Fields of Conflict

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Conflict Archaeology, Material Culture, and the Role of Validation Studies in Interpreting the Past

Douglas D. Scott[1], Joel Bohy[2], Charles Haecker[3], William Rose[4], and Patrick Severts[5]

1. Adjunct Research Faculty, Colorado Mesa University, Grand Junction, CO 81507, ddscott@coloradomesa.edu
2. Skinner Auctions, 63 Park Plaza, Boston, MA 02116, jbohy2skinnerinc.com
3. NPS retired, PO Box 209, Cerillos, NM 87010, cmarhaecker@gmail.com
4. Friends of Minute Man National Historical Park, Concord, MA 01742, br1775@comcast.net
5. Independent consultant, 5783 Hamilton Rd. Pine Mountain, GA 31822, Patrick.severts@gmail.com

INTRODUCTION

Experimental archaeology has emerged as a rigorous approach to the study of material reflections of human behavior. This is an increasingly refined field that lets archaeologists develop insights and methods for making behavioral interpretations of things in the archeological record. To study firearms, archaeologists need to design and carry out appropriate experiments and draw on technical methods developed by firearm examiners, engineers, and physicists. Recent battlefield archaeological investigations have given new impetuous to identifying the rifling characteristics of historic rifled firearms, the external ballistic capability of such firearms, and the combat efficiency of such arms. The goal of this study was to collect information on the ballistic capability of late eighteenth smoothbore firearms.

The live fire experiments were designed to capture information on flintlock firearm performance and capabilities that will benefit goal audiences in their understanding and interpretation of archaeologically recovered spherical lead balls. To achieve these objectives, we designed the experiments to collect data on:

1) the velocity, range, and ballistic performance of common spherical lead balls of the type used in the Colonial era.

2) factors that could cause variation in ball impact, and

3) how deformation of lead balls can be linked to velocity, impact range, and target media.

Components of the Live Fire Experiment

The live fire experiment used common types of French and Indian War and Revolutionary War flintlock firearms. Other components of the experiment included the firing range, consideration of the black gunpowder used as a propellant, standardization of the lead balls, the construction of authentic style cartridges, and the methods of data collection.

Firearms Used in the Experiment

Seven flintlock shoulder fired firearms were used in the live fire experiment. The seven are a reasonable representation of guns commonly used in the French and Indian Wars and the Revolutionary War. They are all custom-made replicas of actual Revolutionary War flintlock firearms. One Colonial fowler, a copy of the .580-caliber Thomas Earle Fowler represents the type of weapon used by Colonial militias and minute man companies. Two British Long Land Pattern Brown Bess guns, the 1742 pattern and 1756 pattern in .76-caliber, represent the standard British infantry firearm used in the French and Indian War as well as the American Revolution. Another common British gun of the era is the Artillery Carbine in .65-caliber, which also represents the British Officers Fusil and the British Sergeants Carbine. Two French patterns, 1728/41 and

1763/66 were also fired. The pattern 1728/41 has a slightly oval bore, as does the original from which it was copied. The bore in .70-.71-caliber. The French 1728/41 musket was also used in the French and Indian Wars as well as by Revolutionary War militia companies and militiamen. The pattern 1763/66 has a .68-caliber bore. The seventh gun was a replica 1740 Potsdam musket, .73-caliber, of the type often carried by Hessian units recruited by the British.

Firing Range

For this study a 100-yard range was constructed to contain or concentrate the fired projectiles in a safe and manageable way. At 100 yards a 7.5-foot high palisade wall was constructed from freshly cut oak and pine logs. Directly in front of the palisade wall a sand backstop 5.5-foot high by 10-foot wide was mechanically piled using fine clean sands. These media were chosen to replicate soil impacts and wood impacts of various types to add to the data of the study. In addition to the palisade and sand backstop a shooting bench was constructed to provide a stable base for consistent shooting. While demonstrating accuracy was not the goal of the live fire experiment, the bench and target provided a stable aiming point for all shots. The range was established with safety as the priority.

Figure 1. The firearms used in the live fire experiment. Top to bottom, British Artillery Carbine, British 1742 Long Land Pattern musket, British 1756 Long Land Pattern musket, French 1728/41 musket, French 1763/66 musket, Thomas Earle fowler, and a Potsdam 1740 musket.

The palisade wall was constructed to provide additional data on impacts of projectiles on selected wood species. The trees selected; live oak (Quercus virginiana), loblolly pine (Pinus taeda), and red maple (Acer rubrum) were all about four-inches in diameter. Each is a common species found along the east coast, which allowed for a reasonably accurate recreation of a Colonial block house palisade wall. Constructed with two 25-foot long 6-inch truss supports screwed in place with 10-inch screws, the log palings were placed between two living oaks that were 20-feet apart. These acted as addition supports for the palisade line. Each 4-inch post was placed in a 12-inch deep post hole and backfilled after wood post placed. After placement, baling wire was utilized as lashing to secure the post in place. After all posts were in place they were trimmed to the same length. It was not the intention for the palisade to act as a backstop but rather to add data on bullet impact and deformation. Because of the chance of projectiles passing though the gaps or wood post, a tarpaulin was placed on the backside of the palisade to track projectile trajectory.

The sand backstop in front of the palisade wall not only provided a backstop for projectiles but also offered soil impact data. For this, clean loose sands were chosen to minimize escapement or deflection. After each firing a metal detector sweep of the backstop was conducted to expedite the locating of the fired projectile and to keep the sand free of potential hazards. Just to the front of the sand backstop a target stand with a silhouette target provided a defined aiming point. The target frame was constructed of 4x4 inch treated pine lumber with a sheet of fiberboard as a target backing. A man-sized head and torso standard paper silhouette target was affixed to the fiberboard.

Figure 2. Charles Haecker and Corinne Rose standing on either side of the target frame. Note the sand backstop behind the target and the palisade wall behind the backstop. The stake in front of the target is at 94 yards from the shooting bench, with the palisade at 100 yards from the bench location.

In this study, we used Swiss FFg black gunpowder as the priming and propellant charge in all weapons. Only the charge weight was varied among the guns fired and for purposes of achieving lower velocities for shooting into tissue simulant.

The spherical balls used in the live fire experiment are commercially cast soft lead bullets. The experimental spherical ball weights show a minimum of 1.5 grain (0.1-gram) to a maximum of 4.6 grain (0.3-gram) weight variation in the 20% sample weighed. The measured ball diameter also showed very little variation, being about 0.001 to 0.003 inch among all the balls measured. They have far less variation in weight and diameter than any of the published historical ball diameters or archaeological specimens reported. Typically, balls were less than bore sized to allow ease of loading, especially after multiple rounds were fired which caused black powder fouling in the bore. The common term for this is windage.

Figure 3. Unfired cast lead balls used in the experimental firing. L to R, .315 buckshot, .282 buckshot, .520 ball, .580 ball, .626 ball, .663 ball, and .69 ball.

Cartridges and Cartridge Paper

Prior to the live fire experiments Corinne and William Rose rolled a series of cartridges in each of the calibers to be used following eighteenth century guides on cartridge construction. Proper weight laid paper in a trapezoid shape was rolled around a wood former. A ball or a ball and three buckshot were placed in one end, the top twisted closed and the former removed. The appropriate powder charge for the caliber was then poured into the other end of the cartridge, twisted closed and the excess laid paper folded over to form a tail. Linen twine was then wetted and tied below the ball or ball and buck to hold the bullet in place. Finally, a ball point pen was used to mark the completed cartridge with the type and ball diameter.

Figure 4. Laid cartridge paper cut to standard form and ready for rolling cartridges.

Figure 5. Corinne and William Rose rolling cartridges in preparation for the experimental firing.

Figure 6. Completed cartridges with notes on the laid paper body denoting ball size and intended firearm.

To determine what happens when large-caliber lead balls were used in combat or hunting we observed impacts of experimentally fired balls into ballistic gelatin, an accepted tissue simulant with end coverings to simulate clothing of the era, and into a sand backstop. We also used a wooden palisade made up of dry loblolly pine, green loblolly pine, live oak, and maple palings to obtain bullet impact information. Projectile deformation associated with varied ranges were catalogued. The results of these experiments will permit archaeologists to better interpret recovered projectiles. We employed a "clean range" and recovered each fired bullet immediately after it was fired (recovery was by metal detecting and was around 80% - a few got away).

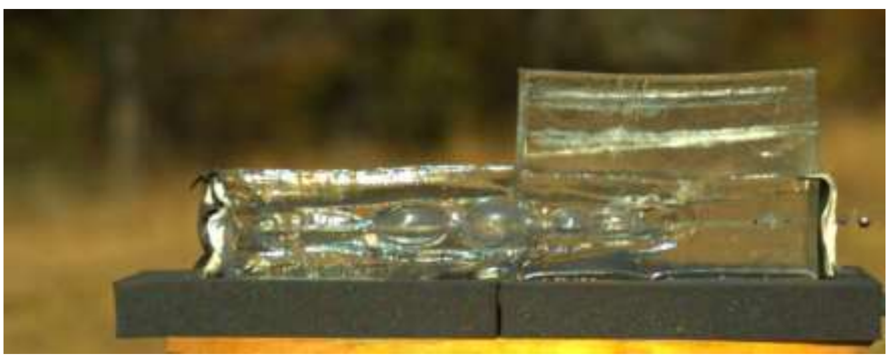

Figure 7. A .69 diameter ball fired from a British 1756 Long Land Pattern musket exiting 32 inches of gelatin. Note the initial wound cavity, bits of cloth in the wound cavity on the right and a larger piece of cloth exiting the block behind the ball.

Figure 8. A fabric impressed .69 diameter ball fired from the British 1756 Long Land Pattern musket with 75 grains of powder at 25 yards. The fabric impressions resulted from passing through the simulated uniform clothing.

The live fire experiment resulted in the firing of 74 spherical balls and 63 buckshot. The breakdown for each caliber fired by number of shots fired with recoveries noted, and total number of balls recovered per caliber.

12 - .520 balls were fired – 6 known shot sequence recoveries – 2 unknown attribution – total 8=75%

19 - .580 balls were fired – 9 known shot sequence recoveries – 1 unknown attribution – total 10=52%

23 - .626 balls were fired – 10 known shot sequence recoveries – 9 with unknown attributions – total 19=82%

20 - .69 balls were fired – 5 known shot sequence recoveries - 6 unknown attribution – total 11=55%

63 .282 and .315 buckshot were fired in 18 separate shots – 2 known shot sequence recoveries - 8 with unknown attribution- total 10=16%

Total ball and buck fired 137 - Total known recoveries 32=23% Total unknown recoveries 26=19%. Total recovered 58=42.3%

Figure 9. Metal detecting underway to recover a ball after a shot at the 94-yard range.

Ball Deformation and Determination of Original Caliber

The deformed pure or soft lead spherical ball is particularly noted for being difficult to determine its original nominal caliber in archaeological contexts due to impact. Several formulae have been advanced that use the weight of the deformed spherical ball to calculate its approximate original diameter. Arrowood and Berglund (1980) developed one formula that gave a 99.5% level of confidence when at ± three standard deviations. Daniel Sivilich devised a similar formula (1996; 2009) with only one standard degree of error which has proved quite reliable and replicable. Branstner (2006) attempted to improve the Sivilich formula by recalculating the density of lead and reformulating the Sivilich formula. Sivilich (2016:25-27) subsequently revised his formula and included new data on lead density to more accurately determine an original caliber, with only one degree of standard error.

We tested the revised Sivilich formula against the recovered fired balls from the live fire experiment. We knew the original ball diameter weight before firing and we weighed the fired balls as well as calculated the fired ball weight loss by caliber and average weight loss for each ball diameter. The weight of the recovered balls was used to test the 2016 Sivilich formula.

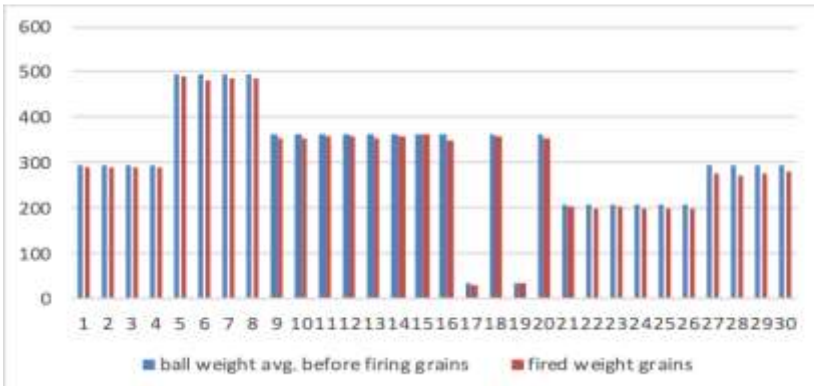

Figure 10. Ball weight before firing compared to weight loss with recovered balls. Note that items 1-4 are .580 balls, 5-8 are .69 balls, 9-16, 18, and 20 are .626 balls, 17 and 19 represent .282 buckshot balls, 21-26 are .520 balls, and 27-30 are .580 balls. The overall average weight loss of fired balls is 2.4%, although this generally increases as velocity increases ranging from 0.4 to 7.5%.

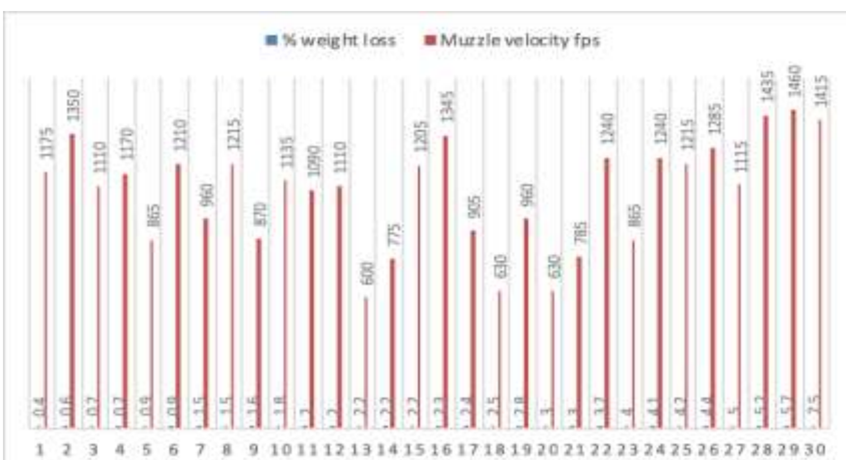

Figure 11. The percent of fired ball weight loss compared to muzzle velocity. The weight loss range is from 0.4 to 7.5%. To some degree the fired ball weight loss is partially dependent on the hardness of the media it struck when the ball's flight terminated.

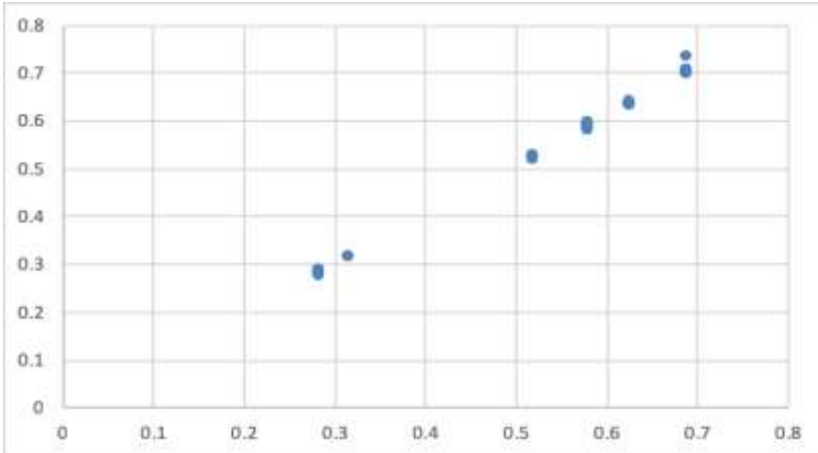

Figure 12. The measured ball diameter compared to the calculated ball diameter using the Sivilich Formula (2016). The differences are well within one standard deviation with an R value of .998.

The revised Sivilich Formula proved exceptionally reliable and accurate. A regression correlation was run comparing the two data sets. Sivilich's Formula tends to overestimate the ball diameter from a few thousandths of an inch to about one-hundredth of an inch. The R value was calculated to be .998 with less than one standard error of deviation. The R value is near ideal and proves the Sivilich Formula to be accurate and reliable for calculating the original ball diameter using weight or mass from recovered archaeological specimens.

Lead Bullet Deformation Index

Another valuable lesson derived from the live fire experiments is the validation of bullet deformation and a general correlation with velocity. Deformation seen in the lead balls fired in the various guns in the current experiment largely mimic the results reported by MacPherson (1994:126-130). Balls fired into tissue simulant, the loose sand backstop, dry soft woods, and wet pine, showed the least deformation. The smaller balls, .520-caliber and .580-caliber showed the least deformation and the larger balls, .69-caliber, showed the largest deformation at any given velocity, which is consistent with metal yielding functions correlated to the bullet's sectional density (MacPherson 1994:142-143).

Figure 13. Unfired buckshot and bullet examples as used in the live fire experiments. l to r – 0.28-inch buckshot, 0.31-inch buckshot, 0.520-inch ball, 0.580-inch ball, 0.626-inch ball, 0.662-inch ball, and 0.69-inch ball.

Figure 14. Unfired. 0.69-inch ball, 0.69 ball fired at 600 f/s that struck ground surface at 100 yards, 0.69 ball fired at 630 f/s that struck a wood table, foam, and ballistic gel at 25 yards and was collected laying on the foam at the back of 32 inches of ballistic gel, and a 0.69 ball fired at 630 f/s that was captured in the ballistic gel at 25 yards after passing through 28 inches of gel. Note fabric impression on second and fourth balls.

Figure 15. Unfired 0.626- inch ball, 0.626 ball fired at 775 f/s recovered from a soil and sand backstop at 100 yards and a 0.626 ball fired at 785 f/s and captured in ballistic gel at 25 yards after passing through 30 inches of gel. Note ramrod mark on second ball and fabric impressions on third ball.

Figure 16. Top row: Unfired 0.282-inch buckshot and fired 0.282-inch buckshot at 865 f/s. Second row: Unfired 0.626-inch ball and fired 0.626-inch ball at 865 f/s. Third row: Unfired 0.69-inch ball and fired 0.69-inch ball at 870 f/s. Note each recovered in the sand and soil backstop at 100 yards.

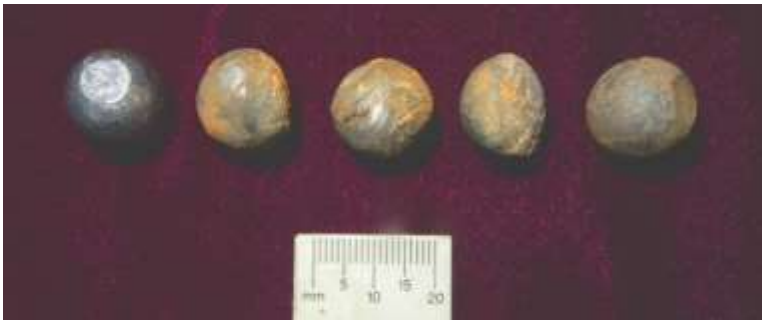

Figure 17. Unfired 0.626-inch ball, fired balls l to r fired at 905 f/s, 960 f/s, 960 f/s, and 1090 f/s. All balls recovered at 100 yards in sand and soil backstop. Note third ball from the left passed through a pine 4x4 target frame upright and the fourth ball from left also struck the edge of the pine target frame before embedding in the backstop.

Figure 18. Left column, unfired 0.626-inch ball, fired 0.626 balls at 1110 f/s and 1175 f/s, both found in sand and soil backstop. Second column, unfired 0.282 buckshot and fired 0.282 buckshot at 1110 f/s found in sand and soil backstop. Third column, unfired .580-inch ball and fired 0.580 ball at 1135 f/s found in sand and soil backstop. Fourth column, 0.580 ball fired at 1155 f/s, and Fifth column, 0.580 ball fired at 1170 f/s and found in soil and sand backstop. All balls recovered at 100 yards.

Figure 19. Top row, Unfired 0.626-inch ball, fired 0.626 ball at 1205 f/s and found in sand and soil backstop, fired 0.626 ball at 1215 f/s which nicked the target frame post and was found in the sand and soil backstop. Bottom row, Unfired 0.520-inch ball, fired 0.520 ball at 1215 f/s that hit oak palisade paling and ricocheted back into sand and soil backstop, fired 0.520 ball at 1250 f/s which hit a pine palisade paling and ricocheted back into sand and soil backstop, 0.520 ball at 1240 f/s that struck an oak palisade paling and fell to the ground below the fence, and 0.520 ball fired at 1285 f/s that went through a 4x4 pine target frame upright and was recovered in the sand and soil backstop. All balls found at 100 yards.

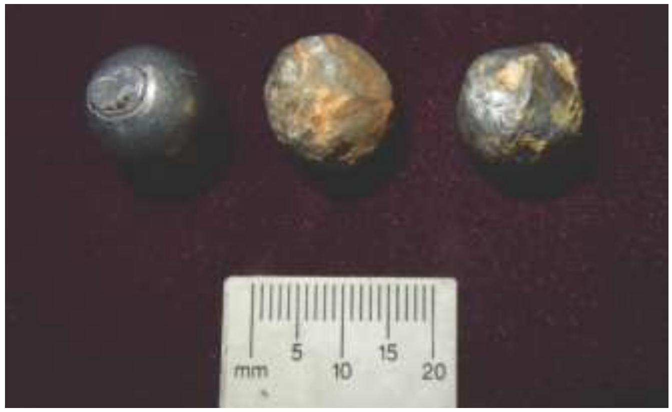

Figure 20. Unfired 0.520-inch ball and two fired 0.520 balls, center fired at 1345 f/s and hit pine target frame and right fired at 1350 f/s and hit pine target frame. Both found in sand and soil backstop at 100 yards. Note banding on last ball from being upset in firing from the musket.

Figure 21. Unfired 0.580-inch ball and fired balls, second – fired at 1415 f/s and struck oak palisade paling and found in sand and soil backstop below fence, third – fired at 1435 f/s and found in sand and soil backstop, fourth – fired at 1480 f/s and found in sand and soil backstop. All balls recovered at 100 yards.

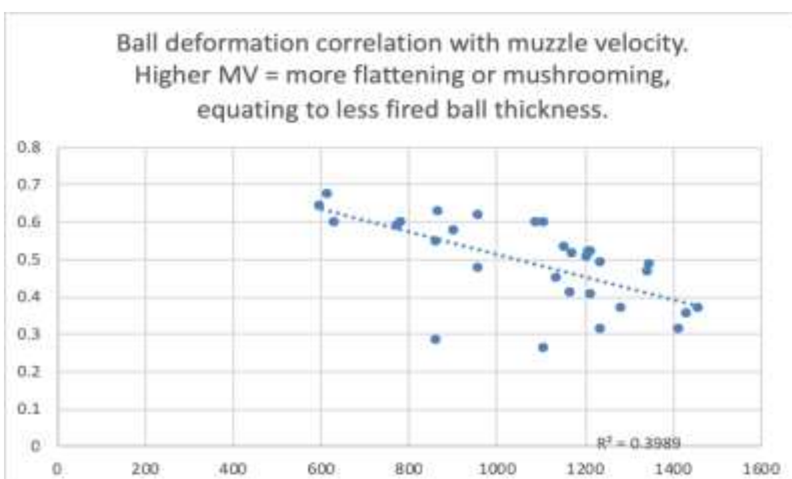

Figure 22. Muzzle velocity compared to thickness or flattening of fired balls. The fired ball thickness is in tenths of inches on the left and muzzle velocity is shown on the bottom as feet

per second. There is general agreement that balls flatten at higher velocities, but the linear regression trendline indicates the relationship is only about 40%. This further reinforces the fact that the nature of the media the ball strikes at the end of its flight as well as remaining velocity and kinetic energy are significant factors in deformation.

A Lead Bullet Deformation Index was developed that we believe many archaeologists will find useful. The LBDI we present requires additional testing and validation, but we believe that it has utility as an independent ordinal scale to assess impact deformation on conflict sites. The LBDI assessment can be of use in determining possible firing line distances on battlefields which will expand the archaeological interpretative potential of bullet datasets.

For more than 30 years an intuitive scale based on personal experience with shooting muzzle loading weapons has been used to assign value to impact deformed bullets. The scale is descriptive using Low, Medium, and High Velocity Impact terms as a means of defining impact deformation (e.g. Scott et al. 1989). The current live fire experiments where bullets fired at known velocities were recovered allows a new more quantitative-base index scale to be suggested. While this scale has recognized weaknesses, it does refine and replace the even less precise Low, Medium, and High Velocity Impact scale that is in common use (e.g. Scott et al. 1989).

Using the ball deformation data acquired during the live fire experiment we created an ordinal or nominal bullet deformation rating scale to equate to an approximate velocity range. We emphasize that the **Lead Bullet Deformation Index** scale we propose cannot be used as a one-to-one correlate to absolute velocity and the amount of deformation, rather it is intended to give the user an approximation of the relationship between velocity and deformation. Using the ordinal rating scale model results in a number that can be tested using ANOVA, Regression, or Chi-square tests.

We define the **Lead Bullet Deformation Index** to be:

Based on a mixed qualitative and quantitative set of observations of the fired bullet a rating scale number can be determined. Measurements should include the maximum diameter (diameter A), the thickness or amount of flattening (diameter B), and the minimum diameter that is not in the plane of deformation (diameter C). These data can be plotted and trendlines applied through scatter plots and various statistical regression procedures to observe and refine trends. Qualitative observations range from the amount of impact scarring present from minimal to extreme as to the degree of impact flattening (commonly called mushrooming) the bullet exhibits.

The ordinal scale is:

1. Likely velocity is less than 800 f/s based on little or no visible scarring or flattening. Diameter measurements are essentially consistent for the three measured points on the ball.

2. Likely velocity is between 800 and 1100 f/s based on slight to moderate visible impact scarring, possibly some imbedded residue or negative impressions (sand or rock inclusions or impressions), and some impact flattening that is less than half the diameter of the ball. Diameter measurements show flattening to less than one half the ball's original diameter or caliber.

3. Likely velocity is greater than 1100 f/s based on significant impact scarring and flattening of ball to becoming totally mushroomed. Measurements should reflect the thickness of the flattening relative to the measured diameter as extreme.

We suggest when there is a question of whether a ball falls in one ordinal range or another that it is appropriate to use an 0.5 number. An example is that a ball shows some minimal impact scarring and some moderate flattening would be assigned a 1. However, the measurements in the A and C axes are essentially the same, but the thickness or flattening measurement is notable and could be assigned a 2. We suggest assigning it a 1.5 rating. That data can be used to refine any statistical analysis. We do not endorse any finer intermediate resolution between the numbers as this will only be pure speculation and confuse any statistical analysis.

OTHER OBSERVATIONS

The microscopic examination of unfired and fired lead balls revealed changes in the microstructure of the balls' surface that are observable and clear. We have not yet examined the effect of patination on the observability of those surface changes in archaeological samples, but knowing they do and did exist on fresh lead bullets offers another line of investigation and interpretation to determine if a ball has been fired or not.

Figure 23. A 40x magnification of the bore band seen on balls fired in smooth bore guns. Note the micro striations run parallel to the line of the bore. This ball also has buckshot dimpling on the upper right surface.

Microscopic examination of fired balls can often reveal several other micro characteristics that may aid in identifying the media in which the ball imbedded or passed through. Traces or impressions of wood, soil (e.g., sand or gravel), fabric impressions or fabric adhering to the ball surface, or even bone embedded in the ball aid in the interpretation of the shooting incident under investigation.

Figure 24. A 75x magnification of the surface of an unfired lead ball. The lines are a result of the differential cooling at a micro scale of the lead ball when it was cast in a mold. Mold lines and these microscopic cooling lines are indicative of a cast ball. These microscopic cooling lines are largely obscured when a ball is fired.

Figure 25. A 60x magnification of a ball fired in the 1728/41 French musket at 870 f/s that hit the sand backstop. Some slight impact scarring is seen in the upper portion of the image and the fine sand particles impressed on the ball as it struck the backstop.

Figure 26. A 40x magnification of a ball fired from the British 1756 Long Land Pattern musket that passed through the simulated uniform cloth and gelatin blocks. The fabric impressed its weave on the ball providing a textile analyst data for interpretation. The raised circular area on the left of the ball is a sprue from casting the bullet in a mold.

CONCLUSIONS

Much of the work we undertook was designed to aid archaeologists in better understanding of the potential information that can be gained from bullet analysis from archaeological sites. We have focused on conflict sites specifically and the role bullet analysis has in yielding information that expands and enhances their interpretive value. An additional intent in conducting the live fire experiments is to provide well controlled and defined data to forensic firearm examiners so they may use the information to identity historic firearm types involved in law enforcement cases either by inclusion or exclusion.

Our data exhibits excellent correspondence with ballistic performance models, further validating those models and allowing us to compare our data findings with various data sets. A particularly valuable finding is that the approximate original caliber of fired and deformed lead balls can be accurately determined using the Sivilich Revised Formula. This validation of the Sivilich Formula is of real value to archaeological investigations.

Our live fire experiments were designed to determine Colonial era musket and fowler bullet performance. Accuracy was not a major component of the study; however, general shot accuracy was noted. The least accurate firearms were the British Long Land pattern muskets. Regardless of range the shots did hit the man-size torso target or were near misses, but had a very wide spread, often exceeding 30 inches. The 1740 Potsdam musket never struck the target at 100 yards. In part this may have been a function of the shooter's experience level but given the range of shooter experience in the eighteenth century this is not unrealistic. The British Artillery Carbine and the French pattern muskets achieved good target hits at all ranges at about 75% of the shots fired. The Thomas Earle Fowler had an exceptional record for accuracy. Regardless of shooter experience, and nearly every shooter fired the fowler at least once, over 85% of the shots hit the target at all ranges. This led several of the shooters to observe they would rather have been Minute Men or Colonial Militia than British or Hessian troops during the Revolutionary War. Firearms had an enormous impact on the European settlement and conquest of the western hemisphere. We see this study as the first step in creating a wide-ranging data base on effectiveness and external ballistic performance of firearms in general, and in this specific study of Colonial era muskets and fowlers specifically. We also see this study as the first step in creating a data base on bullet performance of firearms that were used in the New World after 1492.

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