side-band sonar scans with historic trace element analysis to reconstruct the Civil War-era bathymetry, sediment depths and archaeological sensitivity of East and West Foundry Coves. Historic bathymetric maps were digitized, scaled, and georeferenced using early CAD software and then compared with the geophysical data to indicate the relative depths of sediments within West Foundry Cove (figure 3). Comparisons between 1857, 1905, and 1933 maps showed considerable differences in channel, cove, and marsh sediment depths between the mid-nineteenth and early twentieth centuries.[6]

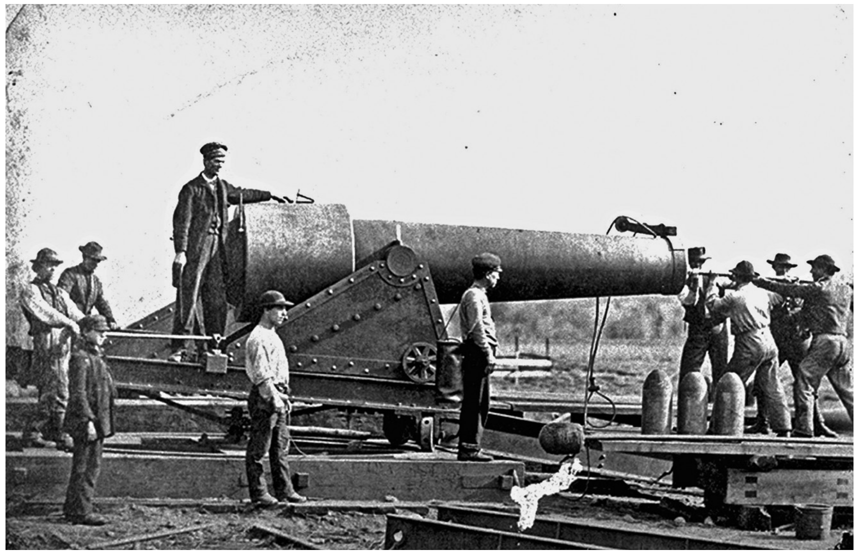

Figure 2. Photo of a 30,000-lb. Civil War cannon taken at Cold Spring, NY, 1863. Courtesy of the Putnam County Historical Society, Cold Spring, NY.

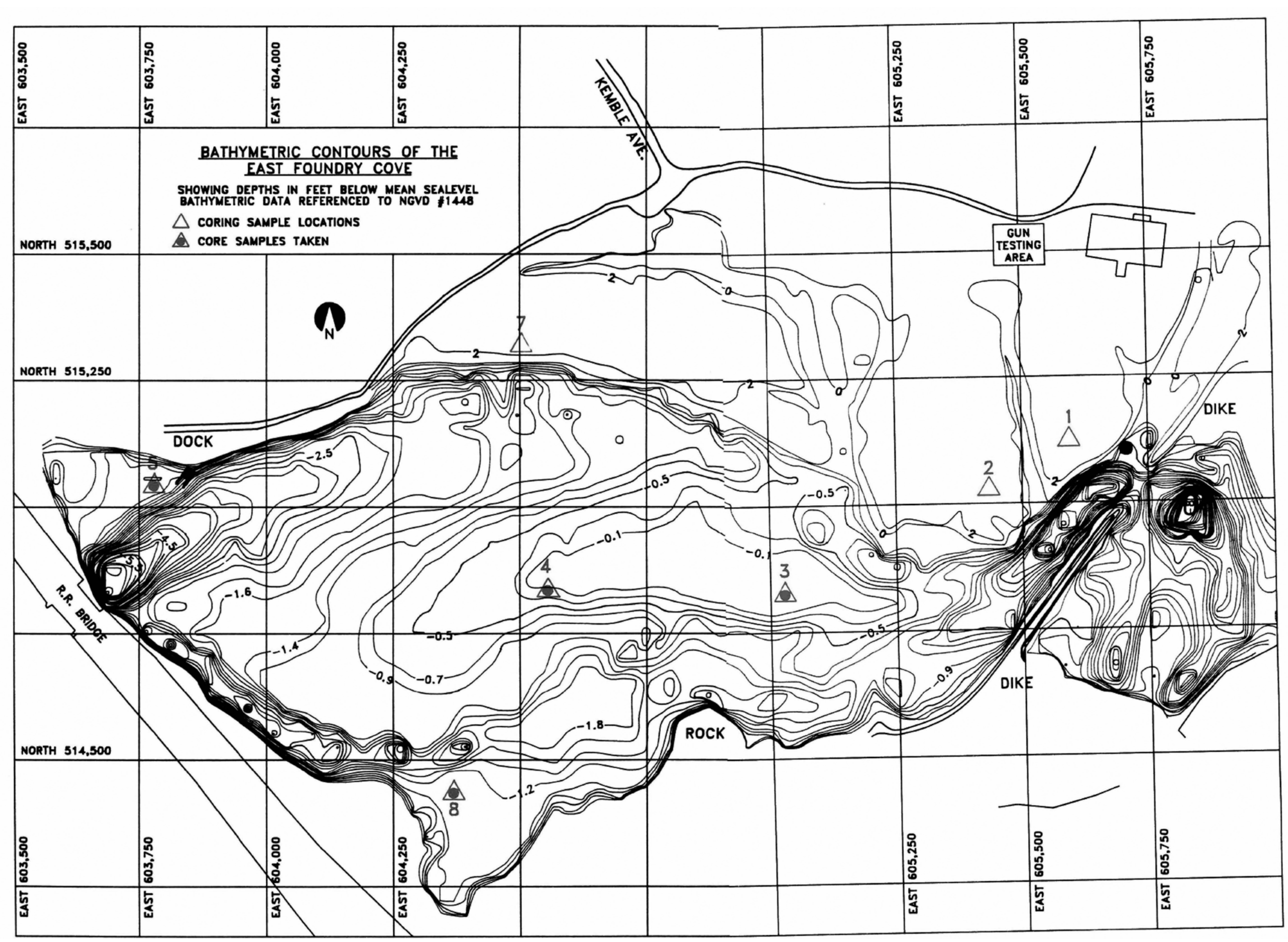

Figure 3. Detailed bathymetric map of coring all sample locations relative to core samples. The triangles with dots show where five were recovered. Map by G. Myers.

Based upon the comparison of eleven discrete sets of overlapping depth readings, both the absolute depth accumulations and the computed rate of sedimentation between different areas of West Foundry Cove and the shoreline of Cold Spring showed a wide range of variation. The computer-based comparisons of historic bathymetric records showed varying sediment accumulation totals, ranging between 6 in. and 9 ft. for different areas of West Foundry Cove between 1857 and 1905. Negative accumulations identified for the period spanning 1905–1933—that is, where the cove was deeper in places than indicated on previous surveys—suggested that extensive areas of West Foundry Cove and the shore front had been dredged during the first half of the twentieth century. Because of this heavy dredging activity, it was not possible to use this more recent map series (1905–1933) for establishing estimates of sediment accumulations for this period. Nevertheless, the earlier comparisons between 1857 and 1905 showed significant differences in the depth soundings within West Foundry Cove. One area near sample location (Core 4) showed sediment loss by almost 9 ft. as indicated by lead-line readings between 1857 and 1933.[7]

In addition to the historic map investigation, side-scan sonar and magnetometer instruments crisscrossed the river in front of the Foundry to help identify, avoid, and protect any submerged resources. Together, they defined the presence and location of twenty-seven anomalies, of which fourteen could be associated with discrete submarine remains. These included two historic barges, two probable shipwrecks, as well as a range of magnetic targets which could not be identified as to function. They did not, however, establish the absolute depth relative to the proposed dredging operations of the anomalies identified by the sonar and magnetometer.

The definition of the depth of the submerged Civil War-era surface, or "historic cove bottom," and the magnetic and sonar anomalies presumed to be on that buried Civil War surface would require other investigative procedures to date the different layers in the vertical column of sediments. Grossman selected metallic trace element analysis as a possible method to identify the depth of the buried historic interface. Analysis of "Vibra-core" sediment cores taken across the study area identified shifting concentrations of historic metallic trace elements in a series of sub-bottom cores. Distinct fluctuations in lead and copper concentrations were identified as potential historic fingerprints because of the belief that their initial presence demarcated the onset of foundry operations in 1817 and that the increase in metal concentration recovered at shallower core depths was coterminous with the surge in foundry output from 1858 to 1867, the years of peak artillery production around the Civil War.

Field Sampling and Laboratory Procedures

A total of six core samples were successfully recovered from within the project area. Three additional cores located within East Foundry Cove Marsh (Cores 1, 2, and 7 in figures 1 and 3) resulted in no recovery of sediments or data. Consequently, no useable sediment or trace element data is available for the marsh area. Of the six useable cores, four (Cores 3, 4, 5, and 8) were successfully recovered to depths of 5-6 ft. within East Foundry Cove. Core 6 was taken in West Foundry Cove, near the intersection of the rail trestle and the Long Dock. It was selected because its location corresponded to the historic bathymetric map coverage provided by the various U.S. Coastal and Geodetic Service (USCGS) sounding records. The sixth, Core 9, served as the control sample and was extracted from the southern embayment of Little Stony Point, to the north of, and outside, the study area to aid in comparison and evaluation of trends in historic trace element fluctuations detected within East and West Foundry Cove. Given the distance and the up-river and generally up-wind location of this control sample core, it served to differentiate between area wide trends in trace metal concentrations through time versus foundry-specific fluctuations within the coves. As such, all interpretations of sediment core data must be evaluated relative to fluctuations indicated by the control Core 9.

All cores were taken from the survey boat using sections of 4-in. diameter aluminum irrigation pipe. A commercial portable gasoline-driven vibration unit was utilized to drive and extract the cores from the sediments of the cove (figure 4). A numbered section of coring pipe was lowered into the water until it reached the upper surface of the cove sediments. At water level, a mark was scribed on the outer wall of the pipe. A second mark was then scribed into the pipe wall 5 ft. above the first. The location of the upper mark served as a visual guide to the coring crew that the limit of the 5-ft. depth had been reached. The bracket holding the Vibra-core hammer was clamped to the core pipe and the vibration unit was used to drive the core pipe into the cove sediments to the upper mark scribed on the pipe wall. The open-air end of pipe was then capped

Figure 4. HASMAT team taking marine *Vibracore* sediment cores to define the Civil War-era Hudson River channel interface and historic sediment depths through trace element analysis in East and West Foundry Coves, Cold Spring, New York. Photo by Joel W. Grossman.

with a rubber plug to reduce compression and the loss of samples upon extraction. In most cases the core was manually winched to the surface and the bottom of the core pipe was capped. The motorized Vibracore assembly was used to retrieve cores which did not release easily from the cove sediments. Water was drained from the core pipe by sawing two drain cuts above the upper mark which designated the upper limits of the core. After the water was removed, the excess coring pipe was cut off and both ends of the core were capped.

The sediment column of each core was recovered by clamping the core pipe horizontally to a cutting table and sawing each section lengthwise through the core pipe wall with a circular saw. After the core pipe was cut away, the sediment column was measured to determine the actual core length and to establish sampling increments. Each sub-sample was cut and handled with disposable plastic implements to minimize the possibility of contamination between samples. All sampling increments were split and sealed in pairs of zip-lock plastic bags, providing one sample for analysis and one for storage in the event that the trace metals analysis required replication.

Although each core was sampled to a depth of 5 ft., the actual core lengths were slightly shorter due to compression of the sediment matrix within the core pipes. The sampling procedure was designed to take sub-samples at 6-in. increments so that a 5-ft. core would yield 10 equal sub-samples. Cores in which the actual lengths measured less than 5 ft. were standardized by spreading the loss due to compression over their entire length. For example, a core taken to a depth of 5 ft. with an actual measured length of 4.7 ft. was sub-sampled at increments of 0.47 ft. (Table 1).

All core samples were analyzed by Robert J. Taylor of the Trace Element Research Laboratory, Department of Oceanography, Texas A&M University. Samples were received on December 24, 1990, in plastic bags, with each plastic bag packed inside a glass jar. Sediment

Table 1
Trace Element Results from East and West Foundry Coves and the upriver control sample, Core 9 (ppm).

	CORE 3				CORE 4				CORE 5				CORE 6				CORE 8				CORE 9 (Control)			
Interv.	*D(ft.)*	*Pb*	*Cu*	*Cd*	*D(ft.)*	*Pb*	*Cu*	*Cd*	*D(ft.)*	*Pb*	*Cu*	*Cd*	*D(ft.)*	*Pb*	*Cu*	*Cd*	*D(ft.)*	*Pb*	*Cu*	*Cd*	*D(ft.)*	*Pb*	*Cu*	*Cd*
1	0.24	120	–	–	0.21	179	111	1246	0.25	141	–	–	0.25	113	–	–	0.24	102	83	–	0.25	70	65	3
2	0.71	141	–	–	0.62	143	100	211					0.75	98	–	–	0.72	124	90	–	0.74	98	71	10
3	1.18	147	–	–	1.04	99	60	8					1.25	64	–	–	1.20	57	43	–	1.23	13	17	<0.5
4	1.65	64	–	–	1.45	83	50	<0.5					1.75	14	–	–	1.68	81	41	–	1.72	14	14	<0.5
5	2.12	33	–	–	1.87	36	31	<0.5					2.25	11	–	–	2.16	53	43	–	2.21	12	13	<0.5
6	2.59	15	–	–	2.28	11	14	<0.5					2.75	12	–	–	2.64	27	23	–	2.70	10	13	<0.5
7	3.06	14	–	–	2.70	7	13	<0.5					3.25	13	–	–	3.12	9	12	–	3.19	11	13	<0.5
8	3.53	11	–	–	3.11	5	12	<0.5					3.75	13	–	–	3.60	10	12	–	3.68	12	14	<0.5
9	4.00	12	–	–	3.53	6	12	<0.5					4.25	12	–	–	4.08	9	12	–	4.17	10	13	<0.5
10	4.47	13	–	–	3.94	7	13	<0.5					4.75	12	–	–	4.56	11	13	–	4.66	8	13	<0.5
11													5.20	12	–	–								

samples were homogenized, sub-sampled into plastic vials, and freeze-dried. Dry sediment was then ground and homogenized in a Spex ball mill. Aliquots of dry sediment (~1 g, weighed to 0.01g) were transferred to 180 ml, tall-form Pyrex beakers. *Aqua regia* (5ml; 3:1 HCl:HNO3) was added, the beakers were covered with watch glasses, and the samples were refluxed on a hot plate for thirty minutes. Sediment adhering to the walls was washed down with ~10 ml of distilled water, and the samples were refluxed for an additional forty-five minutes. The beakers were removed from the hot plate and allowed to cool, and the samples were diluted to volume (20 ml) with distilled water. Samples were analyzed for Pb, Cu, and Cd by flame atomic absorption spectrophotometry (FAAS) on a Perkin-Elmer 306 AA spectrometer, using an air-acetylene flame. Calibration standards were diluted from commercial standards (Ricca Chemical, 1000 ppm) and were matrix-matched to the acid composition of the samples. Background correction was accomplished using a deuterium arc lamp. Reference samples of USEPA municipal digested sludge showed excellent recovery of all three elements. Samples analyzed in duplicate showed that analytical precision was excellent at all concentrations. Procedural blanks processed as samples were below the detection limit of the technique.

Trace Element Time Markers as Proxies

The quantified analysis of trace element levels of lead and copper assumed that the presence and relative concentration of these elements within the sediments of East and West Foundry Cove derive from historic foundry smelting and manufacturing procedures. The team hypothesized that the initial accumulation of both lead and copper correlated in time with the beginning of foundry ordnance production when the foundry opened in 1817. It was also hypothesized that a subsequent peak in lead and copper-alloy concentrations could be correlated with the 1858–1867 period of maximal output of military production for the Civil War under the superintendence of Robert P. Parrott, inventor of the famed Parrott Gun. Finally, the cadmium concentrations would correspond to the era of nickel-cadmium battery production on the site after World War II.

Lead

Lead was used at the foundry in the manufacture of munitions, as a coating medium for weatherproofing guns, for elements of early versions of rifled shells, and for a number of lead-based commercial products before, during, and after the Civil War. The use of lead as a basic element of foundry production probably began prior to the Civil War with the onset of production in 1817, continued through the war years of 1861-1865, and persisted in non-military production at least through the first decade of the twentieth century.

The clear association with—and use by—the foundry of lead and lead-based products was established through the archival investigation as having begun during the initial years of the foundry's operation. The review of the primary archival sources in the National Archives identified a circular or General Order from the Board of Navy Commissioners that refers to the use of lead as early as November 13, 1818—the first year of the foundry's operation. The communication specified that as of that date, all federal cannon at U.S. Navy installations (presumably also including the foundries producing cannon) were to be painted with a lead-based lacquer to protect against the elements.[8] Other entries refer to lead both in the context of the production of ordnance and in reference to its being used as a preservative, but this document in particular establishes that lead was being used as early as 1818.

Based on the primary archival sources it appears that the most intensive use of lead and lead byproducts was in the production and testing of rifled shell designs, specifically for the manufacture of the "sabot" or expanding ring at the base of rifled shells. The body of the elongated rifled shells was formed of cast iron, however, its base was generally manufactured from softer lead alloys. Upon detonation of the shell in the gun, the sabot expanded due to the heat and pressure created by explosive firing. This force melted the sabot which expanded and filled the spiraled grooves of the rifled barrel of the cannon, thereby causing the shell to spin.

Later in the war effort, Parrott replaced his lead sabot with one of brass. Parrott's late Civil War-era rifled shells were distinguished by the use of a brass sabot for the expanding material at the base of the shell, which was adapted for high volume production by 1862. Prior to this date, and at least as early as 1858 if not several years before, Parrott was actively involved in experimenting with different kinds of rifled shells and expanding sabots of different alloys. Some shells were of his own design; others were produced by various manufacturers within the U.S. and in several instances by foreign producers.[9] It has also been implied that

Parrot was experimenting with British shell designs prior to 1862. The diversity of shells being manufactured and tested at West Point Foundry was significant because many of these designs used a lead sabot to impart spin to the shell. Thus, given the diversity of the then-ongoing research and development in shell design, it is highly probable that Parrot was experimenting with lead sabots for rifled shells both shortly before and during the Civil War period (*c.*1858 to 1867). Rifled shell production may have continued for at least a year (possibly through 1867) following the cessation of hostilities.

In addition to the archaeological recovery of shells at the foundry, investigations in the vicinity of the gun testing platform revealed the presence of lead seals from shipping boxes for friction primers and fuses used in the firing of guns. Although secondary to shells and lead-based coatings on guns as a source of lead recovered in the cores, the presence of lead friction primer and fuse box seals on the buried Civil War surface, in addition to other artifacts made of lead, illustrated the range of lead-based products in use at the Foundry site throughout the nineteenth century.

Based on these archaeological associations and archival references, three assumptions can be made regarding the use of trace elements as time markers. First, there should be a clear temporal association between the appearance of lead in cove sediments and the growth of the foundry as a center of weapon development after 1817.[10] Second, based on the archival evidence suggesting both the diversity and volume of ordnance being produced (7,000 shells per week),[11] it appears that the highest levels of lead use and dispersal into the environment probably occurred during the period immediately prior to and during the Civil War. Third, based on the fact that cannon and shell production apparently came to a near standstill at the end of the war, there would have been a significant decrease in lead use and dispersal into the environment at that time. This assumption is further supported by the fact that Parrott retired from the foundry in 1867, marking the beginning of an economic and production decline which lasted until its takeover by the Cornell works at the turn of the century.[12]

Despite the possibility that the output levels of lead products may have dropped substantially after Parrott's departure in 1867, relevant evidence suggests that lead was processed for a variety of products from the 1880s through the first decade of the twentieth century. The most specific evidence survives in the form of three dated Sanborn insurance maps which detailed the location, dimensions, and function of each standing structure at the foundry as of 1887, 1905, and 1912. The 1905 map clearly illustrates a long rectangular building flanking the northern west hillside at the foundry that was described as a "Sash Weights Foundry." Assuming that sash weights for double-hung casement windows were made of both iron and lead, the use of the word "foundry" in the building description on the map suggests that the metal was probably being melted and cast into cylindrical weights at this location. The time span of this activity is bracketed by the fact that the same location on the previous 1887 Sanborn map is referred to as a place for the storage of patterns, indicating that the lead sash weight production did not begin until after 1887. The end of this activity is indicated by the 1912 Sanborn map which labeled the same building as "Sash Weight Foundry (vacant)."

Finally, conversations with local informants yielded additional insight into the production of other lead-based products after the Civil War. One informant spoke of the use of lead compounds for the manufacture of alternator bushings. A local shop owner also mentioned having seen a catalogue of foundry products which included the production of lead and tin ceiling tiles. Although no fixed dates can be assigned, the fact that these references occurred in the context of oral historical recollections indicates that lead compounds and products were produced in considerable volume and diversity throughout the late-nineteenth and early-twentieth centuries.

Investigations of historical patterns of lead accumulation by others in the environment provide some regional and international vectors of contamination by trace elements in general and by lead in particular. Studies of dated historic period sediment cores from the Sacramento-San Joaquin Delta in California identified early lead contamination dating to *c.*1425 CE.[13] Long before European contact, the authors postulate that this early spike in lead levels in California derived from ore smelting in China. Drexler et al. also suggested that a second spike in lead levels took place around 1850 which they associated with California Gold rush. They identified a third benchmark as the period of leaded gasoline, in use from the 1920s through its 1980-1985 phase-out. The eventual removal of lead from fuel in 1988, as well as the effects of the

Clean Air Act of 1970 that removed airborne lead and other contaminants, resulted in a sharp drop in lead levels in several of the most recent uppermost core samples from the West Point Foundry.[14]

Closer to the study area, the measurement of lead levels from high resolution sampling of four shallow (50 cm) cores was undertaken at the Central Park Lake in Manhattan, New York. Plots of lead concentration through time showed a constant increase in lead levels from the late 1800s through to the 1960s and a drop off after the 1980s.[15] The authors attributed the twentieth-century increase in lead levels to the introduction of large-scale incineration of municipal solid waste (MSW), and Chillrud noted that "the similarities between the history of MSW incineration in NYC and the accumulation of trace metals in [Central Park] Lake sediments . . . are consistent with incineration being a major source of several metals in the NYC atmosphere."[16]

Finally, another study of sediment cores from the Pettaquamscutt River basin in Rhode Island showed a "clear maximum in anthropogenic lead isotopes in the mid-1800s."[17] The decline of lead contributions from ore smelting was accompanied by the rise of coal combustion, and at the turn of the twentieth century, "contributions from smelting of Pb ores had decreased to 5% and coal was responsible for 65% of the Pb input."[18]

These different studies illustrate the diversity of potential sources for lead contamination, both local and regional. The California data attributed early lead levels to smelting in Asia. The Rhode Island data attributed nineteenth-century upticks in lead to the smelting of ore and burning of coal. The West Point Foundry data, however, highlights the importance of localized industrial sources of lead pollution.

Copper

The second metal selected as a chronological indicator is copper. Prior to the Civil War, the foundry was engaged in the production of cannon and ordnance, as well as a wide range of non-government commercial products. One secondary reference clearly alludes to the production of brass products early in the foundry's history. In his brief account of the foundry, William Tyrrell stressed the fact that within three years of its initial production "the West Point Foundry was manufacturing iron and brass of all kinds."[19] While it is clear that the foundry was later engaged in the testing and rifling of brass cannon prior to the Civil War, the level of copper alloy production between the 1820s and 1858 cannot be established based on available sources.

Despite the paucity of early references, the role of copper and brass in the production activities at the West Point Foundry during the Civil War is well documented. While there is evidence for the experimental use of lead in Parrott's early prototypes of his rifled shells, as discussed above, by 1862 Parrott had shifted from using a wrought-iron sabot at the base of his shells to using a cast-brass sabot. As detailed elsewhere, Parrott's rifled cast-iron shells represented an adaptation of an earlier design by Dr. Reed, who invented the use of a wrought-iron ring, or sabot, bolted onto the base of the cast-iron shell.[20] While Parrott's earliest rifled shells produced between 1860 and 1862 copied Reed's use of wrought iron as a malleable expanding material, by 1862 Parrott shifted to, and received a patent for, the manufacture of cast-iron shells with a brass ring.[21] Although no figures exist for the amount of copper used during the war, the Union was reported to have produced 1.3 million shells.[22] Although no details are available on production levels at West Point Foundry, it is clear from surviving archival sources and the archaeological evidence that Parrott produced large numbers of fuses and friction timers. Both utilized brass as the primary element for their construction.

The continued use of copper after the Civil War is also documented on Sanborn insurance maps. The earliest of these detailed Sanborn insurance maps dates to 1887 and documents the presence of a brass foundry as a discrete production area in the post-Civil War layout of the complex. No detailed references exist to fill in the use of copper during the time gap between the earlier Civil War era ordnance production which peaked between 1858 and 1867 and the postwar 1887 map. Nevertheless, the combined archival and archaeological evidence clearly document that copper was used at the foundry from the first decade of its operation for both military and non-military products, that it was used in high volumes for shell and ordnance production during the Civil War, and that its use continued after the Civil War at least until 1887, if not later.

Cadmium

In this study, the initial appearances of lead and copper in the vertical core samples were demonstrated to be chronologically significant indicators for the onset of foundry operations during the first quarter of the nineteenth century. The appearance of cadmium, however, serves as a marker to date and calibrate the range of late twentieth-century sediment depths and rates of sediment accumulation within East Foundry Cove. The appearance of cadmium in the sediment records can be fixed in time with some certainty. The initial appearance of cadmium discharge into the general area of Cold Spring began in 1953 and continued until 1979. Between these dates, a nickel-cadmium battery factory discharged 179 metric tons of cadmium-laced toxic waste into the local environment.[23]

This twenty-seven-year period is also punctuated by two shifts in cadmium effluence—in 1965 and 1971. During the initial phase, 1953–1965, the Marathon Battery Company utilized the Cold Spring sewer system to discharge directly into the Hudson River in the vicinity of the Cold Spring pier. During this early period, the battery plant also used its bypass system "approximately 10% of the time" to discharge into a storm sewer and directly to East Foundry Cove. This fact is important because it documents that the initial appearance of cadmium in East Foundry Cove began as early as 1953 and continued on a periodic basis until 1965. By 1965 it was determined that the village of Cold Spring sewer and treatment plant could no longer treat the battery plant's volume of effluent. The plant, then owned by the Sonotone Corporation, responded by discharging cadmium-laden effluent directly into East Foundry Cove marsh. The final phase of cadmium deposition occurred after January 1971 when the company was prohibited from making further discharge into East Foundry Cove. In response, all effluents and cadmium discharge were again redirected into the village of Cold Spring storm sewer and into the Hudson River. This redirection of the cadmium output continued until March 1979 when all battery manufacturing operations and cadmium discharge were discontinued.[24]

Cadmium levels were identified and extracted from East Foundry Cove. Core 9, the upriver control sample, was used to establish background readings from the deepest sample fractions outside and upriver of the ambient limits of foundry impacts. Post-1953 cadmium concentrations recovered from Core 4 yielded high levels of 1246 ppm in the uppermost sample interval (at 0.24 ft. deep). The second sample interval (0.62 ft.) showed a decrease to 211 ppm and the third interval (at 1.04 ft. deep) a further decrease to 8 ppm. Below 1.04 ft., readings for cadmium measured less than 0.5 ppm. In other words, the "background" or prehistoric level for ambient cadmium was less than 0.5 ppm (Table 1). Core 9 also showed very low levels in the upper two intervals and practically undetectable background levels of 0.5 ppm below that depth.

The issue of residual or low-level concentrations of trace metal elements deposited beneath significant accumulations of Cadmium was highlighted within Core 4. In this core, it is suggested that the 211 ppm Cd reading at 0.62 ft. and probably the 8 ppm reading at 1.04 ft. appears to be the artifact or byproduct of human or biological mixing (figures 5-12). The lead author's experience with the archaeological excavation of cadmium deposits underscores the fact that deposits of cadmium are bright yellow and are sharply demarcated by color from underlying deposits.[25] That depositional scenario was encountered during the excavations at West Point Foundry. It suggests that the low concentration levels indicated by the 211 ppm and 8 ppm readings represent residual byproducts of mixing, either from natural or anthropogenic sources from the uppermost sample fraction, downward. Bioturbation, including the actions of worms and burrowing animals are more than adequate vectors of mixing to account for the presence of low levels of cadmium at levels 2 and 3 in the sampling sequence. The near-surface reading of 1246 ppm at 0.21 ft. suggests primary deposition after 1953 (Table 1).

Patterns Through Time

The primary assumption of this study is that the presence of trace elements of copper and lead appear to have derived from historic foundry smelting and manufacturing operations after 1817. Furthermore, the initial uptick, and subsequent increase in deposition of both metals correlated with the onset of foundry ordnance production. The depositional concentrations of copper and lead tripled initially, and then increased ten-fold in East Foundry Cove samples recovered higher in the cores. This increase in concentration presumably represents peak production levels for the period leading up to and including the Civil War (figures 5, 6, 7, and 8). Finally, we assume that the selection and study of both copper and lead were not fortuitous. Both metals have been shown to be associated with key products of ordnance production throughout the military phase of foundry operations from 1817 to 1867.

This study has highlighted six patterns of fluctuations in trace metal element concentrations through time: 1) Strong archival, statistical, and historical correlations through time confirm the presence of lead and

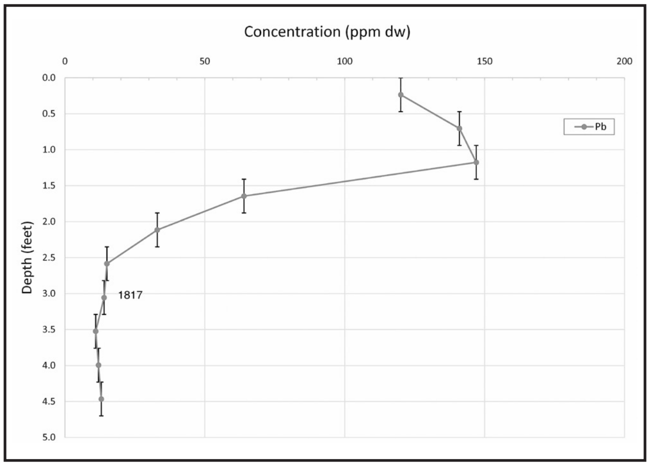

Figure 5. Trace element plot of lead (Pb) by depth for Core 3 in East Foundry Cove. Chart by R.J. Taylor.

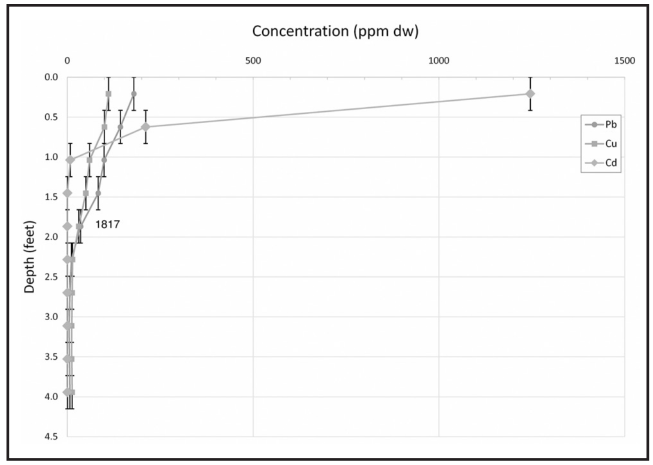

Figure 6. Trace element logarithmic plots of copper (Cu) and lead (Pb) relative to cadmium (Cd) by depth for Core 4 in East Foundry Cove. Chart by R.J. Taylor.

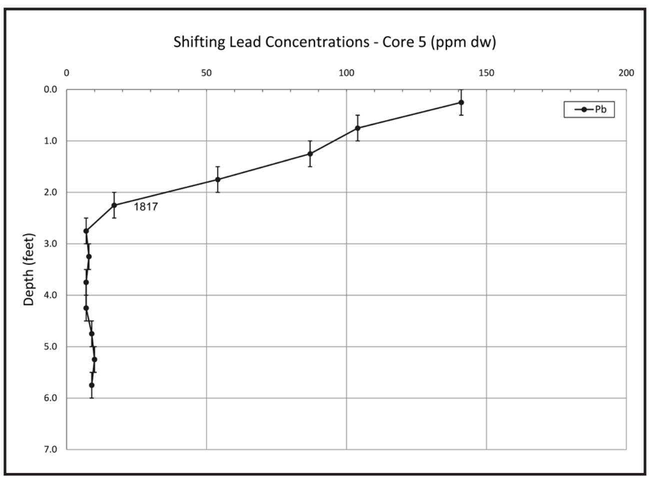

Figure 7. Trace element plot showing shifting concentrations of lead (Pb) in Core 5 in East Foundry Cove. Chart by R.J. Taylor.

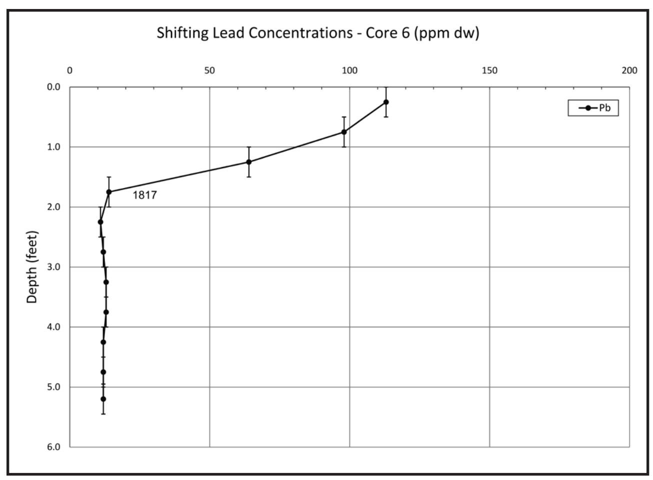

Figure 8. Trace element plot showing shifting concentrations of lead (Pb) for Core 6 in West Foundry Cove. Note uptick in lead levels between 1.25 and 1.75 ft. in depth. Chart by R.J. Taylor.

copper at the foundry. 2) Sufficient evidence from the cores exists to establish low baseline levels of lead and copper concentrations prior to the onset of foundry operations in 1817. 3) Initial upticks in lead and copper levels in the depositional environment correlate with the beginning of foundry production in 1817. 4) Evidence suggests that subsequent peaks in the concentrations of lead and copper from near surface samples correlate with the period of increased production during the Civil War (1858–1867). 5) The presence of significant decreases in concentrations of lead and copper in recent near surface deposits suggests a decrease in post-1971 ambient levels. And 6) interpretation of the sixth pattern is more problematic because the data display incrementally increasing concentrations of copper and lead throughout Cores 4, 5, and 6 with no drop-off in the near surface samples.

As pointed out by Robert Taylor, the historical association of lead and copper as time markers was matched by a strong statistical correlation between copper and lead (figure 9). Copper and lead showed a correlation coefficient (R^2) of 0.965 which suggests that they were deposited in the environment at about the same time.

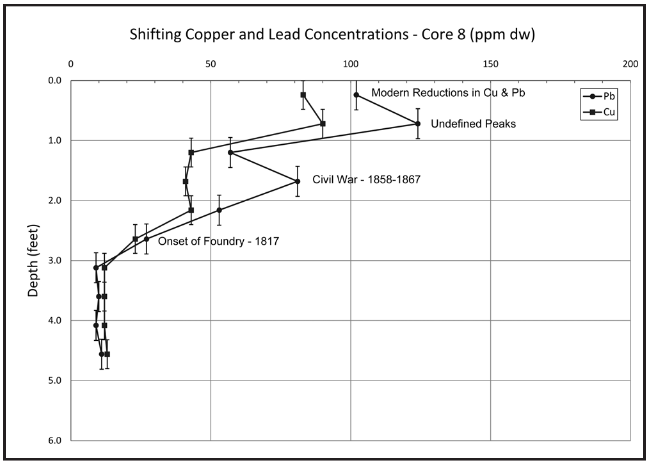

Figure 9. Trace element plots of lead (Pb) and copper (Cu) by depth for Core 8 in East Foundry Cove. Chart by R.J. Taylor.

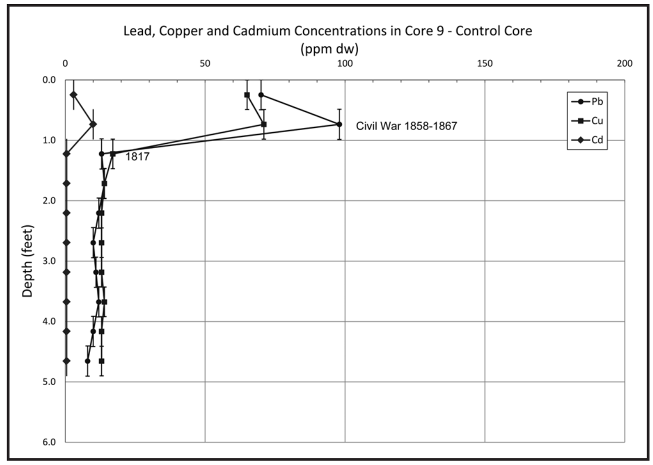

Figure 10. Trace element plots of Copper (Cu) and lead (Pb) relative to cadmium (Cd) in the upriver control Core 9 off Little Stony Point. Chart by R.J. Taylor.

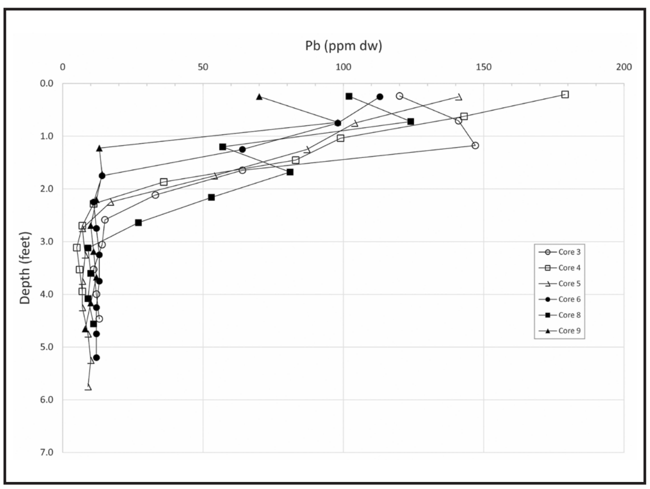

Figure 11. Plot of lead (Pb) values by depth for all six cores. Chart by R.J. Taylor.

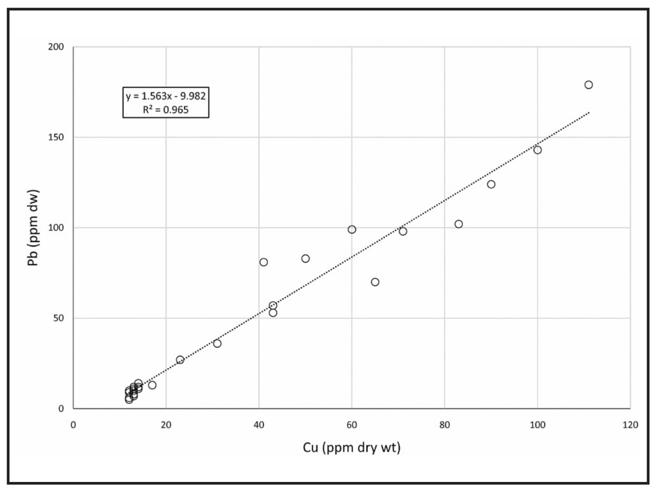

Figure 12. Plot showing strong correlation between copper (Cu) and lead (Pb) in Cores 4, 8, and 9, indicating that both copper and lead followed similar historical trends in East Foundry Cove and for the upriver control sample, Core 9. Chart by R.J. Taylor.

As Taylor underscored:

> There is a strong correlation between Pb and Cu. Enclosed is a scatter diagram including all points from the three cores in which both Pb and Cu were measured [figure 9]. It appears as if there is a similar source for the two elements, and anthropogenic input sure seems like the best bet. The degree of similarity in these profiles vs. depth suggests that the introduction of Cu and Pb commenced at about the same time, and that their relative increases have been similar.[26]

The six statistical plots of core data showed two contrasting long-term trends. Both patterns spanned from the initial uptick in trace metal elements around 1817 through the twentieth century (figures 6, 7, and 8). The first group of three cores (4, 5, and 6) displayed parallel lineal patterns of increasing lead and copper concentrations over time throughout their depositional history. However, as a group, the cores lacked a spike corresponding with archival documentation describing a surge in copper and lead output during the Civil War (figure 9)

The second group of cores (3, 8, and 9) were internally consistent, but showed opposing patterns from the first group. In addition to being statistically correlated through time, copper and lead followed a parallel "zig zag" or "ebb and flow" pattern in tandem with each other. All three cores document a significant decrease in lead and copper values in their near surface samples (figures 5, 9, and 10). In Core 9 (figure 10), the biggest decrease occurred in the two near-surface samples (0.0–1.0 ft.) in which lead dropped from 98 ppm to 70 ppm (down 29 percent). In Core 8 (figure 9) the two near-surface samples (0.0–1.0 ft) showed a drop in lead from 124 ppm to 102 ppm (down 18 percent). In Core 3 (figure 5) lead concentrations decreased incrementally from 147 ppm to 141 ppm to 120 ppm within the three near-surface samples (0.0–1.5 ft). This represents a 29.5 percent decrease in lead in the upper 1.5 ft. of the core.

The six cores establish the pre-Civil War levels of copper and lead in East and West Foundry Coves and in the upriver control sample (Core 9). The baseline readings documented ranges of concentrations over time with depth for each trace metal element. Figure 11 presents a statistical plot of lead levels in concentration versus depth for all cores. Below 2.5 ft., the lead values record a range of similar, low concentrations. Sample data from the deepest intervals in all cores, presumably pre-nineteenth-century historic and prehistoric levels, yielded background concentrations ranging from 5-14 ppm for lead (Table 1). In Core 8 at levels deeper than 2.64 ft., copper displays background, or prehistoric, levels of 12–13 ppm.

The onset of foundry operations in 1817-1818 was initially recorded in the stratigraphy of Core 4 at 2.28 ft. (Table 1) by an uptick in lead ranging from 5-7 ppm to 11 ppm (up 37 percent) (figure 6). Copper initially increased minimally to 14 ppm at 2.28 ft. It nearly tripled in value to 50 ppm at 1.87 ft. These two benchmarks demarcate the depth of the initial, early nineteenth-century output of industrial effluents in East and West Foundry Coves. In comparison, the upriver control sample (Core 9) displayed a significantly shallower increase in copper levels from 13 ppm to 17 ppm at 1.23 ft. (figure 10).

Table 2
Depth of the Initial Uptick in Trace Element Readings

Location	Core No.	Depth of Sediment (ft.)
East Foundry Cove	3	2.12
	4	2.28
	5	2.25
	8	2.64
West Foundry Cove	6	1.75
Control	9	1.23

In general, the combined sediment core samples showed increased levels of lead and copper at depths of between 2.12 and 2.64 ft. below the modern bottom in the East Foundry Cove cores (Cores 3, 4, 5, and 8). The recorded "uptick" depths (Table 2) for Cores 6 and 9 differed, coming from different areas of the Hudson River. Core 6 was from West Foundry Cove and was distinguished by different deposition rates and shallower deposits of trace elements than was the case for the East Foundry Cove core samples (figures 1 and 8). Control sample Core 9 also showed shallower precipitation depths and higher benchmarks for onset of trace element records (figures 1 and 10).

Both lead and copper elements showed significant increases in detectable levels at 1.68 ft. in Core 8 and at 1.87 ft. in Core 4. Both increases correlate with what appears to have been a massive increase in smelting operations during the Civil War years (Table I; figures 6 and 9). This increase is interpreted by the senior author to correlate with higher Civil War-era output at West Point Foundry and is expressed best by the Core 8 data. Lead in Core 8 surged to 81 ppm at 1.68 ft. from an earlier level of 53 ppm at 2.16 ft. deep. The sequence then dropped down to 27 ppm at 2.64 ft., and then down to background counts of 9–11 ppm below 3.12 ft. in depth. The track taken by the copper trace elements also broadly follows the historical outlines of the ebb and flow of brass production at West Point Foundry.

The plot of copper in Core 8 suggests an apparent stand-still in brass production. The three samples showed copper levels ranging from 41 to 43 ppm, occurring between 1.20 ft. and 2.16 ft. in depth, but without displaying any significant variation in concentration. However, the subsequent reading at 0.72 ft. deep, showed copper concentration increased to 90ppm. Copper then dropped to 83 ppm in the uppermost surface sample (0.24 ft. deep). Although speculative, it is intriguing to think that the stagnation the copper levels encountered at these middle-depth ranges (1.20–2.64 ft.) potentially correlates with the diminution of the use of copper and brass for ordnance during the Civil War years in favor of reinforced rifled iron cannon (figure 9).

One sample (Core 6) in West Foundry Cove, northwest of the inlet into East Foundry Cove, was tested only for lead (figures 1, 3, and 8). This "outside" sample displayed a different diachronic pattern compared with cores to the southeast taken inside East Foundry Cove. In Core 6 the initial presence of lead in the vertical plot occurs at a shallower depth in comparison with the plots in East Foundry Cove. The initial uptick in lead to 14 ppm (at 1.75 ft.), above its background range of 12-13 ppm in West Foundry Cove, indicates the depth of the buried historic surface or shoreline bottom. The Core 6 data suggest that the early nineteenth-century surface in West Foundry Cove lies beneath nearly 2 ft. of more recently deposited modern sediments (figure 8).

Taken together, these trends suggest that the local sediment accumulation increased significantly in East Foundry cove following the onset of operations in 1817 and that the increases in lead and copper levels closer to the submerged sediment surface corresponded with the increased production levels of the Civil War years. The data sets indicate three major proxies or trace element markers: the onset of foundry operations in 1817, the apex of maximal operations between 1858 and 1867 correlated with peaks in lead and copper concentrations, and the initial appearance of cadmium in 1953. These historical proxies furthermore suggest one case study for which trace elements, when linked to a specific industry, can help delimit the depth of historic sediments.

Notes

1. We are using 1858 for the onset of the Civil War era because that is when the U.S. Army and Navy began to ramp up military production of ordinance and rifled cannon. This was the period of the Crimean War, and the U.S. was actively involved in the Bosporus with Army and Navy ordnance officers collecting intelligence on cannon design, performance, survivability, and precision, as well as information on European weapons production and deployment. Armaments contracts between Parrott and the Naval and Army Ordnance Bureaus continued until 1867. Joel W. Grossman, "High Caliber Discovery," *Federal Archaeology* 7, no. 2 (1994): 38–43; Joel W. Grossman, "The Role of Espionage and Foreign Intelligence in the Development of Heavy Ordnance at the West Point Foundry, Cold Spring, New York," in *Look to the Earth: The Archaeology of the Civil War*, ed. C. Geier (Knoxville: Univ. of Tenn. Press, 1994), 215–255.
2. The following article is meant to be read in conjunction with the report and associated data tables from the Texas A&M Trace Element Research Laboratory: Robert J. Taylor, "End of Laboratory Report to Joel W. Grossman," in Joel W. Grossman, et al., "A Stage I Archaeological and Historical Sensitivity Evaluation of Foundry Cove and the Cold Spring Waterfront [GIS, Marine Geophysics and sub-bottom sedimentation & Trace element coring]," prepared for Malcolm Pernie Inc. under contract with the U.S. Environmental Protection Agency, New York, 1992, Appendix B, www.GeospatialArchaeology.com/RTaylor1991.pdf.
3. See the special issue of *IA* 35.1 and 2 (2009) devoted to the West Point Foundry for further information.
4. For full information on this research, see Joel W. Grossman, "The Archaeological Discovery and Excavation of R.P. Parrott's Civil War Era Gun Testing Facility at West Point Foundry," prepared for the USEPA, Region II under contract with Malcolm Pirnie, Inc., 1991; Grossman, "Stage I Archaeological" (see n. 2); Joel W. Grossman, "High Caliber Discovery" and "The Role of Espionage" (see n. 1); Joel W. Grossman, "From Raritan Landing to Albany's Riverfront: The Path Toward Total 3D Archaeological Site Recording," in *People, Places and Material Things: Historical Archaeology of Albany, New York,* ed. Charles Fisher, New York State Museum Bulletin 499 (Albany, NY: State Education Department, 2003), 167–186; Joel W. Grossman, "Inter-Regional Studies: Archaeology of Toxic and Hazardous Environments," in *Encyclopedia of Archaeology*, ed. D. Pearsall (Oxford: Elsevier/Academic Press, 2008), 3: 2134–2156.
5. For the terrestrial discoveries, see Grossman, *Archaeological Discovery*; Grossman, "Stage I Archaeological" (see n. 2) and "From Raritan Landing" (see n. 4); Harold Holzer, "Lincoln's Secret Arms Race," *Civil War Times* 34, no. 4 (1995): 32–39; and Tamara Stewart, "Excavating Hazardous Sites," *American Archaeology* 14, no. 1 (2010): 38–43. For the riverene discoveries, see Grossman, "Stage I Archaeological."
6. Grossman, "Stage I Archaeological," Appendix A (see n. 2).
7. Ibid.
8. *Journal of the Board of Navy Commissioners*, vol. 1, Record Group 45, National Archives and Records Administration, Washington, DC.
9. Grossman, "Archaeological Discovery," 186–189 (see n. 4); Grossman, "High Caliber Discovery" and "The Role of Espionage" (see n. 1); Jack W. Melton Jr., "Sabot and Stability System," http://www.civilwarartillery.com/sabotsystems.htm.
10. M. Wilson, *Thirty Years of Early History of Cold Spring and Vicinity, with Incidents. By One Who Has Been a Resident Since 1819* (Newburgh, NY: Schram Printing House, 1886 reprint).
11. William G. Tyrell, "Parrott's Famed Cannon Perfected and Produced at Cold Spring Foundry," *New York State and the Civil War* 1, no. 11 (1962): 38.
12. Katharine Cornell Gorka and Andrew H. Cornell, *Cornell Iron Works: The history of an enduring family business* (Mountaintop, PA: Cornell Iron Works, 2013).
13. Judith Z. Drexler, et al., "A millennial-scale record of Pb and Hg contamination in the peatlands of the Sacramento-SanJuaquin Delta of California," *Science of the Total Environment* 551–552 (2016): 746.
14. Ibid., 738, 746–749.

15. Ibid. and figure 5, p. 660.
16. Stephen N. Chillrud, et al. "Twentieth Century Atmospheric Metal Fluxes into Central Park Lake, New York City," *Environmental Science and Technology* 33, no. 5 (1999): 660–661.
17. Anna Lúcia Lima, et al., "High-resolution historical records from Pettaquamscutt River basin sediments: 2. Pb isotopes reveal a potential new stratigraphic marker," *Geochimica et Cosmochimica Acta* 69, no. 7 (2005): 1813–1824 at fig. 2, p. 659.
18. Ibid., 1819.
19. Tyrell, 4 (see n. 11).
20. Grossman, "Archaeological Discovery" (see n. 4).
21. Ibid. See also Robert P. Parrott. Projectile For Rifled Ordnance. US patent 33,099; and Robert P. Parrott. Projectile For Rifled Ordnance. US patent 33,100. Both filed Aug. 20, 1861.
22. Tyrell, 8 (see n. 11).
23. Jeffrey Levinton and Josepha Kurdziel, "Foundry Cove and Constitution Marsh: History and Ecology of a Polluted Site and Its Restoration," report and video prepared for NY Dept. of Environmental Conservation, the Hudson River Foundation, and Stony Brook Univ., 1989, http://life.bio.sunysb.edu/marinebio/foundryframe.html; Jeffrey S. Levinton, "Foundry Cove: Icon of the Interaction of Industry and Aquatic Life," in *Environmental History of the Hudson River: Human Uses that changed the Ecology, Ecology that Changed Human Uses*, ed. Robert Henshaw (Albany, NY: SUNY Press, 2011), 233–247.
24. P.L. Klerks, *Adaptation to Metals in Benthic Macrofauna*, PhD diss., State Univ. of New York, Stony Brook, 1987; A.B. Knudson, P.L. Klerks, and J.S. Levinton, "The fate of metal contaminated sediments in Foundry Cove," *Environmental Pollution* 45 (1987): 291–304; Joshua A. Mackie, Susan M. Natalia, Jeffrey S. Levinton, and Sergio A. Sañudo-Wuilhelmy, "Defining metal levels at Foundry Cove (Hudson River, NY): Response to localized dredging of contaminated sediments," *Environmental Pollution* 149, no. 2 (2007): 141–148; Levinton, "Foundry Cove" (see n. 23).
25. Grossman, "High Caliber Discovery" and "The Role of Espionage" (see n. 1); Grossman, "Inter-Regional Studies" (see n. 4).
26. Robert J. Taylor to Joel Grossman, personal communication, 1991; and Taylor (see n. 2).