The Identification of Fired Bullets Having Bearing Surfaces with General Contour Variations but Minimal Fine Striae

By: Eric R. Collins, Deputy Sheriff-Criminalist, Office of the Sheriff, Contra Costa County, Forensic Services Division, Criminalistics Laboratory, Martinez, California, USA

Keywords: Aberrant rifling, age hardening, axial engravings, bald bullets, bore scope, casting, criteria for identification, fouling, gross contour variations, lead alloys, lead bullets, leaded bore, pattern matching, QCMS, Quantitative Consecutively Matching Striae Theory, Russian Nagant M1895 revolver, slippage, subclass characteristics, work hardening, 7.62 mm Nagant, 7.62mmx38R, 32 S&W Long ammunition

ABSTRACT

The author received a 7.62mm caliber Russian Nagant M1895 revolver for function testing and comparison to a series of questioned bullets that had been submitted to the laboratory in a homicide case. The questioned bullets had very poor quality rifling impressions that were devoid of nearly all fine striae. The bore of the submitted revolver contained an extremely large amount of lead fouling and produced markings on test-fired bullets having the same general appearance as the questioned bullets. Despite the minimal amount of fine striae on the questioned and test-fired bullets, the author was able to identify the questioned bullets as having been fired in the revolver based on the overall agreement that existed between the contour variations and axial engravings on the compared bullets and silicone casts from the revolver's bore.

Background

In 2009, the author received a firearms identification case relating to a homicide in which the victim had reportedly been shot six times. The evidence submitted to the laboratory consisted of the following items: four fired lead round nose bullets recovered from the victim at autopsy; one fired lead bullet from the victim's car; a Russian Nagant M1895, 7.62mm caliber, double-action revolver recovered from the suspect's car; and two items from the dresser drawer of the suspect's residence: one fired 32 S&W Long cartridge case and one unfired 32 S&W Long cartridge with a lead round nose bullet.

For those not familiar with the Nagant M1895 revolver, it has a few notable features. The Nagant revolver is a Belgian-designed sidearm that was adopted by the Russian military forces in 1895 (hence the model's name) as well as numerous other countries. This revolver was manufactured predominately in Belgium and Russia in both single and double-action (most common) variants. Additional variants included a model chambered in 22 Long Rifle, a shortened model, and a target model with adjustable sights. Its mechanical design is unique among revolvers in that the cylinder moves forward when the hammer is cocked in order to close the gap between the cylinder and breech end of the barrel, helping to create a seal with the forcing cone of the barrel. The original 7.62x38mmR cartridge designed for use in this revolver also has an unusual design, with a tapered mouth and a bullet that is seated entirely inside the case, so as not to impede rotation of the cylinder. In use, this cartridge design permits the mouth of the cartridge to be inserted into the breech of the barrel when the cylinder moves forward, reinforcing the gas seal created by the cylinder mechanism. This dual seal helps to minimize the escape of gases through the cylinder gap when the cartridge is fired, increasing the pressure behind the bullet and resulting in significantly greater muzzle velocities over conventional revolver designs. The power and effectiveness of the original 7.62mm Nagant cartridge is reportedly similar to that of the 32 S&W Long, which is often substituted for the relatively uncommon 7.62mm ammunition (32 S&W and 32 H&R Magnum cartridges will also work, but headspacing and/or overpressure problems associated with these cartridges when used in the Nagant revolver make them less desirable choices). Reported muzzle velocities for this firearm, when used with the prescribed 7.62mm Nagant ammunition (other cartridges will not attain the gas seal), are over 1000 feet per second. The Nagant revolver was deemed obsolete in Russia by 1930, but production did not cease entirely until around 1950. Total production runs for the Russian manufactured Nagant revolvers are estimated at over 2.5 million [1, 2, 3, 4, 5].

The Nagant revolver has a 7-chamber cylinder and an approximately 4 ½-inch barrel with four conventionally-rifled lands and grooves having a right hand twist. Loading and unloading of the cylinder is accomplished through a

Date Received: October 10, 2011
Peer Review Completed: November 14, 2011

loading gate on the right side of the frame, and a built-in hand ejector rod is used to remove the fired cartridge cases one at a time. The hammer of the Nagant revolver has an integral firing pin that is exceptionally long and pointed, a design that is necessary in order for the tip of the firing pin to contact the cartridge's primer after the cylinder has moved forward. While these revolvers are popular among collectors, they are still relatively plentiful and available for sale in the U.S. through various merchants for around $100.

The M1895 Nagant revolver received as evidence in this case is shown in **Figure 1**. According to its manufacturer markings, this particular revolver was made at the Tula arsenal (Russia) in 1940 [4].

Figure 1: The Questioned Russian 7.62mm Nagant Revolver.

The four lead bullets recovered during the autopsy of the victim in this case all had the same design, with round noses and slightly concave bases. They ranged in quality from nearly pristine to grossly deformed, having anywhere from less than two to all four land and groove impressions intact for comparison. The bullets weighed approximately 90-97 grains (~5.8-6.3 grams) and had diameters very close to 0.30 inches (7.62 mm). Based on these class characteristics, the bullets were determined to likely be 98-grain, 32 S&W Long bullets. It should be noted that at least two commercial manufacturers, Italy's Fiocchi and the Serbian company Prvi Partizan, have in recent years produced 7.62mm Nagant ammunition, but these cartridges are loaded with 98-grain full metal jacketed bullets [1, 5]. While the lead bullet recovered from the victim's car had the most deformation, its class characteristics were similar to the rest of the submitted bullets. The land and groove impressions on these bullets were barely recognizable as such; the shoulders of the impressions were very poorly defined and only a few toolmarks that could be considered striations were discernable. The rifling marks on the bullets amounted to little more than a series of gross contours, giving the bullets an overall "bald" appearance (**Figure 2**). At first glance, the chances of successfully identifying these bullets to a particular firearm seemed poor.

Examination of the questioned revolver using a bore scope revealed exceptionally heavy lead fouling in the bore. These deposits greatly obscured the working surfaces of the original rifling (**Figures 3 & 4**). The revolver was test fired using three rounds of laboratory-supplied Winchester-Western 32 S&W Long ammunition and the single unfired 32 S&W Long cartridge (CBC brand) that was found in the suspect's bedroom. The barrel was not cleaned prior to test firing. The gun functioned as designed. All of the test-fired bullets had a similar "bald" appearance to the questioned bullets. At this point in the examination, the question was: Would it be

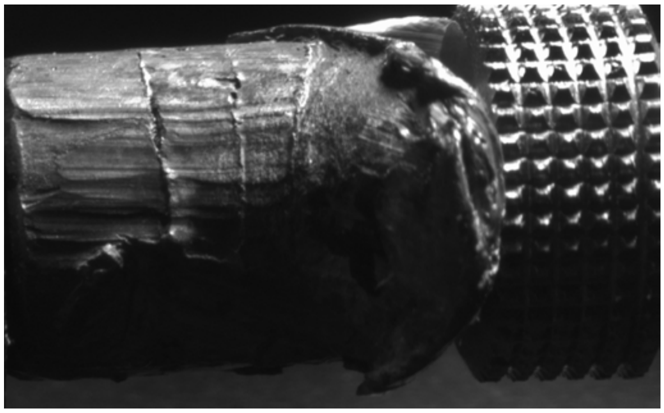

Figure 2: Land impression of one of the questioned bullets (nose at right), which is representative of the quality of rifling impressions observed on all of the questioned bullets.

possible to identify the questioned bullets as having been fired from the suspected gun given the poor quality of the markings on the questioned and test-fired bullets, or was a conclusion that the questioned bullets were "unsuitable for comparison" justified?

Historical Perspective: Biasotti's "Bald" Bullet Case

After starting work on this case, the author was informed of a similar case from 1981 where several "bald" bullets were successfully identified to the gun that fired them by Criminalist Al Biasotti of the California Department of Justice's (DOJ) Sacramento laboratory. Mr. Biasotti died in 1997; hence, this information was gathered through personal communication between the author and Criminalist John Murdock, who was familiar with the case due to the fact that he and Biasotti had team taught courses in firearms identification in which it was frequently featured as an example. In this case, Biasotti examined firearms evidence submitted from a homicide that

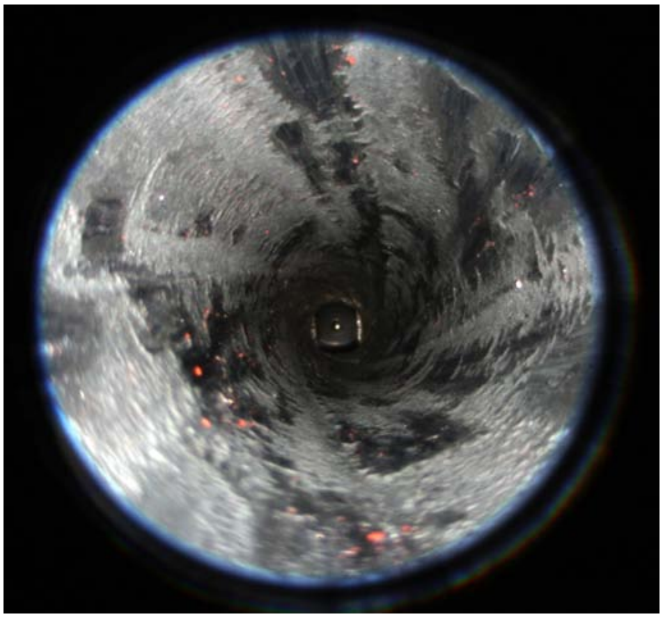

Figure 3: Photograph taken through bore scope of heavy lead deposits inside barrel of questioned Nagant revolver, as viewed from muzzle end with direct lighting.

Figure 4: Additional photograph of bore, taken from a position closer to breech end with incident lighting to show surface texture of lead buildup.

had occurred in a county within the San Francisco Bay Area. The evidence consisted of five evidence bullets, designated A through E; a 38 Special caliber Amadeo Rossi model 68, 5-shot revolver; and twelve test-fired bullets prepared by a local county sheriff's crime lab and a California DOJ regional crime lab. Due to the poor quality of the evidence bullets, comprehensive documentation of the evidence and microscopic comparisons was essential. Biasotti fired eleven additional test bullets and based his conclusions on the agreement of the surface contours and axial engravings* of the rifling marks around the circumference of each bullet. On one of his note pages, Biasotti drew a diagram of each bullet as a cylindrical projection, basically mapping in two dimensions the damaged areas and those areas suitable for comparison (**Figure 5**). He also organized his notes by preparing a chart summarizing the data associated with all 23 test firings (**Figure 6**). In order to prepare for the presentation of the identifications in court, he prepared a display on a piece of illustration board (13" x 16 ½") containing 18 photographs of his comparison of the evidence bullets to the test-fired bullets and the intercomparison of the test-fired bullets (**Figure 7**). This is an extreme example of the need for many photographs when the detail present for identification is marginal and is distributed over large areas of toolmarked surfaces. While the photographs featured on the board shown in **Figure 7** depict the sets of bullet comparisons in overall views at low-power magnification (~5X), it should be noted that Biasotti also took a series of photographs showing the specific areas of agreement of the axial engravings and contours between the questioned and test bullets in juxtaposition at the dividing line of the field of view. These additional photographs were taken at higher magnifications (up to 75X).

---

*In this context and throughout this article, the term "axial engravings" (or "axial striae", "axial markings") is used to refer to any linear toolmarks that are approximately aligned with the longitudinal axis of a fired bullet, as differentiated from those striae that run parallel to the shoulders of the land and groove impressions. The reader should note that this is a more generalized usage of the term "axial engraving" than what currently appears as the definition in the AFTE Glossary (5th edition): *"Reproducible striations on a bullet which occur during firing and before engagement with the rifling. These are caused by the misalignment of the bullet with the axis of the bore. Also called FORCING CONE MARKS and OUT-OF-TIME MARKS."*

The author suggests that there are several possible causes of axial engravings other than misalignment, including, but not limited to the following: marks left by the mouth of a cartridge case as the bullet is propelled out of the case during firing; marks left by irregularities or burrs along the forward edge of a chamber in a revolver cylinder that contact the bullet during firing but before engagement with the rifling; and inconsistent rotation of the bullet as it moves down the bore. This latter example, where the bullet travels through the bore of the barrel without significant rotation due to a lack of engagement with the rifling caused by an accumulation of foreign material (fouling), is, in the author's opinion, the likely cause of the axial engravings observed on the bullets featured in this article.

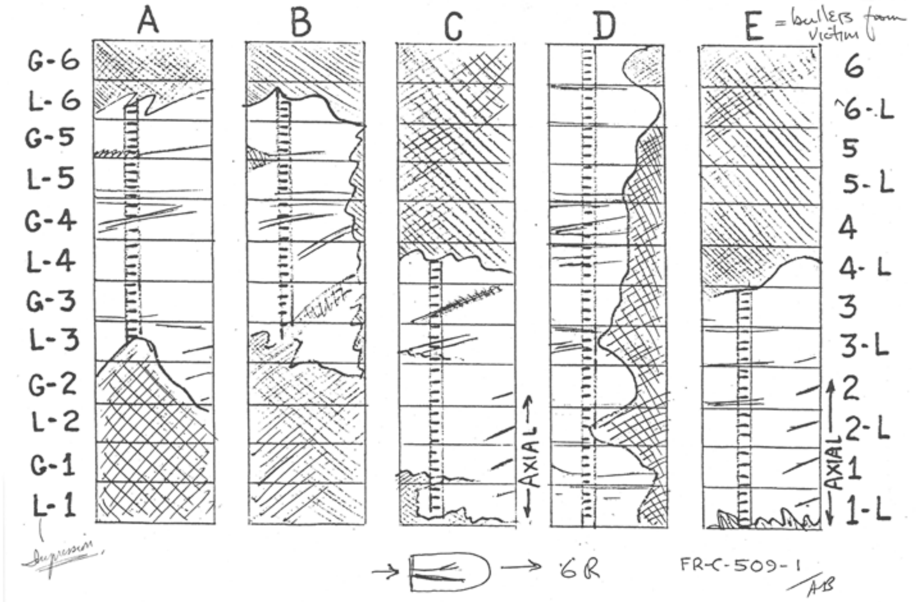

Figure 5: Page from Biasotti's notes, showing mapping of the land and groove impressions of each of the evidence bullets. (Courtesy of John E. Murdock)

TESTS FROM: PR 38 SPL AMR MODEL 68 SR# D–397706

TEST#	TYPE AMMO.	AMMO. SOURCE	CHAMBER# USED FOR TESTS	BARREL PREPARATION	DATE OF TESTS	TESTS MADE BY:
T (1–2)	38 SPL. + P S&W 158 GR SWC	ITEM 4 (WITH GUN)	?	DRY PATCH	11 / 13	ALAMEDA S.O. CRIME LAB
T (1–3)	SAME	ITEM 5 (WITH GUN)	1, 2, 3.	NONE	11 / 16	DOJ / FRESNO LAB
T (4)	38 SPL. FED. 158 GR WC	DOJ / FR LAB	4	SOLVENT, DRY PATCH	11 / 16	SAME
T (5–7)	38 SPL. R.P. 158 GR W.C.	SAME	5, 1, 2	SAME	11 / 16	SAME
T (8–12)	38 SPL + P S&W 158 GR SWC	ITEM 6 (PURCHASED BY VISALIA P.D; SAME AS WITH GUN; ITEM 4 & 5)	3, 4, 5, 1, 2	SAME	11 / 18	SAME
T (13–17)	SAME	SAME	1, 2, 3, 4, 5	SOLVENT, BRASS BRUSH, DRY PATCH	11 / 19	DOJ / SACRAMENTO LAB (A.A. BIASOTTI)
T (18–20)	SAME	SAME	1	SAME	11 / 19	SAME
T (21–23)	SAME	SAME	1	SAME	11 / 23	SAME (DRY COTTON RECOVERY)
FINAL CLEANING	N/A	N/A	N/A	SAME	11/23	SAME

Figure 6: Chart from Biasotti's notes, summarizing the data associated with all of his test-firings. (Courtesy of J.E.M.)

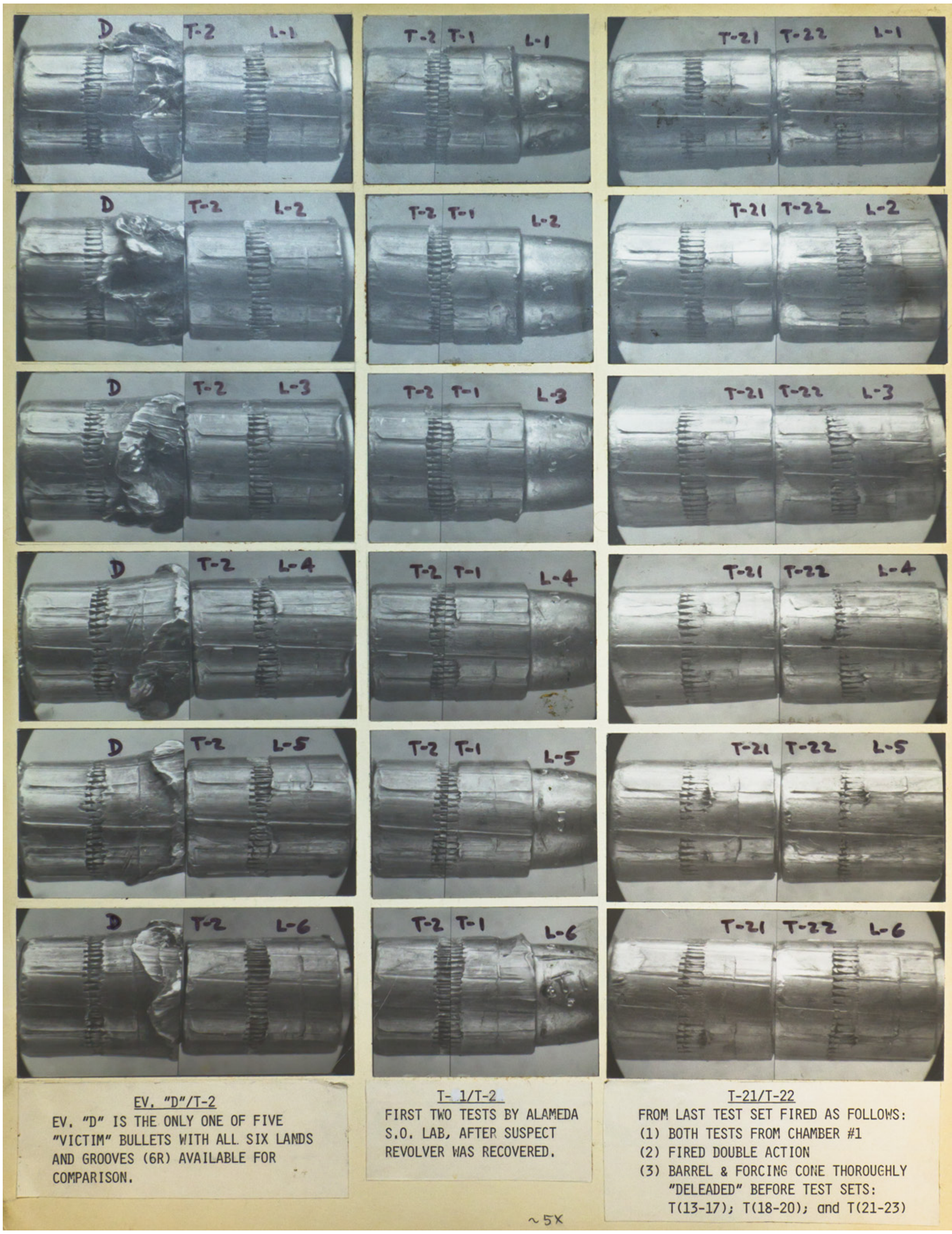

Figure 7: Biasotti's "Bald Bullet Board", used to summarize the microscopic comparisons he conducted. Note descriptions at bottom of each column of photographs. (Courtesy of J.E.M.)

With Biasotti's precedent in mind, and given the variation observed in the contours of the questioned bullets in the case at hand, the author decided that identification of the bullets was possible. The theory of toolmark identification is based on the principle that the working surfaces of most tools leave unique markings on items with softer surfaces depending on the processes used to finish the tool's surface and any subsequent use, abuse, or wear the tool may undergo. In firearms identification, or more specifically, bullet identification, the working surface usually being examined is the rifling of the gun barrel. In this case, a significant portion of the working surface under consideration was formed by the buildup of lead deposits lining the bore that had apparently accumulated over the course of many repeated firings using unjacketed lead ammunition, forming a type of *aberrant* rifling. These deposits were not uniform and obscured most of the original bearing surfaces of the lands and grooves. The irregular appearance of the lead buildup, with areas of pitting and unevenness, led the author to hypothesize that the surface may leave a unique signature on bullets fired through this barrel. However, because these deposits were lead, it was unknown just how quickly any such characteristics that may be transferred to fired bullets by the lead buildup might change with successive firings. Even if it is assumed, for a moment, that the questioned bullets were indeed fired from this gun and were also the *last* bullets fired from this gun, might the coating of lead in the bore be eroded or otherwise changed by test firing such that the test-fired bullets would bear no resemblance to the questioned bullets, even though they were all fired from the same gun?

Evaluation for Subclass Characteristics

Due to the minimal amount of striated detail present on the questioned and test bullets, the entire circumference (land *and* groove impressions) of each of the bullets had to be examined in order to determine if there were enough areas of agreement on which to base a conclusion of identity. Based on the appearance of the fouled bore surfaces, as shown in **Figures 3 and 4**, and the apparently random nature of the lead deposition, the presence of subclass characteristics within the bore would not seem to be of concern; however, it was not known how much, if any, of the original tooled rifling surfaces remained exposed (or thinly concealed), and if those surfaces contained any subclass characteristics that could be imparted to the fired bullets. Since the entire undamaged bearing surfaces of each bullet were expected to be used for identification purposes, and the questioned gun was available for examination, the author felt the potential for subclass influences should be evaluated and ruled out before a conclusion of identity could be made. The most efficient and direct way to do this is through the examination of bore casts to see if there are any striae that continue unchanged over the entire length of the bore; the theory being that if striae are continuous in the barrel under study, they could also exist in that configuration in other rifled barrels produced in sequence.

After test firing, the bore of the 7.62mm Nagant revolver was cast using brown Forensic Sil (AccuTrans® AB). The revolver was placed in a vise in a vertical position; a piece of thin cardstock was then placed between the barrel and the cylinder through the cylinder gap and the hammer was cocked, making it easy to plug the breech end of the barrel for casting by using the revolver's gas-sealing design. After curing, the cast was removed and examined. There was some concern that the silicone-based casting material might preferentially adhere to some of the lead buildup and remove it from the bore when the cast was extracted, altering the tool working surface. However, it was noted that when the cast was removed from the barrel, only minute amounts of the lead fouling adhered to the cast (**Figure 8**). The barrel cast recorded nearly all of the fine, irregular details possessed by the leaded bore.

The four land and groove impressions on the cast (eight total impressions) were successively numbered at both ends of the cast. A section of the muzzle end and a section of the breech end of each land and groove impression was then juxtaposed and compared, looking for any markings that appeared unchanged in the same relative position, orientation, and/

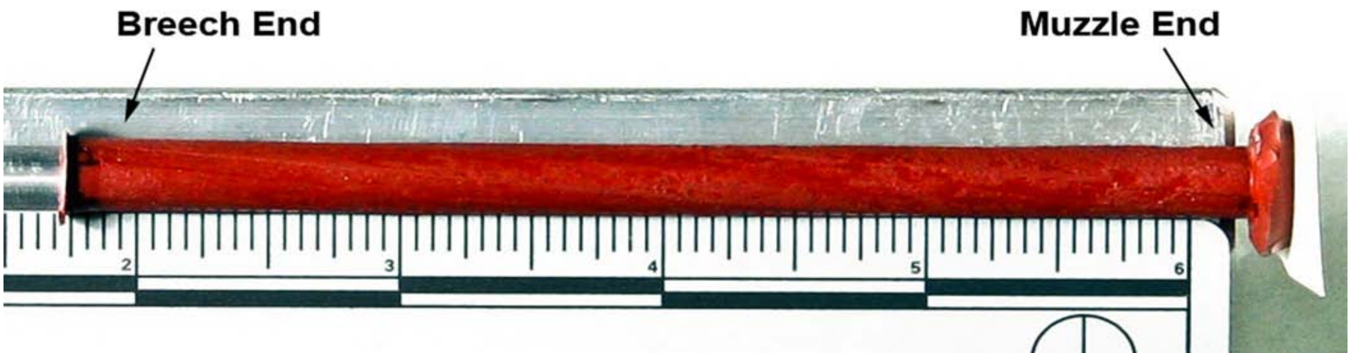

Figure 8: Forensic Sil bore cast from questioned revolver. Areas having irregular, dull appearance correspond to areas of lead fouling.

or contour from breech to muzzle, the hallmark of subclass characteristics. While examining the bore cast, the author found very few discrete striae or apparent manufacturing marks. Impressions of irregular patches of fouling deposits and possible corrosion were present along the land and groove impressions around the entire circumference of the bore. The pattern of deposits appeared random and non-repeating. Discernible toolmarks, in the form of linear, parallel contours, within the land and groove impressions were not continuous from the breech end to the muzzle end. Therefore, no subclass influences were evident in the bore of the revolver. See **Figure 9** for the breech-to-muzzle comparisons of the bore cast.

Due to the unusual nature of the altered bearing surface of this rifling, another phenomenon that had to be considered before trying to establish the identity of the questioned bullets was *bullet slippage*. Not to be confused with the type of slippage (or skidding) that occurs to a bullet immediately after firing as it continues forward on a straight course before it begins to rotate as it is engaged by the rifling, the term "slippage" as it is used here refers to a situation where a fired bullet is not gripped tightly enough by the rifling (due to a buildup of foreign material such as lead), as it moves down the bore, to prevent it from slipping during its rotation, resulting in the possibility of one or more land impressions (or sets of contours) marking the bullet in more than one location around its circumference. For instance, two successive apparent land impressions on a bullet subjected to this kind of slippage during firing could, in theory, have been created by a single land in the bore. This condition may be very difficult to replicate in test fires. In the case under discussion, a microscopic examination of the questioned and test-fired bullets showed that the discernible toolmarks that were present on the bullets continued along the same direction in successive land and groove impressions without an appreciable change in direction or orientation. This indicated that no discernible slippage had occurred to the bullets during firing and therefore the bore could be treated as one continuous working surface for purposes of identification.

Microscopic Comparisons and Criteria for Identification

The test-fired bullets from the 7.62 Nagant revolver were intercompared with one another and then compared to the bore cast from the 7.62mm Nagant revolver using a Leica FS C comparison microscope. The five questioned bullets were subsequently compared to the test-fired bullets and the bore cast in the same manner. The test-fired bullets showed good reproducibility of the gross contours produced by the leaded bore of the revolver, allowing the phase orientation of all of the test-fired bullets to be easily determined. Several of the contours present on the test fires also corresponded in appearance, location, and orientation to visible features on the cast of the bore. Examples of the agreement observed in the test-to-test and cast-to-test comparisons are shown in **Figures 10 through 13**.

This case prompted a discussion between the author and some of his laboratory colleagues, all of whom, including the author, routinely apply the Quantitative Consecutive Matching Striae (QCMS) criteria for identification of striated toolmarks in their firearms identification casework. One of these colleagues was Criminalist Murdock, who was instrumental in developing the criteria. At first, it was thought that this numerical criteria could be applied the same as it would be for a typical striated toolmark comparison, except instead of tabulating consecutive striae, one would count consecutive contours to see if the prescribed threshold for identification would be met. Upon further reflection, however, it was decided that since the QCMS standards were developed specifically for striated toolmarks, applying the same criteria to successive contour variations, for which no studies have been performed, was too great of a leap to make. The application of QCMS in this instance would not be appropriate unless enough fine striated markings existed, in addition to the gross contours, to meet the threshold for identification (which they did not). In addition, the typical surface contours encountered on the bullets in this case, which appeared very consistent from one bullet to the next, exhibited slightly greater variation in form and position than that allowed for striae being tabulated under the guidelines of QCMS, which mandates that no differences can exist in width, position, or depth (if discernable) in order for a particular set of striations to count as part of a run of consecutive striae. The greater variation observed in contoured marks such as those examined in this case is to be expected, due to the amorphous and irregular surface that marked the bullets, in contrast to a more uniform working surface that may produce discrete striations and wear in more predictable ways.

However, based on the microscopic bullet-to-bullet and bullet-to-bore (cast) comparisons, as well as the previously described evaluation of the bore's working surfaces, the author determined that a sufficient basis for identification existed in the overall pattern of longitudinal contours and axial striae that were present in the land and groove impressions of the fired bullets. The condition of the revolver's bore as received by the laboratory and the direct correspondence of surface features in the bore to features on the test-fired bullets indicated that the pattern of contours observed on the test-fired bullets were unique to this gun barrel. The questioned bullets were therefore identified to the test-fired bullets on the basis of the totality of the agreement observed using conventional pattern matching as it is customarily defined [6].

Just as it was in Biasotti's case, thorough photodocumentation of the microscopic agreement observed between the compared

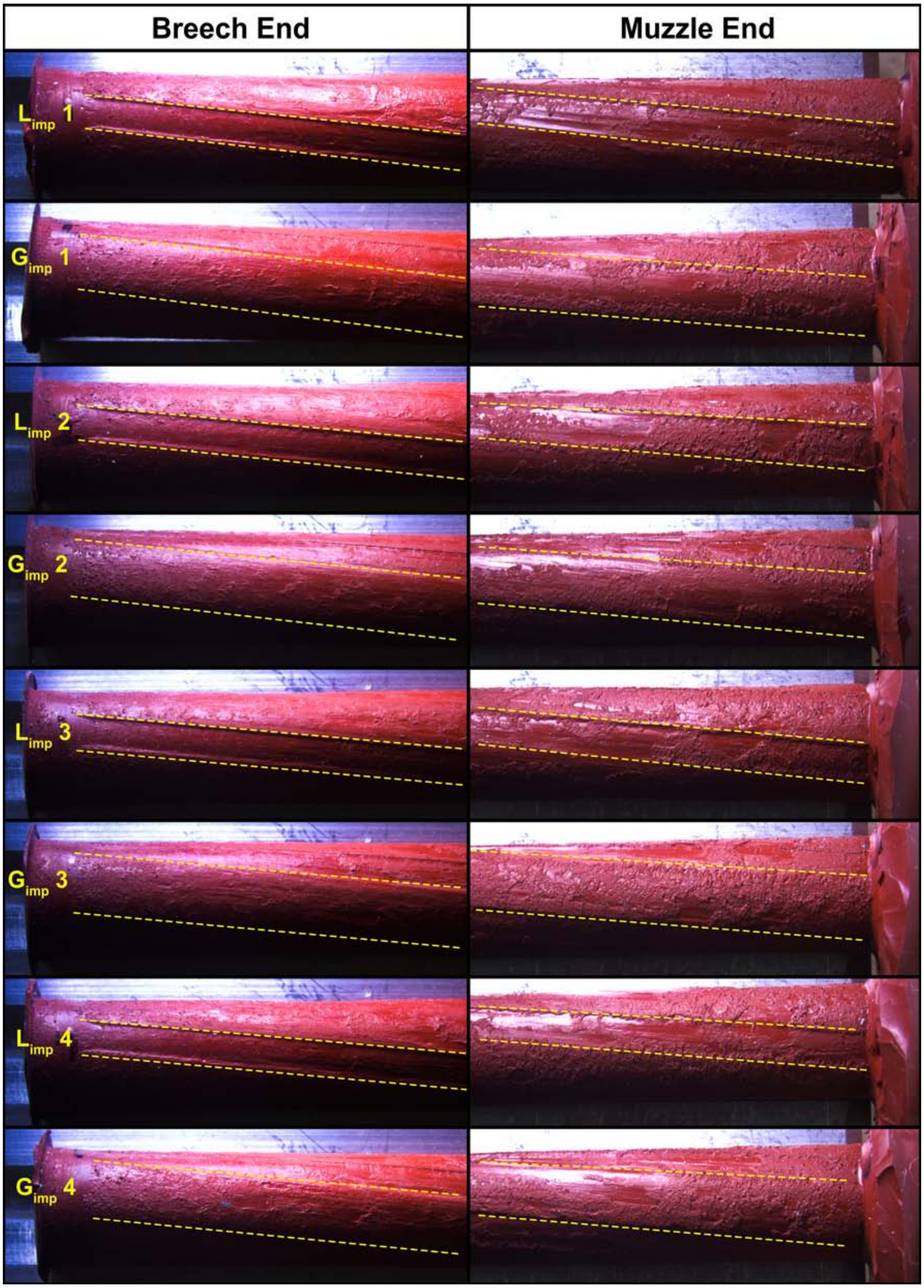

Figure 9: Comparison of breech and muzzle ends of bore cast, showing differences in microscopic characteristics (no subclass carryover). Yellow lines indicate shoulders of designated impression. Magnification: 4X.

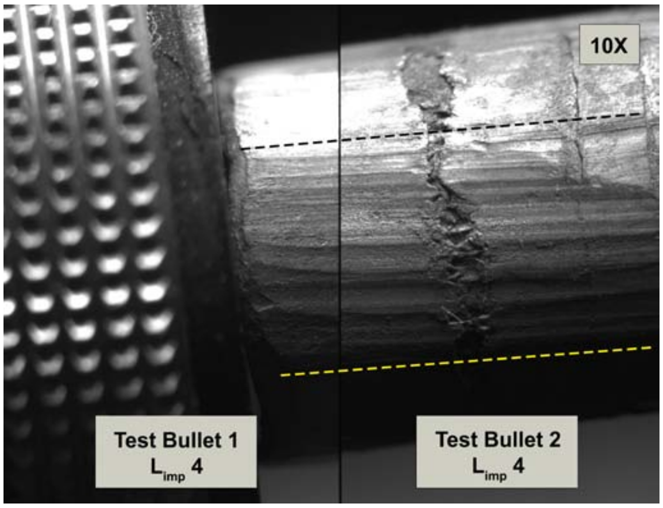

Figure 10: Comparison of land impression #4 on test-fired bullet 1 (T-1, left) vs. test-fired bullet 2 (T-2, right). Dashed lines indicate approximate boundaries of impression (different colors are for visibility purposes only).

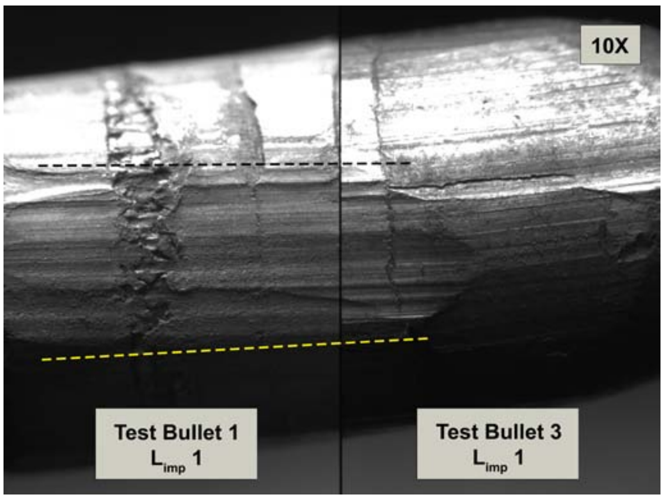

Figure 11: Comparison of land impression #1 on T-1 (left) vs. T-3 (right).

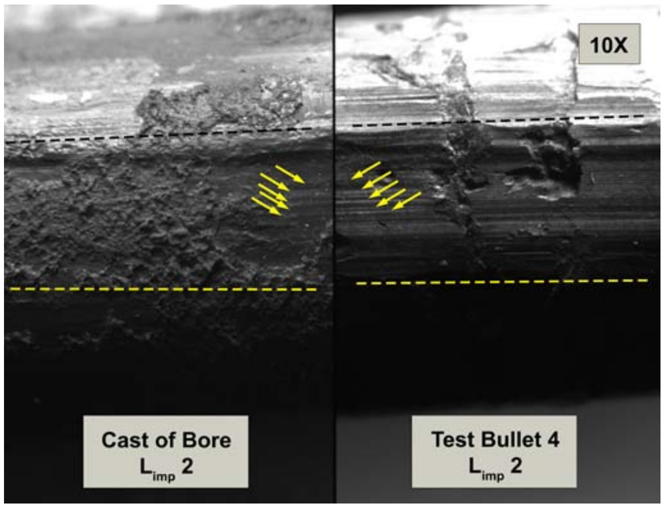

Figure 12: Comparison of land impression #2 on bore cast from questioned revolver (left) vs. land impression #2 on T-4 (right). Arrows indicate peaks of corresponding contours.

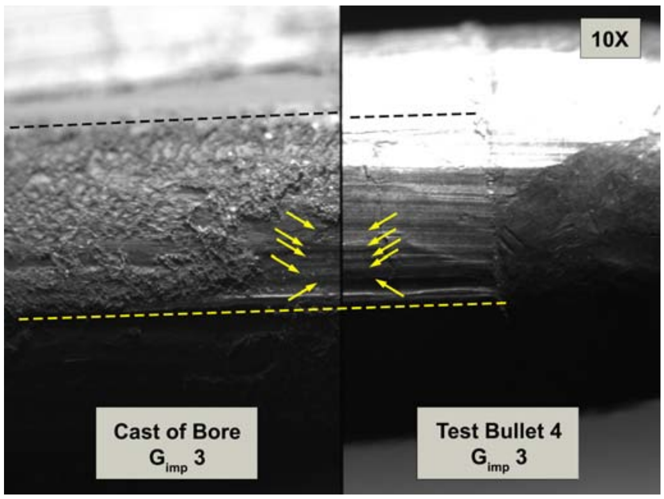

Figure 13: Comparison of groove impression #3 on bore cast from questioned revolver (left) vs. groove impression #3 on T-4 (right).

bullets was very important due to the unusual nature, wide distribution, and relatively low quantity of the individual characteristics that provided the basis for this identification. A series of photographs taken for one of the questioned bullet comparisons is shown here as **Figures 14 through 21**. For the sake of brevity, additional orientation photographs (taken at lower power magnification) of the areas depicted in this series of photographs are not shown. Representative photographs of the intercomparison of two of the questioned bullets, which exhibited exceptionally good agreement, are shown in **Figures 22 through 25**.

Incidentally, the fired cartridge case that was submitted in this case was also identified as having been fired in the 7.62mm Nagant revolver on the basis of microscopic agreement found in the breechface and firing pin impressions.

Conclusion

The case discussed in this article serves to illustrate several salient points regarding the examination of poorly marked bullets fired from fouled bores. Before any definitive

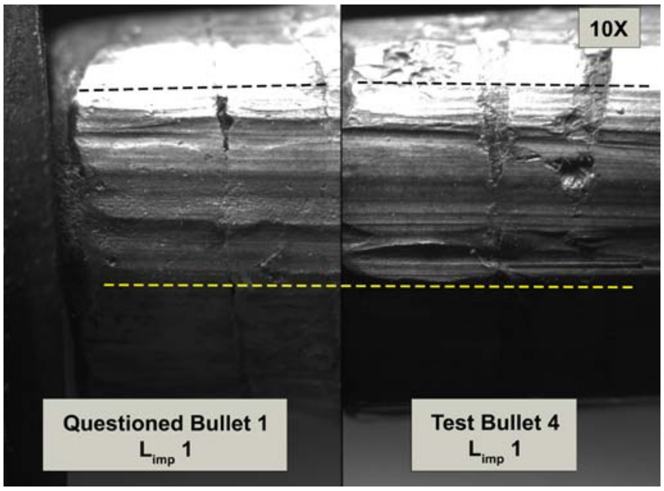

Figure 14: Comparison of land impression #1 on questioned bullet 1 (Q-1, left) vs. test-fired bullet 4 (T-4, right).

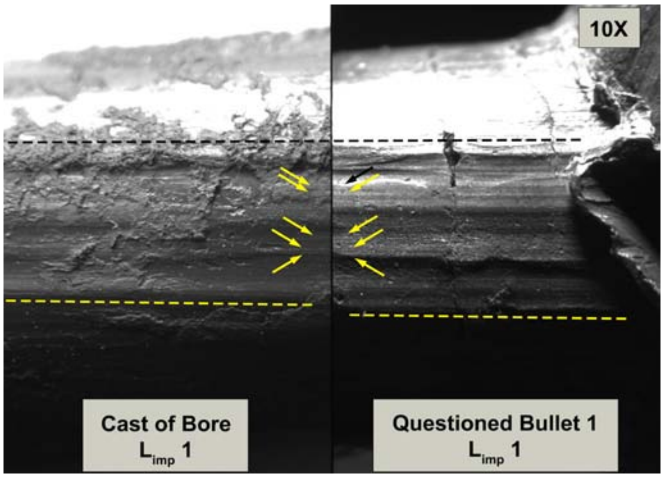

Figure 15: Comparison of land impression #1 on bore cast from questioned revolver (left) vs. corresponding impression on Q-1 (right). Different colored arrows are for visibility purposes only.

conclusions are made regarding the identity of the questioned bullets such as the ones discussed here, the working surface of the suspected tool (bore) should be evaluated for potential subclass influences, if possible. Unlike the comparison of two bullets having individual, firearm-produced, fine striae in conventionally rifled land impressions with well-defined shoulders, where the examiner would be justified in identifying the bullets as having been fired from the same gun without having the actual gun to examine (provided there was sufficient agreement of the type of toolmarks not seen in subclass carryover), examination of the suspected working surface becomes more important when the remaining characteristics from the original tooled working surface are as subtle and sparse as they were on the bullets in this case.

An examination with a bore scope followed by casting with a suitable material such as Forensic Sil or Mikrosil™ is a good way to directly assess the condition of the bore and amount of fouling present. Close examination and comparison of the breech and muzzle ends of the cast with one another will indicate to the examiner if there is possible subclass carryover in the form of continuous striae or other characteristics that remain unchanged for the entire length of the bore or repeat at regular intervals. Since the bullets discussed in this article had some remnants of toolmarks from the original working surface (bore), including areas within the grooves, that were relied upon along with the contour variations for identification, the author felt an evaluation of potential subclass influences was appropriate before issuing a final determination. However, it should also be noted that given a similar situation in which an examiner feels there is sufficient agreement in contour variation alone for identification (regardless of whether or

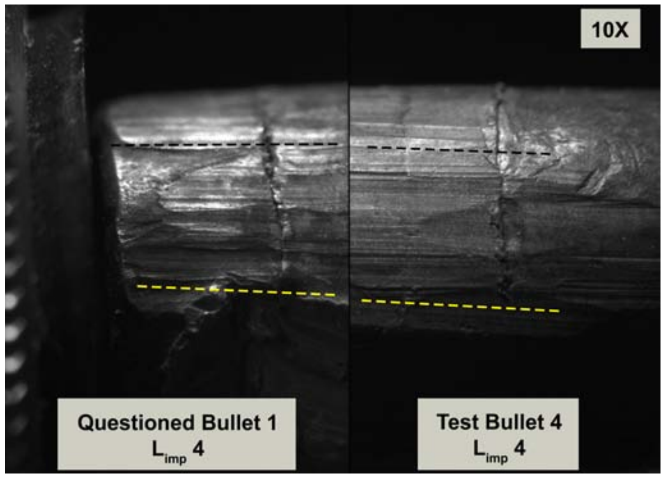

Figure 16: Comparison of land impression #4 on bullet Q-1 (left) vs. T-4 (right).

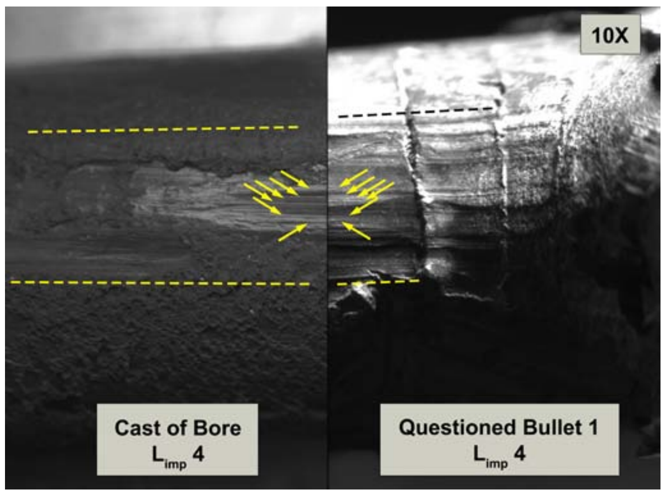

Figure 17: Comparison of land impression #4 on bore cast (left) vs. Q-1 (right).

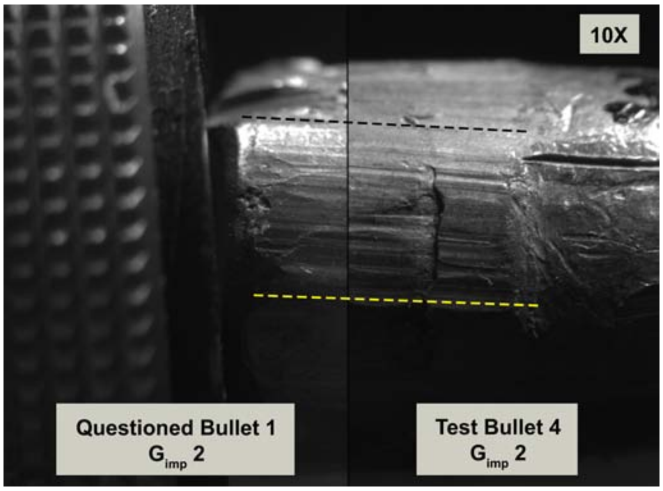

Figure 18: Comparison of groove impression #2 on bullet Q-1 (left) vs. T-4 (right).

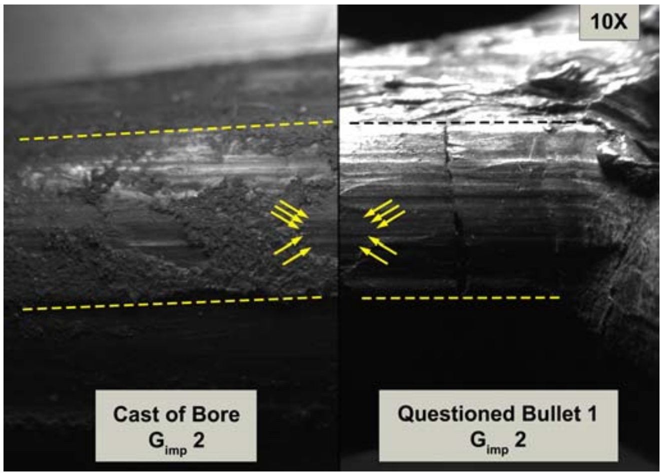

Figure 19: Comparison of groove impression #2 on bore cast (left) vs. Q-1 (right).

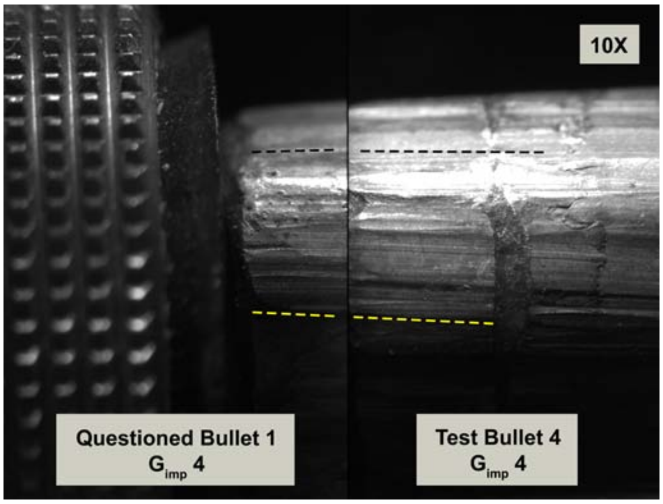

Figure 20: Comparison of groove impression #4 on bullet Q-1 (left) vs. T-4 (right).

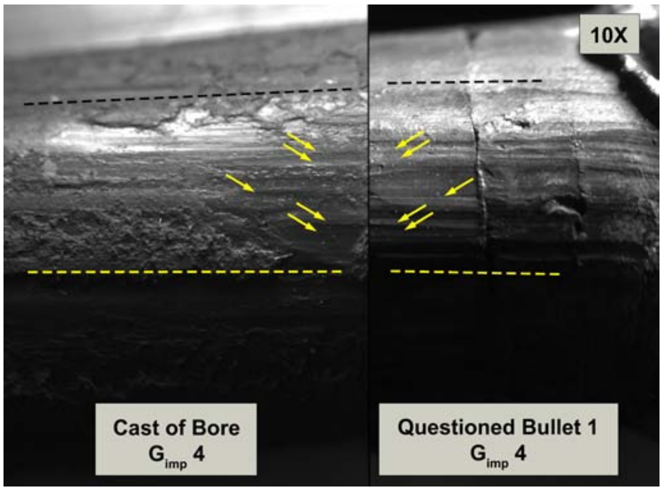

Figure 21: Comparison of groove impression #4 on bore cast (left) vs. Q-1 (right).

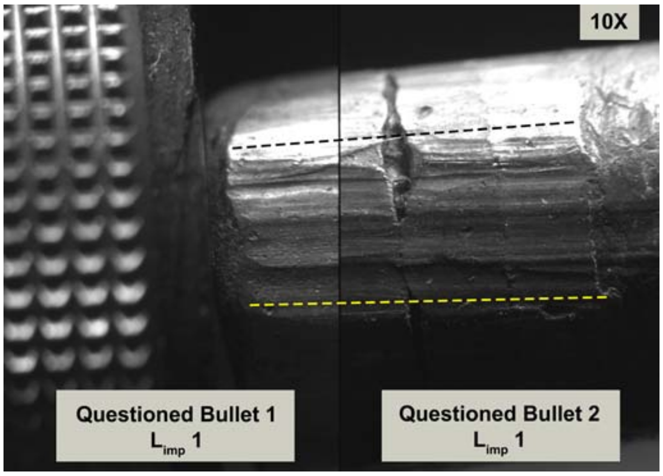

Figure 22: Comparison of land impression #1 on bullet Q-1 (left) vs. Q-2 (right).

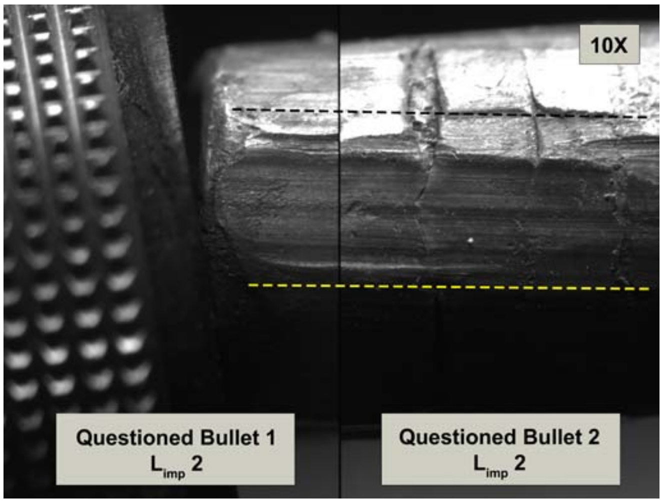

Figure 23: Comparison of land impression #2 on bullet Q-1 (left) vs. Q-2 (right).

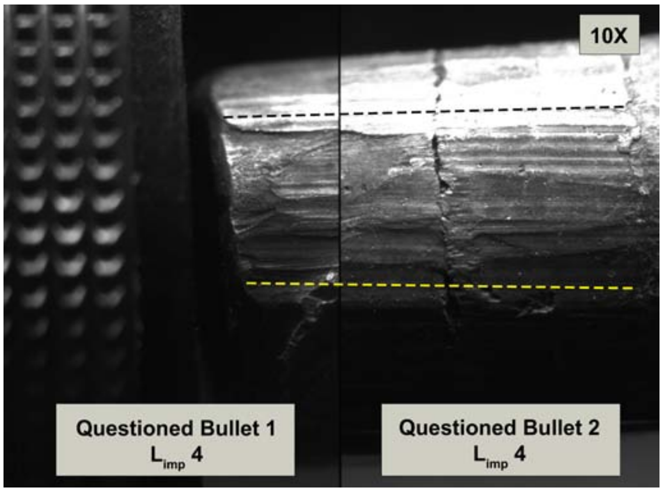

Figure 24: Comparison of land impression #4 on bullet Q-1 (left) vs. Q-2 (right).

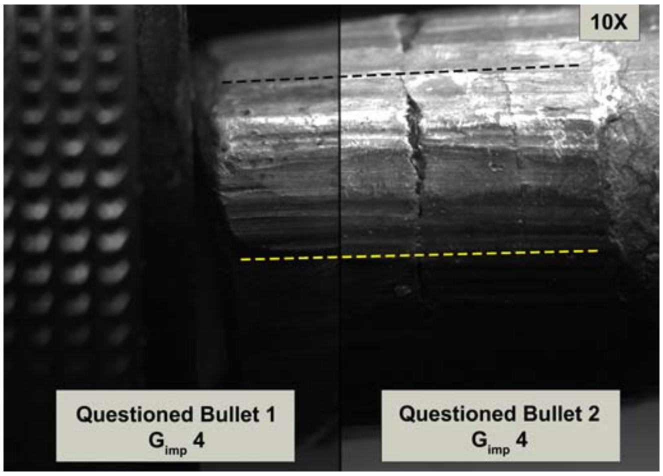

Figure 25: Comparison of groove impression #4 on bullet Q-1 (left) vs. Q-2 (right).

not it is believed that marks imparted by remnants of the original tooled working surface are present), the issue of subclass characteristics may be a moot point due to the fact the identification is based on unique characteristics imparted by a non-manufactured working surface.

Since these types of firearm cases involve such an unusual working surface, one that is comprised mostly, if not entirely, of a foreign material, the bore should be left undisturbed from the time of collection until it is examined. Even placing a plastic zip tie through the barrel of a gun to secure it in an unloaded condition for transport from a crime scene should be avoided, as this practice has the potential to dislodge some of the fouling which may change the rifling characteristics to some extent. A grossly fouled bore should also not be cleaned prior to test firing, for obvious reasons.

In cases such as this, the time interval and history of the gun between when the crime (shooting) occurred and when the gun was collected can be even more of a critical factor than it is in the typical firearms identification case because of the potentially high rate of change of the bore's characteristics. In the case under discussion, the aggregate lead fouling formed a working surface that reproducibly marked another lead surface (the bullet). At first glance, it seems counterintuitive that reproducible markings can be produced on bullets by such a working surface, since one might expect the rate of change of the fouled bore characteristics to be relatively rapid due to lead's inherent malleability and the extreme heat and friction associated with firing. However, there are some factors that may account for the hardening of lead fouling deposits to a point that would not only resist rapid deformation, but also allow them to mark lead bullets reproducibility. One seemingly plausible explanation is that the lead buildup in the bore becomes work hardened by the repeated passage of fired lead bullets over a period of time. Yet, lead and lead alloys do not appear to work harden like other metals having higher melting points since lead is capable of recrystallization (the process whereby a new, stress-free grain structure replaces a distorted grain structure in a cold worked metal, usually through heating, or annealing, above a specific minimum temperature for a specific time) at room temperature [7,8]. Alternatively, some sources suggest that lead alloys are capable of a certain degree of work hardening (also known as strain hardening) under the proper stress and temperature conditions [9,10]. Lead alloys containing antimony, arsenic, and/or tin, such as those commonly used in bullets, after being heated and allowed to cool, have been shown to actually get harder as they age [11,12]. This property is well known to those who regularly cast their own lead bullets for reloading [13,14].

After conducting a survey of some of the relevant research that has been published regarding the hardness properties of lead, it was discovered that several other factors may also determine the relative hardness or softness of a given working surface comprised of such bore deposits. These include the specific percentages of antimony, arsenic, and/or tin in the alloy, the temperature to which they are heated during the firing process, the rate at which they are cooled, the specific manner in which the lead is worked or deformed during and after it is deposited along the surfaces of the bore, and how long the deposits may sit undisturbed [15-19]. Ultimately, it appears that the mechanism responsible for the hardness of the fouling deposits in this case cannot be well understood without further testing that is specific to compositional bullet lead, the internal ballistics of firearms, and possibly the composition and grain structure of the specific deposits in this case. Whatever the cause, the rate of change of the leaded bearing surfaces within the Nagant revolver's bore was slow enough to allow for the reproduction of individual contour and axial markings that could be identified from test to test and from the test to questioned bullets. If the bore had been cleaned or if a single round of jacketed ammunition had been fired through the bore after the questioned lead bullets had been fired, this gun would likely not have lent itself to identification. Firearms having thinner and/or softer fouling deposits than the one featured in this case may not consistently reproduce markings on test-fired bullets to allow for identification, since the characteristics may change from one shot to the next.

The non-striated nature of the markings potentially produced by a heavily leaded bore will not easily lend themselves to tabulation using numerical criteria such as QCMS, so the traditional approach of relying on the relative height/depth, width, curvature, and spatial relationship of the topographical features of the marks on the questioned and test-fired bullets provides the most appropriate basis for identification. Examination and comparison of the bore cast to the bullets may help provide useful comparative information. Because of the limited characteristics available for comparison, this author feels it is good scientific practice to support any conclusion of identity regarding such toolmarks with extensive photographs. This means taking an overall (orientation) photograph at low-power magnification and a close-up photograph at higher magnification of the characteristics being compared for each land and groove around the circumference of the bullet.

Examinations such as the one conducted in this case and the accompanying documentation are not new concepts, as illustrated by Biasotti's case from 1981 and possibly many others that have not been publicized. Biasotti's work also provides an example of additional examination documentation that can be used to supplement photography. While this level of documentation may seem excessive to some, it should be kept in mind that the complexities of this type of identification examination are also somewhat out of the ordinary. And, it is the author's opinion that it is the out-of-the-ordinary cases that require the most thorough documentation.

References

[1] Barnes, F.C., Cartridges of the World, 12th Ed., edited by Layne Simpson, Wisconsin: Gun Digest Books, 2009, p. 311.

[2] Hogg, I.V. and Weeks, J.S., Military Small Arms of the 20th Century, 7th Ed., Wisconsin: Gun Digest Books, 2000, pp. 72-73.

[3] Popenker, M. R., "Nagant model of 1895 (Belgium - Russia)," World Guns [Internet], c2010. Available from: <http://world.guns.ru/handguns/double-action-revolvers/rus/nagan-arr-195-e.html>. Accessed 2011 Sept 9.

[4] "M1895 Nagant Revolver," 7.62x54r.net [Internet], c2009. Available from: <http://7.62x54r.net/MosinID/MosinRareNagant.htm> after searching for term "revolver" on homepage at <http://7.62x54r.net> and clicking on "M1895 Nagant Revolver - 7.62x54r.net Home Page" link. Accessed 2011 Sept 9.

[5] "7.62x38mmR," Wikipedia, The Free Encyclopedia [Internet], 2011 Aug 29. Available from: <http://en.wikipedia.org/w/index.php?title=7.62%C3%9738mmR&oldid=447263123>. Accessed 2011 Sept 13.

[6] Biasotti, A., Murdock, J. and Moran, B. "Firearms and Toolmark Identification". In Faigman DL, Saks MJ, Sanders, J, Chen, EK., Modern Scientific Evidence: The Law and Science of Expert Testimony, Vol. 4, Chapter 35, pp. 712-713. Edition 2009-2010. St. Paul: Thompson-West.

[7] Hofmann, W., Lead and Lead Alloys: Properties and Technology, Springer-Verlag, New York, 1970, p. 262.

[8] "Recrystallization" [definition], All Metals and Forge Group [Internet], c2011 by L.A. Weiss. Available from: <http://www.steelforge.com/steelresources.htm?search=recrystallization&submit=Submit+%BB>. Accessed 2012 March 20.

[9] Riddington, J.R. and Sahota, M.K., "Stability of Lead Alloy Compressive Work Hardening," Materials & Design, Vol. 20, No. 1, Mar. 1999, pp. 13-17.

[10] El-Sayed, M.M., Abd El-Salam, F., and Abd El-Haseeb, R., "Effect of Structure Transformation on Work Hardening Characteristics of Lead-Based Bearing Alloys," Physica Status Solidi (A)-Applied Research, Vol. 147, No. 2, Feb. 1995, pp. 401-407.

[11] Dean, R.S., Hudson, W.E., and Fogler, M.F., "The System Lead-Antimony—II,"¬ Industrial and Engineering Chemistry, Vol. 17, No. 12, Dec. 1925, pp. 1246-1247.

[12] "Heat Treating of Lead and Lead Alloys," Key to Metals [Internet]. c2010. Available from: <http://www.keytometals.com/article88.htm>. Accessed 2012 March 5.

[13] Trope, M., "The Hard Line!: Heat Treating Cast Bullets for Better Performance [Internet]," c2004. Available from:<http://www.gun-shots.net/wp-content/uploads/alloyhardness.pdf>. Accessed 2012 March 20.

[14] "Lead Bullet Hardness," Tacticool Products [Internet], c2007. Available from: <http://www.tacticoolproducts.com/bullethardness/>. Accessed 2012 March 5.

[15] Naramore, Earl. Principles and Practice of Loading Ammunition, Harrisburg: The Stackpole Company, 1954, pp. 366-379, 452-457.

[16] Hofmann, op. cit., pp. 75-94, 126-128, 189-194, 262-267.

[17] Riddington et al., op. cit.

[18] El-Sayed et al., op. cit.

[19] Dean et al., op. cit.