People v. Aceves – A Case of .22 Caliber Rimfire Gunshot Residue Matching

Bryan R. Burnett
Meixa Tech, LLP
1624 Debann Road. Building B
Cardiff, CA 92007

(760) 634-5939
(760) 632-7967 FAX
brburnett@meixatech.com

ABSTRACT

This is the analysis of a shooting where the assailant shot the victim twice with a .22 revolver. The ammunition was Remington with a single metal primer. The weapon attributed to the shooting is shown to have likely last fired Federal three-metal primered ammunition and thus could not have been the weapon used in the shooting. This paper examines the effect of previous-shot gunshot residue contamination as well as the gunshot residue compositional differences in samples from the breech, target and bore. This work also shows that the accumulation of gunshot residue within a .22 revolver, especially from different ammunitions, makes the resultant gunshot residue composition from a shot unpredictable. The antimony that covers most modern .22 bullets is likely to contribute substantial amounts of antimony to the gunshot residue of some shots.

INTRODUCTION

The analysis of gunshot residue by scanning electron microscopy/energy dispersive spectroscopy usually involves samples from hands. However, occasionally a case has required a comparison of different samples from the same shooting. People v. Aceves is such a case, where gunshot residue samples from the bores of two different weapons, the victim (target) and the alleged assailant (breech) are compared.

Figure 1. Images of the People v. Aceves case. A: Preoperative image of the victim's right face. One bullet wound is shown at the arrow. The second wound was apparently on the neck. B: One of bullets that was extracted from the victim. A brass coating as well as the three cannulares identify the bullet as Remington manufacture. C: The unknown manufacture .22 revolver in the ivy patch. D & E.: Cartridges from the revolver of unknown manufacture . F: One of the casings from the same revolver.

Gunshot residue sample comparison usually depends on determining the presence of elements specific to a particular ammunition type (e.g., Heye and Guinn 1988; Wrobel, et al.1998). The elemental composition of gunshot residue from the weapon's bore or from the casing is assumed to correspond to the elemental composition from the muzzle or breach. However, Burnett (1989A) and Cheylon, et al. (2002) have shown that bore, muzzle and breech gunshot residue samples from the same center-fire cartridge are different in relative elemental compositions.

It has been generally known that there is more variation in primer metal compositions between .22 ammunitions from the different manufacturers

than that found in standard center fire ammunitions (e.g., Wrobel et al. 1998). To assist analysts in .22 caliber gunshot residue matching, Ward (2001) has suggested establishment of a database listing the primer components of various ammunitions. Such a database has been constructed by Wrobel et al. (1998) for .22 caliber ammunitions available in Australia, but this information appears not have been utilized outside of Australia.

It has also been noted since the beginning of the use of scanning electron microscopy in gunshot residue analysis that there is a potential of contamination from previous shots of different ammunition in a gunshot residue sample analysis (e.g., Wolten et al. 1977; Wallace and Keeley 1979). Apparent contamination has even been observed for a firearm that has been thoroughly cleaned (Lebiedzik 2003). Burnett (2003A) has documented in a .22 semi-automatic pistol that gunshot residue breech deposits from one type of ammunition may have significant contamination by elements from shots fired previously with different ammunition.

Latex glove (found at defendant's apartment):
Interior surface: 3 spherical particles composed of PbSb
Exterior surface: 2 spherical particles Pb
1 spherical particle PbSb
1 irregular particle PbSb

Blue shirt (found at defendant's apartment):
4 particles PbSb
2 Particles Pb
1 particle PbBa
"…five of those particles have generally spherical shapes and two of them are not spherical …"

S&W M-18 .22 revolver (implicated as the weapon used in the shooting):

"I found several consistent particles of gunshot residue … Principally, those particles were lead only, particles of lead and antimony and lead and barium particles."

Second .22 revolver (unknown manufacture due to deteriorated condition):
"On the second gun barrel swabbing I found subsequent several consistent particles of gunshot residue. They were all lead only particles."

Figure 2. Extracts from the testimony from the prosecution GSR expert regarding the analyses of various evidence items of concern in this article. No scanning electron microscope images or spectra were presented during the testimony.

Thus, comparison of gunshot residue samples must take into account contamination from previously fired ammunition and the compositional differences of gunshot residue samples (bore, target and breech). This study will provide a foundation for gunshot residue matching of .22 caliber samples in regards to the case of People v. Aceves.

People v. Aceves. Aceves was accused of an attempted murder that occurred in Chula Vista, San Diego County, California in 1995. The victim was shot in the head evidently at close range (Fig. 1A, arrowhead) and apparently the neck (below the ear? Fig. 1A) at an unknown range. The medical report that documents the victim's injuries was not available. One .22 bullet was recovered from the victim almost intact (Fig. 1B), and the second bullet (likely the headshot) had fragmented (not shown). Both bullets were found to have remnants of brass metal on their surfaces and by the appearance of the one bullet (Fig. 1B) were identified as Remington manufacture.

The defendant's father was discovered to have a .22 caliber Smith and Wesson (S&W) Model 18 revolver in his home along with a box of Peters (a Remington brand) .22 LR "Golden Bullet" cartridges. These cartridges had round-nose bullets with brass coatings and head stamps of "U." The S&W revolver (hereafter referred to as "Aceves S&W revolver") was proposed by the prosecution to be the weapon employed in the attempted murder by virtue of the associated box of Peters ammunition.

The father of the defendant told the author and apparently the original defense criminalist (V. Parker Bell) on this case that the last cartridges fired in the Aceves S&W revolver were Federal brand. The father did not recall if any of the Peters .22 cartridges that were associated with this revolver had been fired in the weapon. Unfortunately, he was a victim of a progressive dementia and appeared to have provided different information to another investigator.

More than a year after the shooting, another .22 revolver was alleged by an unknown party to have been the weapon involved in the shooting. A revolver was recovered from an ivy-covered area (Fig. 1C) near where the shooting occurred. The nine-shot revolver of unknown make (due to its deteriorated condition) was loaded with seven Remington/Peters .22 cartridges (in various degrees of deterioration, e.g., Figs. 1D and 1E) and two casings of the same brand (one of the casings is shown in Fig. 1F). These cartridges had "U" head stamps, which were the same type of ammunition found with the Aceves S&W revolver and the same bullet type extracted from the victim.

The victim apparently noted that her assailant wore a blue shirt and was wearing surgical gloves. The investigators took samples from the bores of both of the .22 weapons. Samples were also taken from a surgical glove and a blue shirt that were found in the defendant's apartment.

In the Aceves trial, the gunshot residue expert for the prosecution presented his findings. His results, taken from the transcript of his testimony, are presented in Fig. 2. Noteworthy in this person's testimony is that there were no spectra or any other documentation presented to the court in support of his testimony. The expert testified in trial that gunshot residue particles analyzed from these weapons' bores "could not be excluded" as a source of the consistent gunshot residue particles found on the gloves and the blue shirt. The prosecution, by not excluding the Aceves S&W .22 revolver from the shooting implied a circumstantial connection of the defendant to the victim. This along with other circumstantial evidence and the victim's identification of the defendant as her assailant convicted the defendant of the attempted murder in 1996.

There are problems with the gunshot residue evidence and its interpretation that was presented by the expert:

1) The scanning electron microscope samples taken by the prosecution expert from the two bore samples were not properly prepared. There were fabric fibers projecting from the sampler surface and the samplers appeared to have been coated with metal (gold-palladium?). Considering the numerous fibers projecting from the disk, it is surprising that this analyst could get any spectra at all. Indeed, no spectra or spectral integrations for the trial of Aceves were submitted. Thus, his results could not be evaluated beyond his testimony.
2) The gunshot residue compositions of the bore wipes were insufficiently characterized. Although the prosecution expert never defined what he meant by "several" particles (Fig. 2), it appears that insufficient numbers of particles were analyzed to allow for reliable comparisons. For that matter, there were no test firings of known ammunition to enable a comparison as to which brand (Federal or Peters) had been fired prior to the bore wipe of the Aceves S&W revolver. If the last cartridge fired in this revolver was Federal, not Peters, differences in the primer composition of these brands may be reflected in the gunshot residue deposit in the bore as well as on the target and on the hands of the assailant.

Figure 3. The housedress worn by the victim. A: The dress on the floor of the victim's apartment. B: The mannequin with the dress on. Red arrows: point to the likely locations of the shots to the victim's head and neck. White numbers: the locations of the sampling of the dress for gunshot residue and gunpowder flakes. C: The victims dress at samples 1 and 2 on the right shoulder. D: The front of the victim's dress at samples 3 and 4.

3) There was no attempt to determine if gunshot residue was deposited on the victim's dress. The likely reason was that the majority of the dress was soaked with blood (Fig. 3A) and the prosecution expert apparently decided not to deal with this evidence. Critical here is that there are two possible primer compositions for the cartridges of the Remington/Peters bullets (Burnett 2003B) extracted from the victim.
4) The relationship between the composition of gunshot residue deposits in the bore of a weapon, on a target and on the hands (in this case clothing and a surgical glove) of the shooter has not (in this author's knowledge) been empirically examined for .22 caliber weapons prior to this article. Thus, the comparison by the prosecution expert of gunshot residue samples lacks foundation.

The design of the experiments (ammunition type and number of shots fired) is based on the features of People v. Aceves:
1) Two-.22 caliber Remington or Peters (a brand of Remington) shots with brass-coated bullets were fired at the victim.
2) The shots were apparently fired at distances that deposited muzzle and perhaps cylinder-gap gunshot residue on the victim's dress.

Table 1. A listing of the ammunition fired for each sample series and the samples taken in these experiments.

Sample Series	# Fired	.22 Brand/Type	Primer	Bullet Sb Layer	Bullet Cu or CuZn	Samples
1	40	Federal Lightning	PbSbBa	?	no	→ Bore 1
2	18	Aguila (Mexico)	Pb	no	Cu	→ Bore 2
3	24	Federal Power-Flite	PbSbBa	?	no	→ Bore 3
4	24	Federal Power-Flite	PbSbBa	yes	no	
	1	Peters Golden Bullet	Pb	yes	CuZn	
	1	Peters Golden Bullet	Pb	yes	CuZn	→ Target
						→ Bore 4
5	24	Federal Lightning	PbBa	?	no	→ Bore 5
6	24	Federal Lightning	PbBa	yes	no	
	1	Peters Golden Bullet	Pb	yes	CuZn	
	1	Peters Golden Bullet	Pb	yes	CuZn	→ Target
						→ Bore 6
7	22	Peters Golden Bullet	Pb	yes	CuZn	
	2	Peters Golden Bullet	Pb	yes	CuZn	→ Target, Cyln Gap
						→ Bore 7
8	24	Federal Lightning	PbBa	?	no	
	2	Peters Golden Bullet	Pb	yes	CuZn	→ Target, Cyln Gap
						→ Bore 8
9	24	Winchester Wildcat	PbBa	yes	no	
	2	Remington	PbSbBa	yes	CuZn	→ Target, Cyln Gap
						→ Bore 9
10	24	Winchester Wildcat	PbBa	yes	no	
	2	Peters Golden Bullet	Pb	yes	CuZn	→ Target, Cyln Gap
						→ Bore 10
11	12	Remington	PbSbBa	yes	CuZn	
	2	Remington	PbSbBa	yes	CuZn	→ Target, Cyln Gap
						→ Bore 11

There are two types of Remington/Peters primer compositions to consider in this case:
1) The primer metal consists principally of lead (Pb). Cartridges with a head stamp of "U" or "Rem" have this primer type (Burnett 2003B) and were sold with the brand names "Peters" and "Remington."
2) The primer metals consist of the metals lead (Pb), antimony (Sb) and barium (Ba). This primer composition was introduced by Remington in 1989 (Burnett 2003B) and have cartridges with a head stamp of "Rem." The brand name "Peters" was apparently discontinued around this time.

This article will provide results of a study of the gunshot residue produced from .22 ammunitions principally from Remington or Peters (head stamp "U") and Remington (head stamp "Rem"). Examined will be the effect on gunshot residue composition (bore, target and cylinder-gap) of the firing of an ammunition from a different manufacturer prior to one or two shots of Remington or Peters ammunition. The evidence of People v. Aceves will be

compared to these data. These experiments were designed specifically for this case and may have limited applicability to other cases.

MATERIALS & METHODS

A Smith and Wesson M-18 .22 revolver similar to the one allegedly used in the attempted murder was tested. The revolver was thoroughly cleaned including wire brushing the bore. The breech face and cylinder were similarly cleaned. Gunshot residue samplers were constructed of double sticky carbon tape applied to 13-mm diameter x 1.8-mm thick graphite disks (Burnett 2001), which were attached to standard 13-mm diameter aluminum alloy scanning electron microscope stubs. There are three sample types:

1) A sample from the bore of the revolver was taken from a small piece of linen that was passed through the bore (bore wipe, or bore sample).
2) A linen target was shot with the revolver muzzle at 5 cm (target sample).
3) A piece of velum was taped over the cylinder gap (Burnett 2003A) when the revolver was fired (cylinder gap or breech sample).

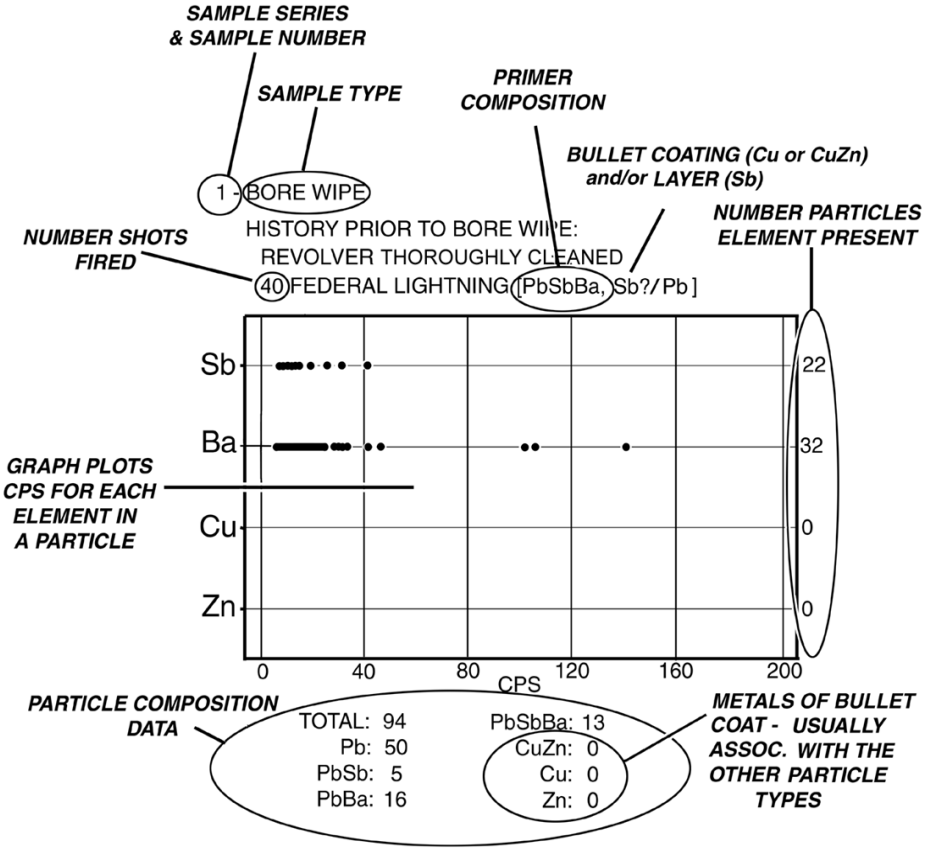

Figure 4. Explanation graph for samples graphed in Figs. 2 through 12. With a few rare exceptions (e.g., one particle with only barium in Sample 4A, Fig. 5), all .22 gunshot residue particles had lead. Lead counts per second (CPS) is not graphed in Figs 2 through 12. Figure explanation:

BULLET COATING … - *The material coating the bullet in this example. "Sb?" - A bullet from this particular lot was not retained for surface analysis (thus the "?").*
NUMBER PARTICLES ELEMENT PRESENT - *This is the number of particles that had this element in this sample.*
NUMBER SHOTS FIRED – *The number of shots fired for the ammunition listed. For some sample series, additional shots were fired with either Peters or Remington ammunition. Target or cylinder-gap samples were often taken for the final one or combined two shots of a series.*
PRIMER COMPOSITION – *The primer composition that was determined by analysis of unfired primer from this ammunition.*
PARTICLE COMPOSITION DATA - *This is a table of the particle composition types.* TOTAL: *total number of particles in analyzed sample.* Pb: *lead only,* PbSb*: lead-antimony*, PbBa: *lead-barium and* PbSbBa: *lead-antimony-barium.* METALS OF BULLET COAT: CuZn: *copper-zinc,* Cu: *copper,* Zn: *zinc - are bullet derived (with perhaps a very small contribution from the casing) and is usually found as part of the composition of other particle types.*

Each sample was dabbed with the gunshot residue sampler. The type of samples taken in each series of experiments varied from only a bore wipe to all three types (bore wipe: 11 samples; target: 7 samples; cylinder gap: 5 samples). Table 1 lists the gunshot residue samples with the primer and

bullet compositions for each ammunition brand. These primer and bullet compositions were determined by scanning electron microscopy/energy dispersive X-ray spectroscopy. Some of the bullets were not sampled (i.e., the cartridges from a particular lot were all fired before the bullet examinations were undertaken) and are indicated in Table 1 as "?" under "Sb Layer" and as "Sb?/Pb" in Figs. 5, 7 and 9.

The diameter of fifty cartridges each from seven different .22 brands was measured to the nearest 0.01 mm with a Mitutoyo Digimatic caliper. For the brass-coated Peters "golden" bullet round-nose and hollow-point cartridges, nine measurements were made of each bullet with the caliper, rotating the bullet approximately 20 degrees between measurements (these bullets were not round). An average diameter was calculated for each bullet.

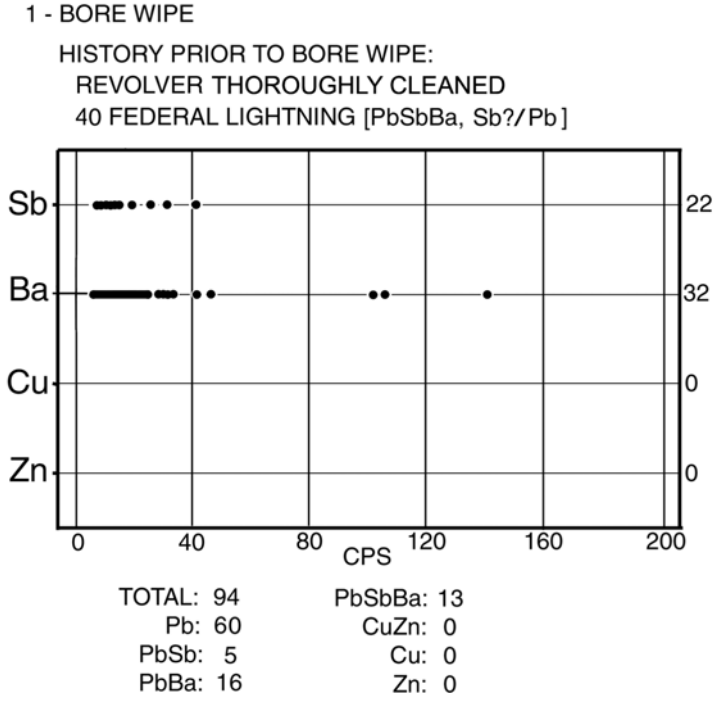

Figure 5. Sample series 1. Graphical display of the results of this sample series. See Fig. 4 for an explanation. The bore wipe is the only sample of this series.

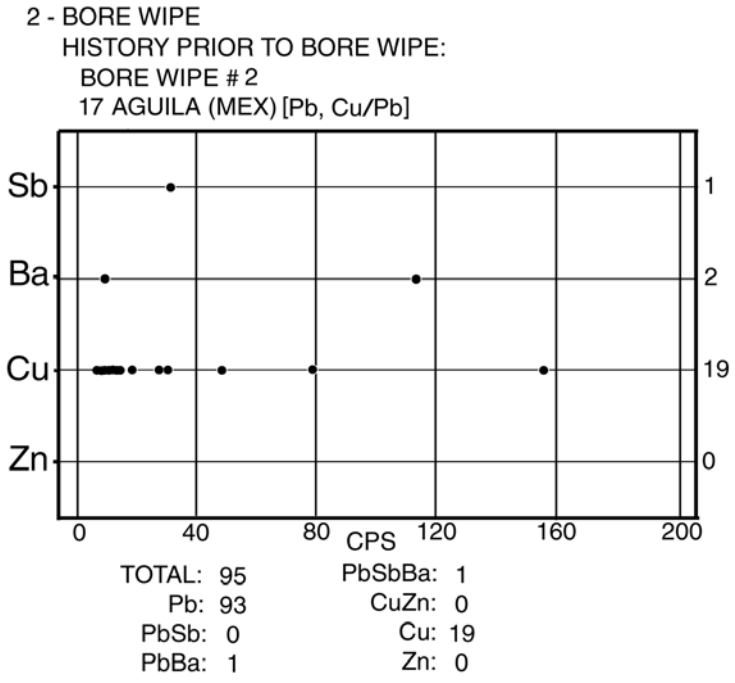

Figure 6. Sample series 2. See Fig. 4 for an explanation. The bore wipe is the only sample of this series.

Evidence from the Aceves case was obtained from both the Chula Vista Crime Laboratory (Chula Vista, California) and the San Diego Superior Court (San Diego, California). The second .22 revolver that was found in the ivy patch (Fig. 1C) was unavailable (lost) for further study.

The bore wipes. New samplings of the bore wipe from the Aceves S&W revolver and the cotton swab from the unknown make revolver were made. The fabric bore wipe and cotton swab were dabbed with carbon-tape scanning electron microscope samplers. The fibers were pressed onto the carbon tape samplers with light pressure from clean Teflon tape so that these fibers would not block X-rays for elemental analysis.

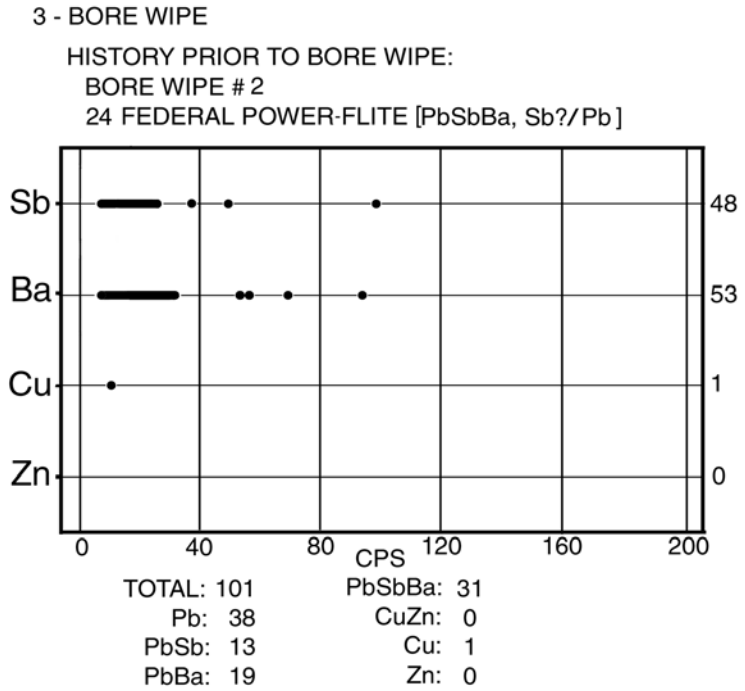

Figure 7. Sample series 3. See Fig. 4 for an explanation. The bore wipe is the only sample of this series.

The victim's dress. The housedress was heavily bloodied (Fig. 3A). A mannequin was clothed with the victim's dress (Fig. 3B) to simulate the position of the dress at the time of the shooting. When the gun delivered the apparent close shot that created the head wound, the right shoulder fabric of the dress may have received a deposit of gunshot residue from the cylinder gap of the revolver. In addition, muzzle gunshot residue may have been deposited on the dress shoulder fabric when the other shot (to the neck?) was made.

Small fabric samples approximately 1 cm square were cut from the dress at the positions shown on the dress in Figs. 3B, 3C and 3D. Fabric samples 1 and 2 (Fig. 3C) were treated with a solution of sodium/calcium hypochlorite (Burnett 1995) to remove the dried blood from the fabric. The fabric squares were rinsed for 15 seconds with filtered water and then dried. Upon drying, the fabric squares were mounted on carbon double-sticky tape/SEM stubs and two drops of Conduct Coat © (Burnett 1995) applied in order to make the sample sufficiently conductive to examine in the high-vacuum scanning electron microscope.

A series of five shots were made with the experimental .22 S&W revolver: 1- Federal Power-Flite (primer: lead-antimony-barium), 2- Federal Lightning (primer: lead-barium), 3- Winchester Wildcat (primer: lead-barium), 4- Peters Golden Bullet (primer: lead) and 5- Peters Golden Bullet (primer: lead). A dry bore wipe was taken at the completion of this five-shot series and processed as described above. The gunpowder flakes (most appeared partially consumed) from each of these shots were collected from a sheet of white butcher paper that was placed under the revolver before each shot. These flakes were applied to a carbon double-sticky tape and examined in the scanning electron microscope without coating. More than 100 metaliferous particles were analyzed from each gunpowder sample.

The cartridges of second revolver. A gunshot residue sample was taken from within one of the casings that was found in the second revolver. Two of the cartridges were separated and a small amount of primer material was extracted from each and mounted on carbon tape/SEM samplers.

The samplers were placed in an ETEC Autoscan scanning electron microscope equipped with an IXRF Systems EDS2000 Microanalysis System. Acceleration voltage was 20 kV and the work distance was 14 mm for all samples. Between 43 and 149 particles, all approximately 1 micron in diameter, were analyzed for 5 seconds for each particle for each sample. Every element of every spectrum was confirmed prior to addition into the database. The element integrations were added to a database and transported to a graphics program (Statgraphics) for a graphical presentation of the particle-element distribution in each sample. These graphs were prepared for presentation in the format explained in Fig. 4.

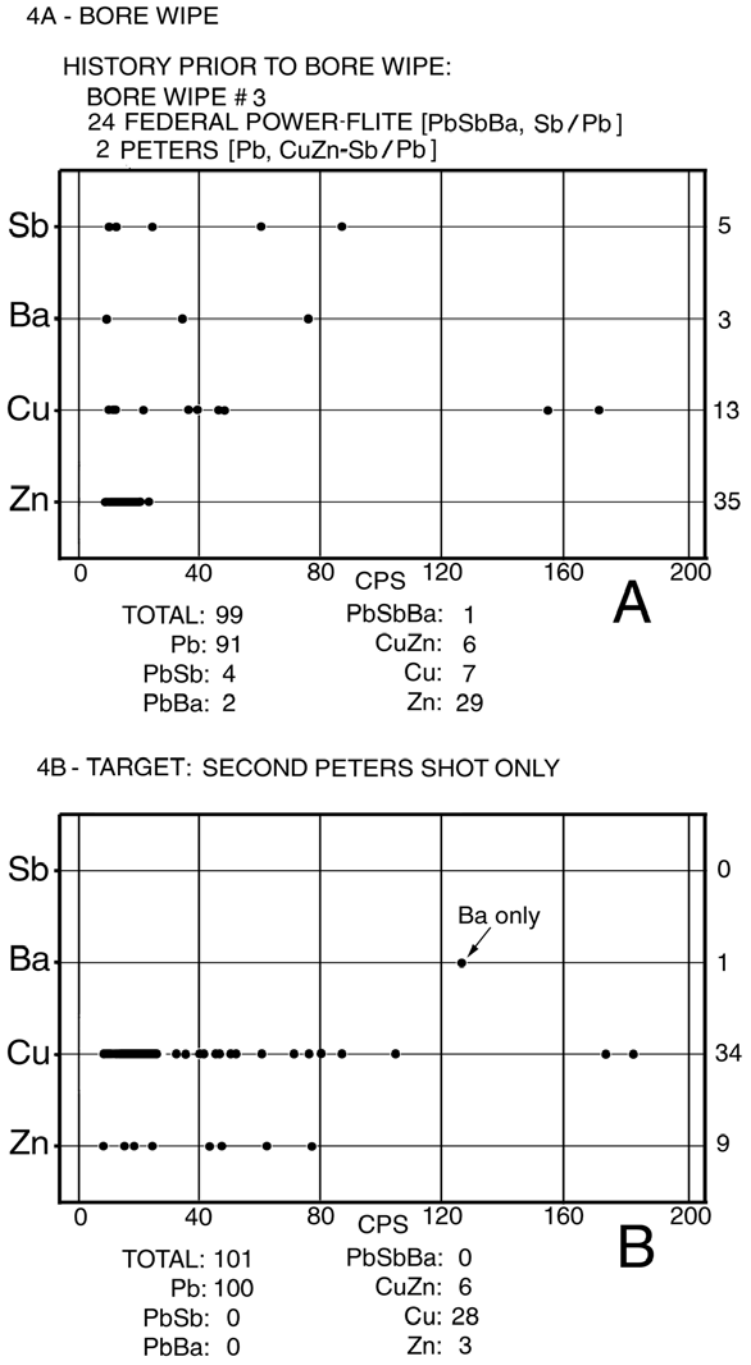

Figure 8. Sample series 4. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target sample was from the last shot in this series.

RESULTS & DISCUSSION

Many of the experiments described in this paper were designed to determine the gunshot residue produced with lead-only primer composition of the Peters ammunition (Figs. 8, 10, 11 12 and 14). This was the primer composition (verified - see below) of the Peters cartridges from two of the evidence items in the case (cartridges with head stamps of "U"). However, the primer compositions of the cartridges from which the two bullets extracted from the victim are not known. The brass-coated bullets are Remington/Peters manufacture and may have come from cartridges either with one-metal (lead) or three-metal (lead-antimony-barium) primers. The gunshot residue generated from the Remington three-metal primer type is also evaluated (Figs. 13 and 15).

Sample series 1 (Fig. 5). This is a single bore wipe that was taken after 40 shots of Federal Lightning (primer: lead-antimony-barium; bullet: no

coating - antimony layer uncertain). The gunshot residue is essentially reflective of the primer type. About 36% of the gunshot residue particles of this sample were associated with barium or antimony or antimony-barium.

Sample series 2 (Fig. 6). Another bore wipe that was taken after 17 shots with Aguila (Mexican manufacture – primer: lead; bullet: copper coated & no detectable antimony layer) ammunition. Only two particles showed components of the previous ammunition type (barium and antimony), which represents 2% of the particle population. Copper, likely from the bullet coatings of the Aguila ammunition, is associated with 20% of the gunshot residue particles.

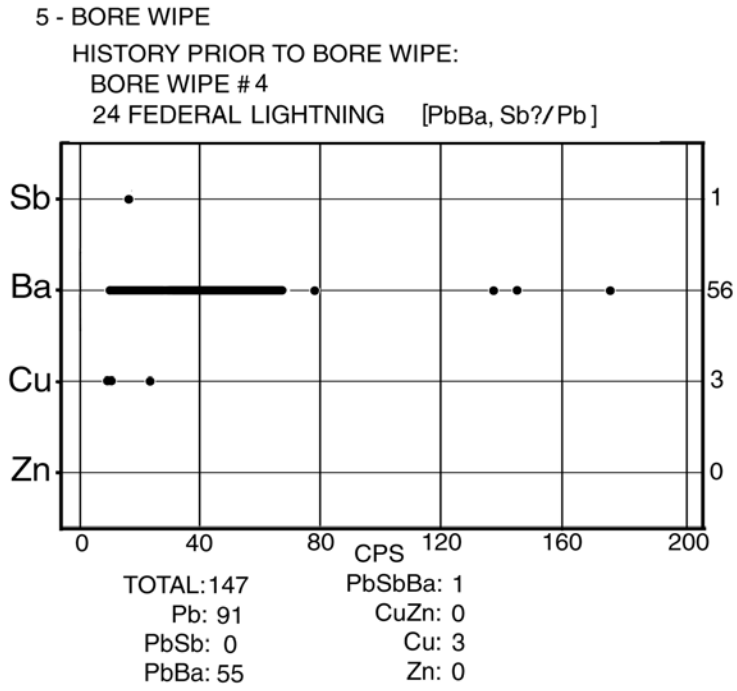

Figure 9. Sample series 5. See Fig. 4 for an explanation. The bore wipe is the only sample of this series

Sample series 3 (Fig. 7). A single bore wipe that was taken after firing 24 Federal Power-Flite (primer: lead-antimony-barium; bullet: no coating & antimony layer uncertain). The bore wipe was reflective of the primer composition for this ammunition. Approximately 62% of the bore gunshot residue had either antimony or barium or both in the gunshot residue particles.

Sample series 4 (Fig. 8). Following 24 Federal Power-Flite (Primer, lead-antimony-barium; bullet, no coating & antimony layer), two shots of Peters (primer: lead; bullet: copper-zinc (brass) coating & antimony layer) were fired. For the bore sample taken after the final Peters shot, some apparent remnants of the Federal shots were present (prior shot contamination = 3%). Copper-zinc and copper were well represented in the bore sample - approximately 13% combined (Fig. 8A). Zinc without copper was observed in a number of particles from this bore sample. For the target sample (Fig. 8B), the gunshot residue particles from the second Peters shot showed only one particle that could be considered as from the previously fired Federal ammunition. Bullet components from the Peters shots are better represented in this target sample (brass and copper combined = 33.7%) than the bore sample. Three particles showed zinc without detectable copper in this sample.

Sample series 5 (Fig. 9). This is a bore wipe which followed 24 Federal Lightning (primer: lead-barium; bullet: no coating & antimony layer uncertain) cartridges. Lead-barium gunshot residue particles dominate the bore wipe sample with a small number of copper and only one antimony-containing particle. These results are likely a reflection of the primer material for these cartridges. Three copper-containing particles are present. The copper is likely from the previously fired Peters, where if there is zinc in these particles, it is at too low a concentration to be detected.

Sample series 6 (Fig. 10). This sample series is a bore wipe and target sample – 24 Federal Lightning (primer: lead-barium; bullet: no coating & antimony layer) shots followed by 2 Peters (primer: lead; bullet: copper-zinc coating & antimony layer) shots where for the target sample (Fig. 10B), only the final Peters shot was sampled. The bore sample (Fig. 10A) in this series is fairly reflective of the gunshot residue produced by the lead-only primer of the Peters. There is a small representation of barium (approximately 6%) of the gunshot residue likely produce by the primer of the previously fired Federal Lightning ammunition. Notable for the bore sample is the presence of zinc without detectable copper for many of the particles. The bullet-derived contribution to the target sample appears to be a reverse of this relationship (i.e., copper without detectable zinc).

Sample series 7 (Fig. 11). There are 24 shots of the Peters ammunition (primer: lead; bullet: copper-zinc coating & antimony layer) in these samples. The bore wipe (Fig. 11A) was taken at the completion of these 24 shots. The target (Fig. 11B) and cylinder-gap samples (Fig. 11C) were taken from the two final shots of this sample series. The bore sample shows that despite the 24 shots of lead-only cartridges, that barium-containing particles still make up more that 10 % of the particles. The likely source of the barium is the previous Federal ammunition that had a lead-barium primer. The

target sample did not have detectable barium and is consistent with the Peters primer and bullet coating. On the other hand, the cylinder-gap sample (Fig. 11C) shows a composition quite divergent from that expected of a cartridge that only has lead metal in its primer composition. In this sample 52% of the gunshot residue particles have both antimony and barium present. Copper-zinc is well represented (78%) as part of most of these particles.

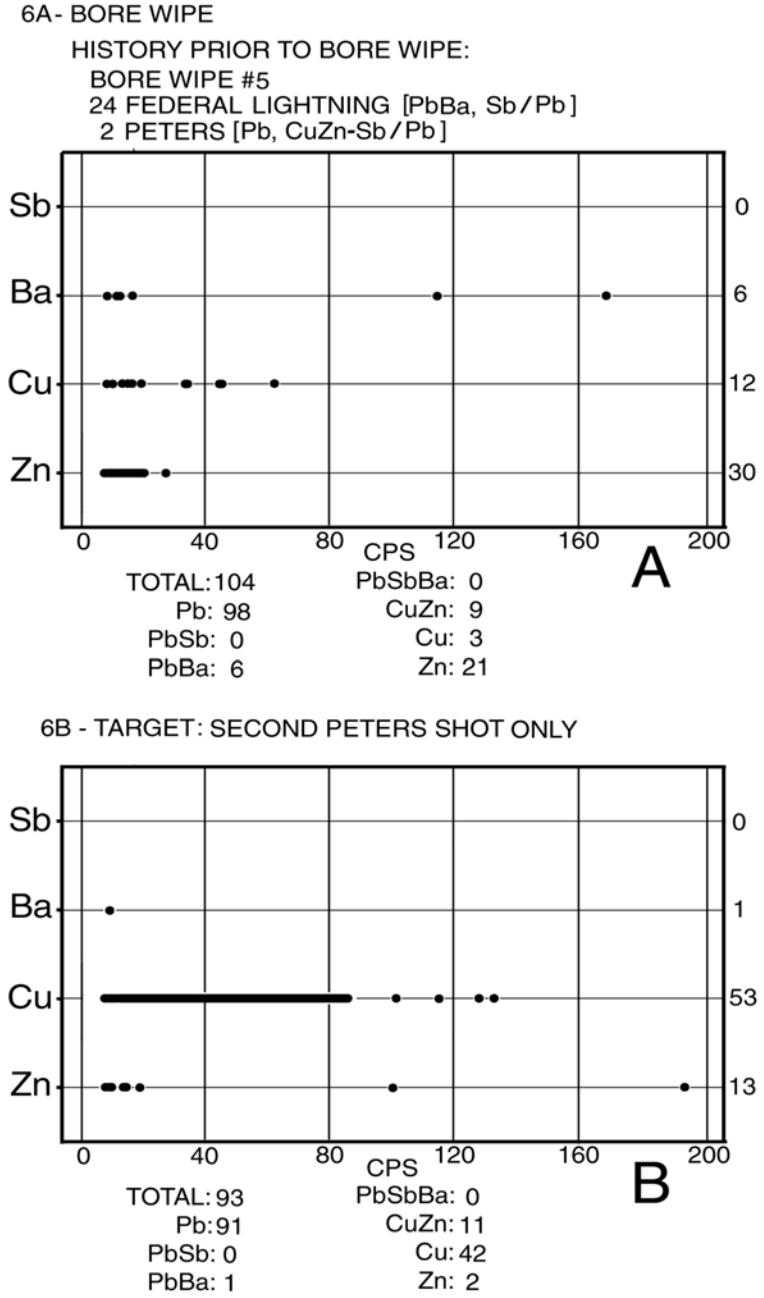

Figure 10. Sample series 6. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target sample was from the last shot in this series.

Sample series 8 (Fig. 12). There are 24 Federal Lightning (primer: lead-barium; bullet: no coating & antimony layer) shots that are followed by 2 Peters (primer: lead; bullet: copper-zinc coating & antimony layer) shots. The target (Fig. 12B) and cylinder-gap samples (Fig. 12C) are from the final two shots. The bore, target and cylinder-gap samples all have 10% or more for both antimony and barium. The barium for all samples is likely from the primer of the previous-fired Federal Lightning shots. Antimony was present in all three of the samples (9 to 15% of the particles) despite the 100 shots fired prior to these from cartridges that did not have antimony in their primers. Evaluation of any one of these samples without knowledge of the ammunition that produced it would likely predict that ammunition's primer contains antimony. The low representation of antimony for series samples 5, 6 and 7 (Figs. 8, 9 and 10) taken prior to sample series 8 (Fig. 12) suggests that the antimony may be coming from the antimony layer on the Federal bullets. These bullets were from a different lot than the previous Federal cartridges (sample series 6 – Fig. 10). The Peters ammunition perhaps can be excluded (but see below) as a contributor of antimony because previous Peters shots from the same lot did not have a substantial antimony contribution to this gunshot residue sample.

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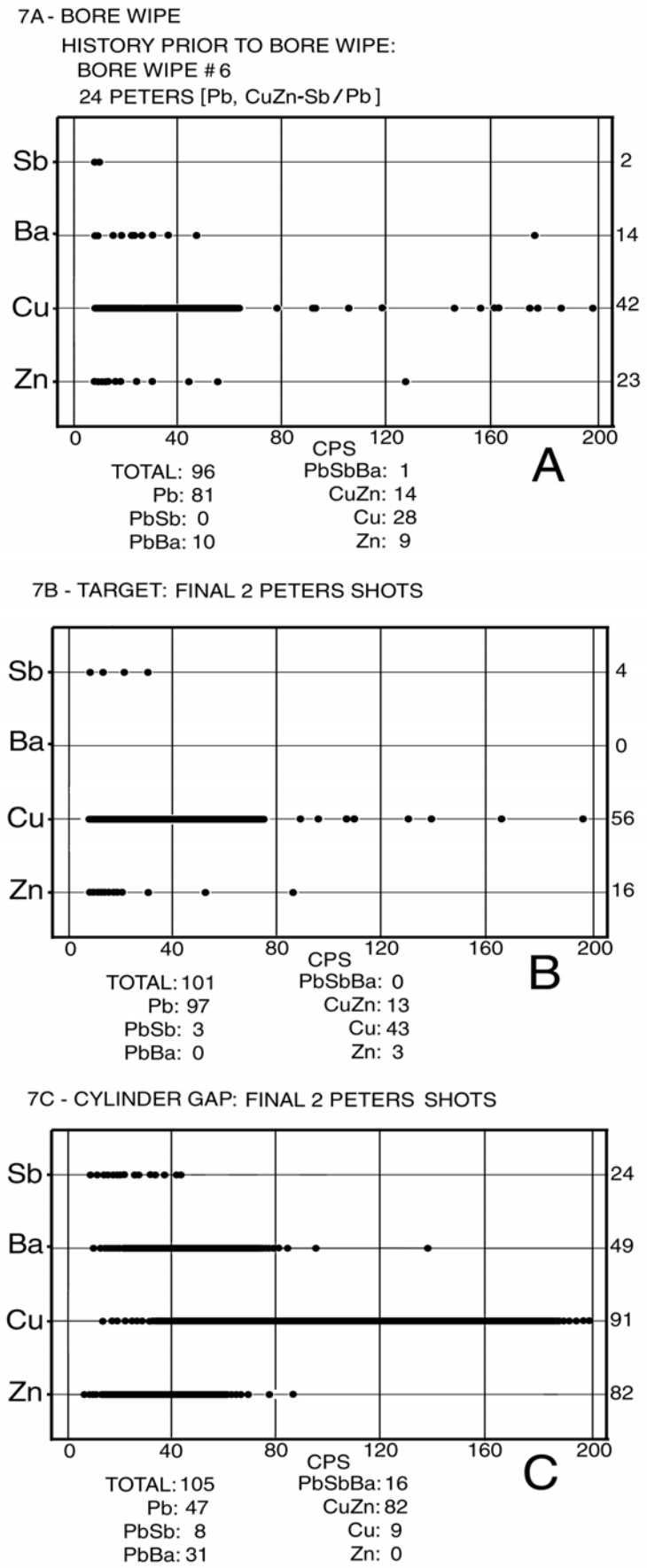

Figure 11. Sample series 7. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target and cylinder-gap samples were taken with the last two shots in this series.

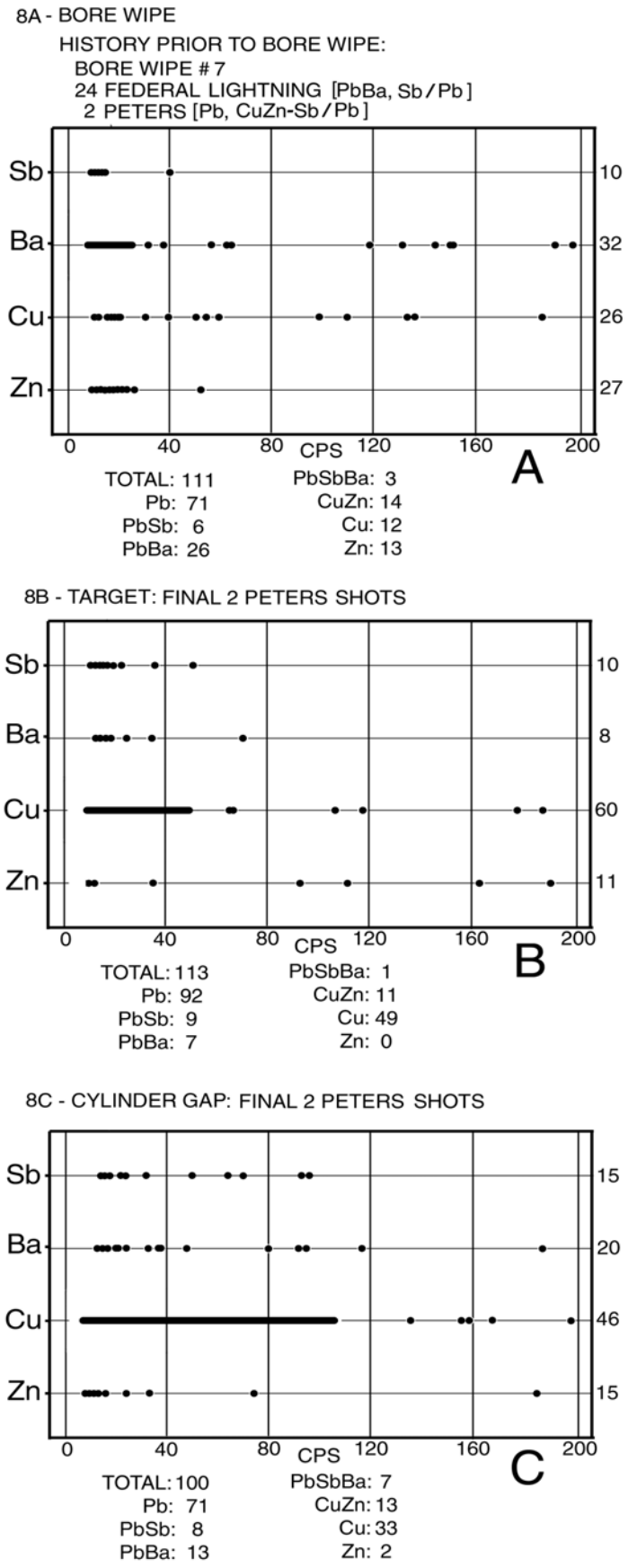

Figure 12. Sample series 8. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target and cylinder-gap samples were taken with the last two shots in this series.

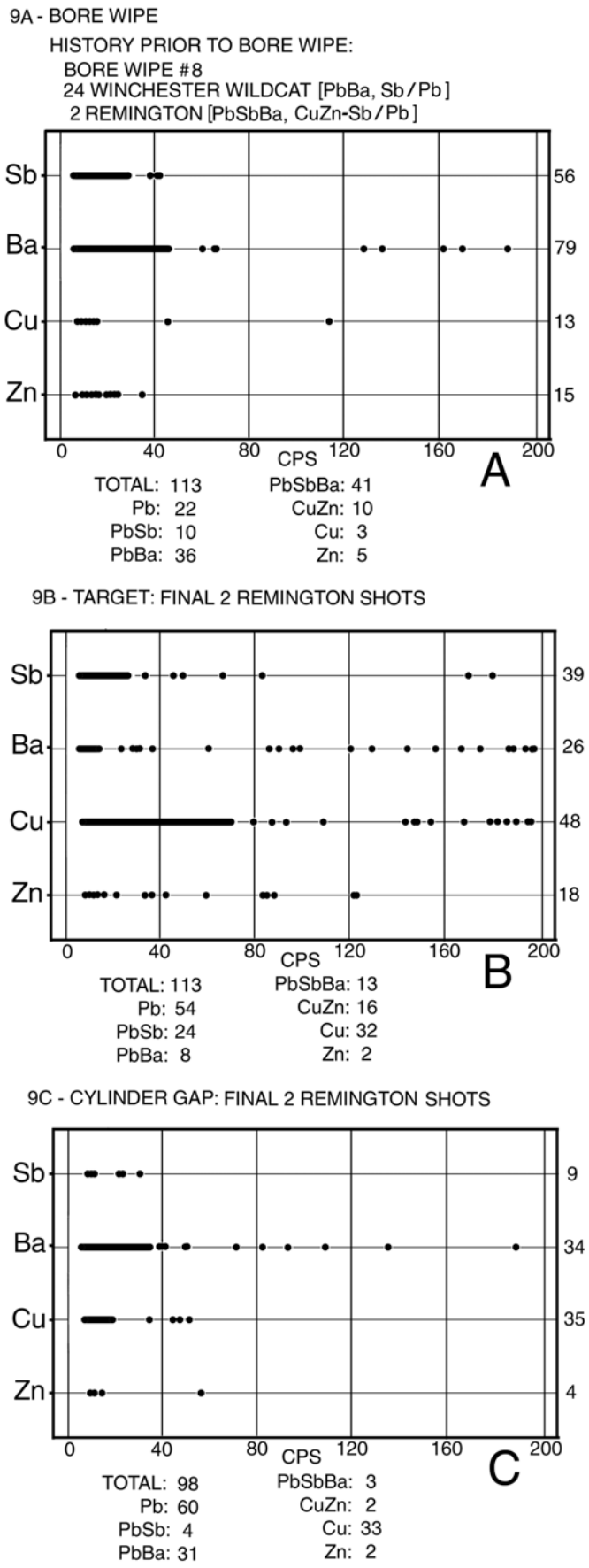

Figure 13. Sample series 9. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target and cylinder-gap samples were taken with the last two shots in this series.

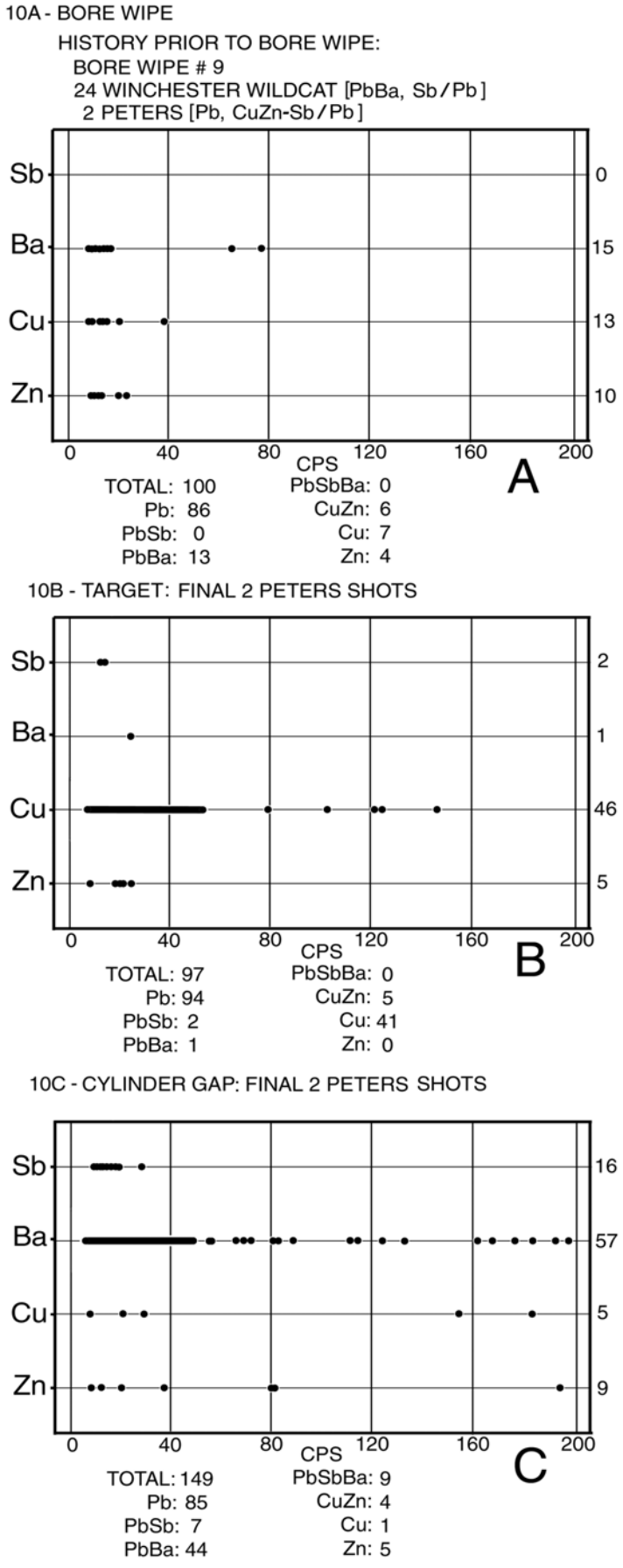

Figure 14. Sample series 10. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target and cylinder-gap samples were taken with the last two shots in this series.

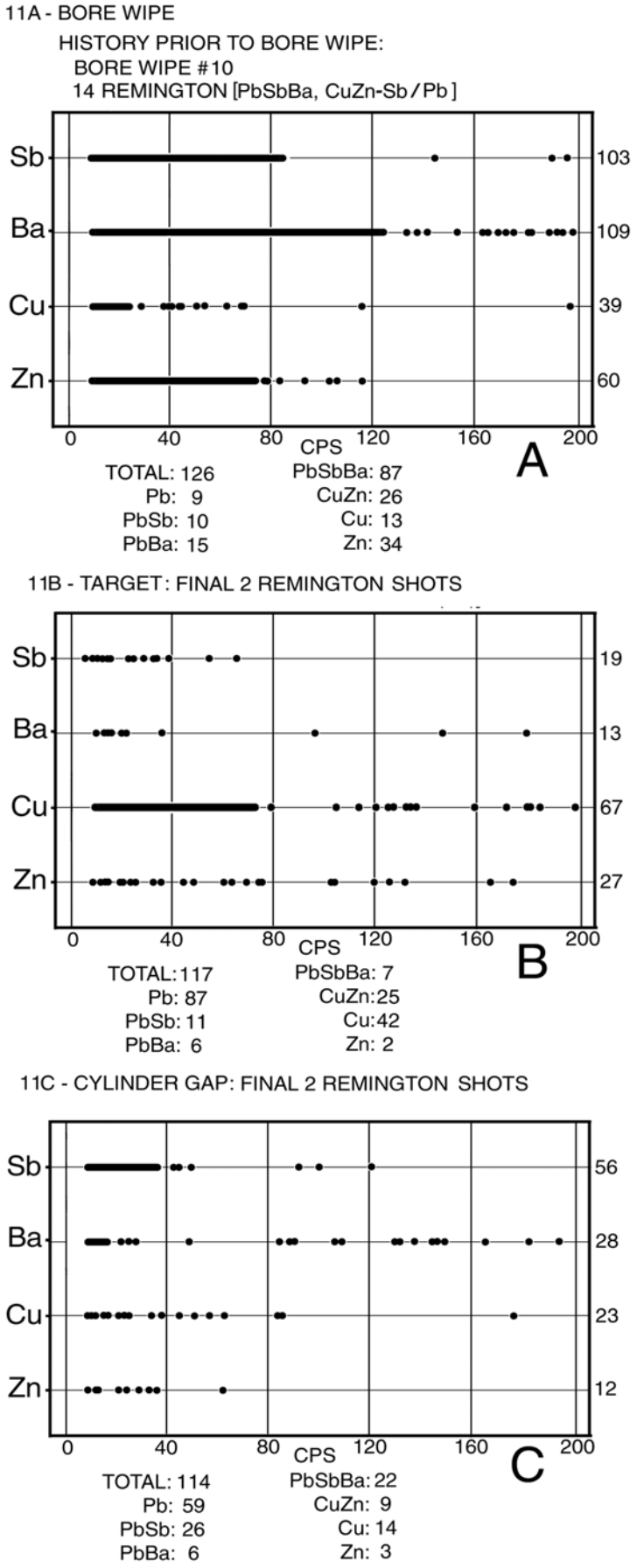

Figure 15. Sample series 11. See Fig. 4 for an explanation. The bore wipe was taken after the final shot of this sample series. The target and cylinder-gap samples were taken with the last two shots in this series.

(continued from page 11)

Sample series 9 (Fig.13). For these samples, 24 shots of Winchester Wildcat ammunition (primer: lead-barium; bullet: no coating & antimony layer) were fired prior to two shots of Remington (primer: lead-antimony-barium; bullet: copper-zinc coating & antimony layer). The target (Fig. 13B) and cylinder-gap samples (Fig. 13C) are from the final two shots. The bore and target samples show high percentages of antimony and barium both of which are likely mostly from the primers of the Remington ammunition. The bore and target samples show brass in the gunshot residue particles (10 and 16% respectively). Copper without zinc in the gunshot residue particles is low in the bore sample and quite high in the target sample. For the cylinder-gap sample, the copper-zinc component is low < 3%, but the copper in the gunshot residue particles is fairly high (34%) and likely originates from the bullet coating.

Sample series 10 (Fig. 14). The 24 Winchester Wildcat (primer: lead-barium; bullet: no coating & antimony layer) shots were followed by two Peters (primer: lead; bullet: copper-zinc coating & Antimony layer) shots. The bore sample (Fig. 14A) is unremarkable in that barium can be found in 15% of the particles presumably mostly from the Winchester primer. Some zinc without copper is found in this sample, a phenomenon noted in bore wipes from pervious sample series following Peters or Remington shots. The target sample (Fig. 14B) is apparently relatively free of contamination (i.e., barium-containing particles) from the previous shots of Winchester ammunition and has a small amount of brass and a high level of copper. However, the cylinder-gap sample (Fig. 14C) is heavily contaminated with barium and to a lesser extent antimony. There are comparatively few copper-zinc- and copper-containing particles in this sample compared to the other cylinder-gap samples (Table 3).

Sample series 11 (Fig. 15). The final 14 shots of this series of experiments were all Remington (primer: lead-antimony-barium; bullet: copper-zinc coating & antimony layer). The bore wipe (Fig. 15A) that followed these shots showed a large percentage of particles that contain antimony and/or barium or both with lead (highly specific gunshot residue particles). Copper-zinc is well represented (21%). Copper (10%) has a fairly low gunshot residue particle association compared to zinc (27%). Interestingly, the bore sample as in some of the previous bore samples (e.g., Fig. 8A) also showed particles containing zinc without detectable copper. The cylinder-gap sample (Fig. 15C) showed a larger percentage of particles containing copper (12%) and fewer brass particles (8%).

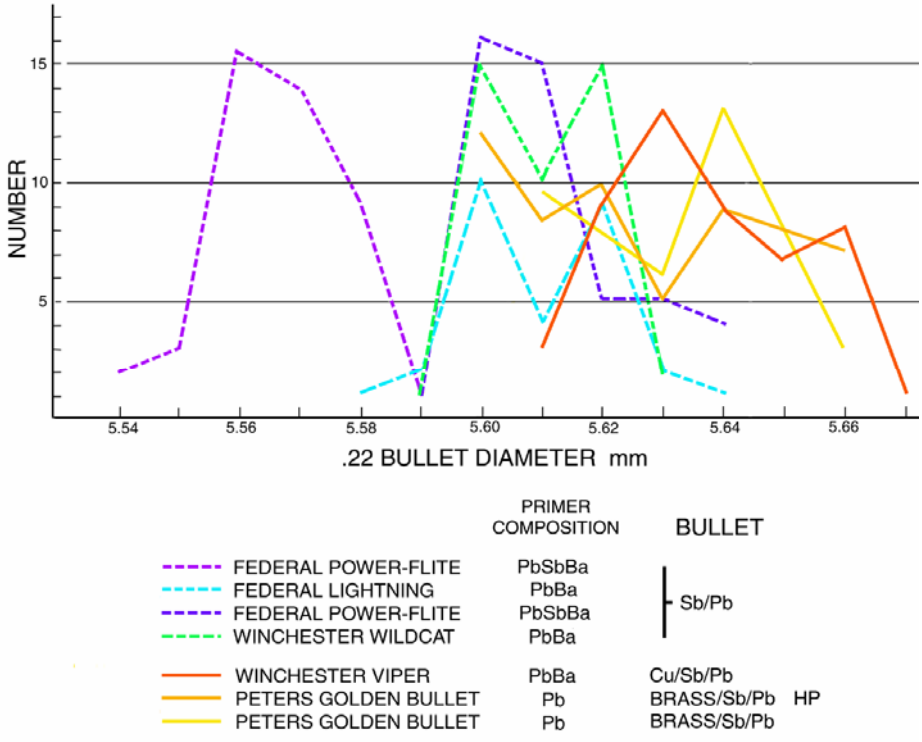

Figure 16. Graph plotting number of bullets verses bullet diameter for the seven .22 ammunitions that are identified in the lower part of the figure. Fifty bullets were measured for each ammunition brand/type. The primer compositions of these ammunitions follow the company/brand entry. Uncoated bullet (lead or antimony-layer on lead) diameters are dashed lines and coated (copper or copper-zinc) are solid lines. "BRASS/ Sb/Pb HP" = brass coat on antimony layer on lead bullet, hollow point.

Bullet diameter. There is a fair amount of variability in the diameters of the .22 bullets (Fig.16). It appears likely that the brass or copper coating is applied to standard-diameter bullets, thus making the coated bullets generally larger in diameter than the uncoated bullets.

The Aceves S&W revolver. The bore gunshot residue particle distribution for the Aceves S&W revolver is shown in Fig. 17A. The percentage of barium in the Aceves S&W revolver bore compared to the experiment series (Table 2) shows this value is above all the samples (sample series 2, 4,

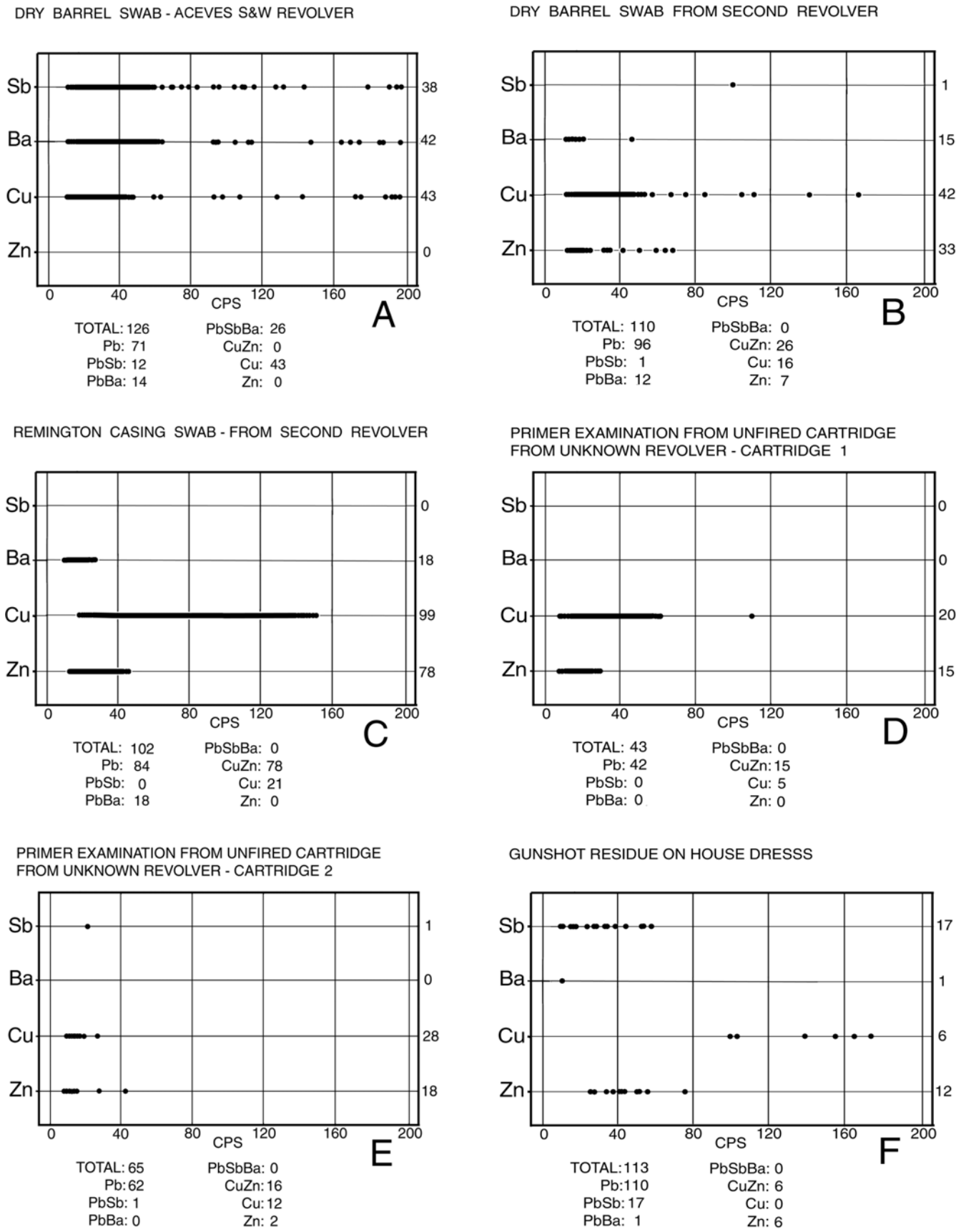

Figure 17. Summary of the elemental analyses performed on evidence items of the Aceves case. A: The dry barrel swab from the Aceves S&W revolver. B: The dry barrel swab from the unknown make 9-shot .22 revolver. C: Casing swab from the fired .22 casing taken from the unknown make revolver. D: Primer analysis from one of the cartridges from the unknown make revolver. E: Primer analysis from a second cartridge from the unknown make revolver. F: Analysis of the metaliferous gunshot residue from the housedress. The results from the two fabric samples were combined.

5, 6, 7, 8, and 10) that were produced by shots that had primers with no barium. The experiment series (sample series 1, 3, 9 and 11; Table 2) where the final shot prior to the bore wipe was with cartridges that contained barium, shows that the Aceves S&W bore, 32.8% barium-containing particles is slightly below the lowest of these values.

The antimony composition of the Aceves S&W revolver bore is well above those percentages produced by antimony-less primers (sample series 2, 4, 5, 6, 7, 8 and 10; Table 3). It is also within the range for those samples that have antimony in their primers (Table 3, sample series 1, 3, 9 and 11).

The barium (Table 2) and antimony (Table 3) levels from the bore of the Aceves S&W revolver indicate the primer that produced this gunshot residue had a composition of lead-antimony-barium. A three-metal primer ammunition that created such bore gunshot residue would be Federal (manufactured prior to 1991) or Remington (after 1989, head stamp "Rem") (Burnett 2003B) or manufactured outside of the United States. Moreover, the Remington/Peters brass-coated bullet can be excluded due to absence of zinc (Table 4) in this bore sample. The experimental data show that virtually all the brass-coated Peters bullets left zinc without detectable copper in the bore (Table 4 and Figs. 8A, 10A, 11A, 12A, 13A, 14A and 15A). The lack of zinc in the bore of the Aceves S&W revolver (Fig. 17A) means that the Peters ammunition was not the last ammunition fired in this weapon prior to the bore wipe. These data also indicate that the last bullet fired in the Aceves S&W revolver was likely copper coated. Therefore, the last shot fired in the Aceves S&W revolver was not a brass-coated Remington/Peters cartridge with a lead-only primer.

The Peters ammunition that was associated with the Aceves S&W revolver was confirmed to have lead as the only heavy metal in the primer.

The .22 unknown-make revolver. The bore swab of the revolver of unknown manufacture shows a large number of lead-only gunshot residue particles with only one antimony-containing particle. More than 10% of these particles have barium present which is within the range of a weapon that fired cartridges with a primer of lead-barium followed by two shots of barium-lacking Remington/Peters cartridges (Table 2). The antimony composition of the bore wipe from the unknown revolver is also consistent with this scenario.

Represented in this population of gunshot residue particles are brass (24%), copper(15%) and zinc (6%). These data are consistent with the firing of ammunition containing a primer composition of lead-barium prior to two Remington/Peters shots (Table 4).

The analysis of one Remington/Peters casings from the second revolver showed 18% of the particles had barium associated (Fig. 17C). This suggests that the gunshot residue in this casing likely was contaminated from residue from the anterior part of the cylinder chamber and, perhaps, the bore of the revolver. Another possibility is that barium was associated with the primer of this cartridge. In order to get a more reliable sampling of

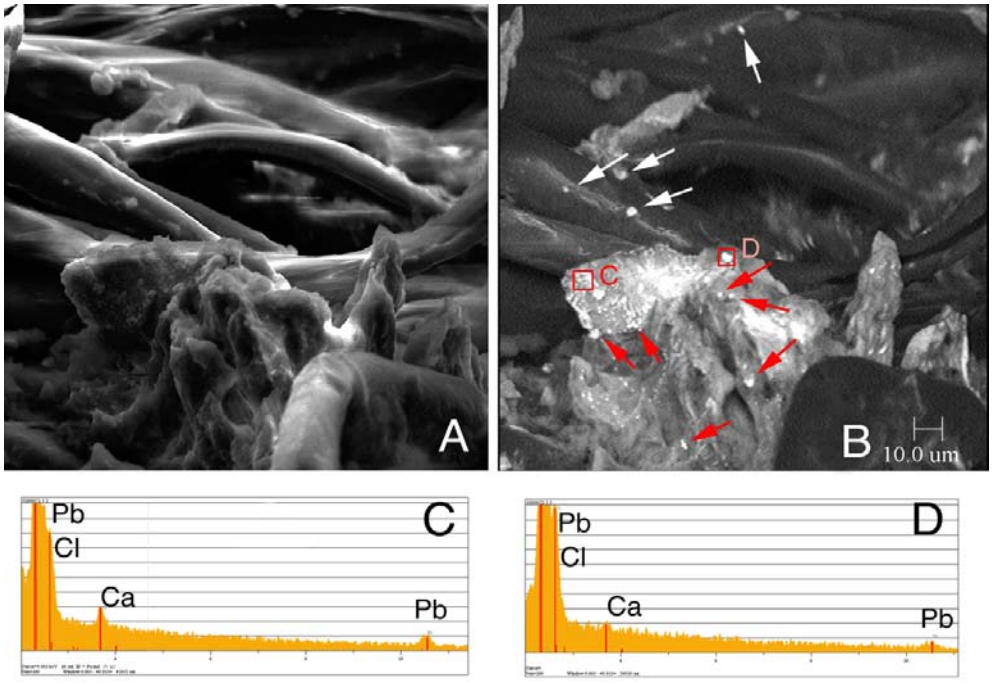

Figure 18. Gunpowder fragment associated with the housedress fibers. A: Secondary image. B: Backscatter image. Red arrows, indicate metaliferous gunshot residue on apparent gunpowder surface. White arrows, metaliferous gunshot residue on the dress fibers. C & D: Spectra of two of the metaliferous particles found on the dress. The chlorine (Cl) is from the dress fibers.

Table 2. The percent of total particles containing barium of the analysis and the case samples. The presence of barium in the GSR from lead-only cartridge shots (Aguila or Remington/Peters) is an indicator of previous-shot contamination. Shaded areas: the cartridge of the final shot of the series contained barium in its primer.

SAMPLE SERIES	PERCENT BARIUM BORE✦	TARGET	CYLINDER GAP
1	34.0	---	---
2	17 2.1	---	---
3	52.4	---	---
4	2 3.0	1.0✦	---
5	38.1	---	---
6	2 5.8	1.0✦	---
7	26 14.6	0⁜	44.8⁜
8	2 26.1	8.9⁜	25.0⁜
9	69.9	23.0⁜	34.7⁜
10	2 13.0	1.0⁜	35.6⁜
11	86.5	11.1⁜	24.6⁜
ACEVES REVOLVER	32.8	---	---
UNKNOWN REVOLVER	13.6	---	---
HOUSE DRESS	---	0.9	---
GLOVES/ SHIRT	---	---	7.1

The final cartridge fired of the series has primer barium

Number of Ba-free primers fired before sample

✦ Sample represents the final shot of series

⁜ Sample represents the final two shots of series

the primer material for the ammunition associated with the second revolver, two of the casings were separated from their respective bullets and the primer material analyzed (Figs. 17C and 17D). The results from these analyses show lead particles with only antimony and no barium. This is consistent with primer composition of Remington/Peters cartridges that have a head stamp of "U" (Burnett 2003B). Also notable for the Remington/ Peters cartridges is the presence of calcium (Ca) in the primer material (Fig. 20).

Gunshot residue on housedress. The housedress had been soaked with blood (Fig. 3A). A digestion solution (Burnett 1993) was used to remove the dried blood from the fabric so that the gunshot residue associated with the fabric could be found and identified with energy dispersive X-ray analysis. Examination in the scanning electron microscope of the housedress fabric showed the presence of apparent gunpowder fragments among the fabric fibers (Fig. 18A). Many of these gunpowder fragments had particles of apparent surface metaliferous gunshot residue (Fig. 18B, red arrows). There were, however, gunshot residue particles associated with the fabric fibers (Fig. 18B, white arrows). One aggregate of particles was found (Fig. 19A, box) that had gunshot residue particles likely derived from the bullet in that all the particles had combinations of lead, antimony, copper and zinc.

The dress received muzzle gunshot residue due to the presence of apparent gunpowder flakes. It also may have received cylinder-gap gunshot residue. The analyses of the gunshot residue particles on the dress showed the presence of calcium for many of these particles (Table 4), but these particles average less calcium/particle counts per second than the test-shot gunpowder gunshot residue. The same is also true for silicon. In addition, the lack of barium from the dress sample gunshot residue indicates that the Remington ammunition used in the shooting had primers of the

single-metal lead, not the thee-metal (lead-antimony-barium) type. Either the Remington/Peters primer material was a different composition for the ammunition that shot the victim or the processing of the fabric of the dress to remove the blood modified the levels of both silicon and calcium.

Table 3. Listing of the percent antimony of the samples series 1 through 11 (Figs. 5 through 15) and the case samples (Fig. 17). For the sample series and results that are shaded, the last shot of that series had antimony-associated primer. Dashed lines: no samples taken. The red number in the "BORE" column is the number of shots preceding that sample that did not have antimony–containing primer . For example, 102 shots preceded the samples of series 8 did not have antimony-associated primers. For sample series 4, there were 24 shots with antimony-containing primers that preceded 2 shots of antimony-free primer cartridges. For series 9, there were 126 shots that preceded this series that did not have primer antimony and the final two shots had antimony-containing primers.

SAMPLE SERIES	PERCENT ANTIMONY BORE✦			TARGET	CYLINDER GAP
1		23.4	?	---	---
2	17	1.5	-	---	---
3		47.5	?	---	---
4	2	5.5	+	0✦	---
5	26	0.7	+	---	---
6	52	0	+	0✦	---
7	76	2.1	+	4.0⁜	22.8⁜
8	102	9.0	?	8.8⁜	15.0⁜
9		49.6	+	34.5⁜	9.2⁜
10	26	0	+	2.1⁜	10.7⁜
11		81.7	+	16.2⁜	49.2⁜
ACEVES REVOLVER		29.7	?	---	---
UNKNOWN REVOLVER		0.9	?	---	---
HOUSE DRESS		---	?	15.0	---
GLOVES/ SHIRT		---	?	---	64.0

The final cartridge fired of the series has primer antimony

Number of Sb-free primers fired before sample

\+ Sb layer on bullet

\- No Sb layer

? Sb layer on bullet uncertain

✦ Sample represents the final shot of series

⁜ Sample represents the final two shots of series

Alleged gunshot residue on defendant's apartment items. The particles found on the blue shirt and the surgical glove (Fig. 2) are suggestive of gunshot residue. However, percent composition of the particles found on the shirt and surgical glove from the defendant's apartment (lead = 29%, lead-antimony = 64% and lead-barium = 7%, Fig. 2) are quite different from any of the experimental compositions. For the experimental cylinder-gap samples with the Peters ammunition (series 7C, 8C and 10C; Figs. 11C, 12C and 14C), particles with the composition of lead-antimony are 7.6, 8.0 and 4.7% respectively.

The apparent contamination of the .22 unknown-make revolver by barium indicates that this revolver had previously fired ammunition with barium-containing primer. If this were the weapon that generated the apparent gunshot residue on the items from the defendant's apartment, it would account for the one lead-barium particle found on the blue shirt. The high number of antimony-containing particles could have been the result of a chance "pulse release" (Burnett 2003A) from a weapon such as the unknown-make revolver firing Peters ammunition. The lack of copper-zinc or

copper with these particles suggest an origin other than the revolvers in question in this case, since most of the cylinder-gap samples from the tests had heavy contributions of either copper-zinc or copper (Table 3). However, lack of copper-zinc or copper associated with these particles is consistent with the results of experiment series 10 (Fig. 14 and Table 3), where only a small percentage of the particles contained copper-zinc or copper. It is possible that the combined sample of particles from the blue shirt and the surgical glove is not large enough to document a copper-zinc or copper association.

Previous shot contamination. The cylinder-gap gunshot residue particles of sample series 7, 8 and 10 (Figs. 11, 12 and 14) show that contamination (identified by presence of barium) from previous shots may for some samples be over 25% (Table 2). Experiment series 7 (Fig. 11) is particularly interesting in that after 22 shots of lead-only primer, apparent contamination (barium-associated particles) in the bore still makes up more than 10% of the gunshot residue. The previous-shot contamination for the cylinder-gap sample of this same series is greater than 40% of the gunshot residue. It is apparent that a breech deposit on the hands of a shooter can have a gunshot residue composition that has little resemblance with the primer composition of the cartridge that was fired in the weapon. Apparent contamination contribution to the gunshot residue samples is also notable with all the samples of the experiment series 8 (Fig. 12) and the cylinder-gap sample of series 10 (Fig. 14C).

Table 4. Percent of the gunshot residue particles that have a copper-zinc (CuZn) or copper (Cu) or zinc (Zn) component for all the sample series. The row labeled "X-bar" is the average of the seven samples of series, 4, 6, 7, 8, 9,10 and 11, (shaded) where the final shot was a brass-coated bullet. There were no samples taken in the areas that lack entries.

PERCENT COMPOSITION

	BORE			TARGET			CYLINDER GAP		
	CuZn	Cu	Zn	CuZn	Cu	Zn	CuZn	Cu	Zn
1	0	0	0						
2	0	20.0	0						
3	0	1.0	0						
4	6.1	7.1	29.3	5.9	27.7	3.0			
5	0	2.0	0						
6	8.7	2.9	20.2	11.8	45.2	2.2			
7	14.6	29.2	9.4	12.9	42.6	3.0	78.1	8.6	0
8	12.6	10.8	11.7	9.7	43.4	0	13.0	33.0	2.0
9	8.8	2.7	4.4	14.2	28.3	1.8	2.0	33.7	2.0
10	6.0	7.0	4.0	5.2	42.3	0	2.7	0.7	3.4
11	20.6	10.3	27.0	21.4	35.9	1.7	7.9	12.3	2.6
$\bar{X}$	11.6	10.0	15.1	11.6	37.9	1.7	20.7	17.6	2.0
ACEVES REVOLVER	0	34.1	0						
UNKNOWN REVOLVER	23.6	14.5	6.4						
HOUSE DRESS				5.3	0	5.3			
GLOVES/ SHIRT							0	0	0

Shaded area: Final shot's bullet for the series is brass coated.

Bullet components in gunshot residue. Zeichner et al. (1997) state for breech gunshot residue that the contribution of bullet antimony to antimony-containing gunshot residue particles usually represents less than 2%. This appears to be often the case (sample series 4, 6 and 10; Figs. 8, 10 and 14 respectively). However, in the series 7 breech sample (Fig. 11C), 23% of the gunshot residue particles have antimony present. The last cartridge fired with a primer containing Antimony was 75 shots previous to this shot – suggesting the bullet as the likely source of this elevated antimony content. But, the in same breech sample, 47% of the gunshot residue particles have barium after 24 shots of Lead-only primered ammunition.

In the experiment series 8 (Fig. 12) the gunshot residue data were generated by two Peters cartridges which followed the firing of 24 Federal Lightning cartridges (primer: lead-barium). Interesting for this series is that the antimony contribution to all samples is somewhat greater than that of the bore and target of the previous series (Fig. 11 and Table 3). The last primer-containing antimony shot was 102 shots previous to this sample. Again, the origin of this antimony is likely from either the antimony layer on the Federal Lightning or Peters bullets. The contribution of bullet antimony, especially to breech gunshot residue is likely in some gunshot residue populations to be substantially greater than the Zeichner et al. (1997) 2% estimate.

The Zeichner et al. (1997) observation of 2% bullet contribution to gunshot residue obviously does not apply to those .22 bullets that have either a coating of copper or brass. Copper/zinc ("brass") was found in 78% of the gunshot residue in one sample (cylinder gap, sample series 7C, Fig. 11C). Copper-zinc contributions to all samples that were taken with one or two shots with the Peters ammunition were usually greater than 10% (Table 3) and even a higher percentage if the component copper- or zinc-associated particles are added to this calculation.

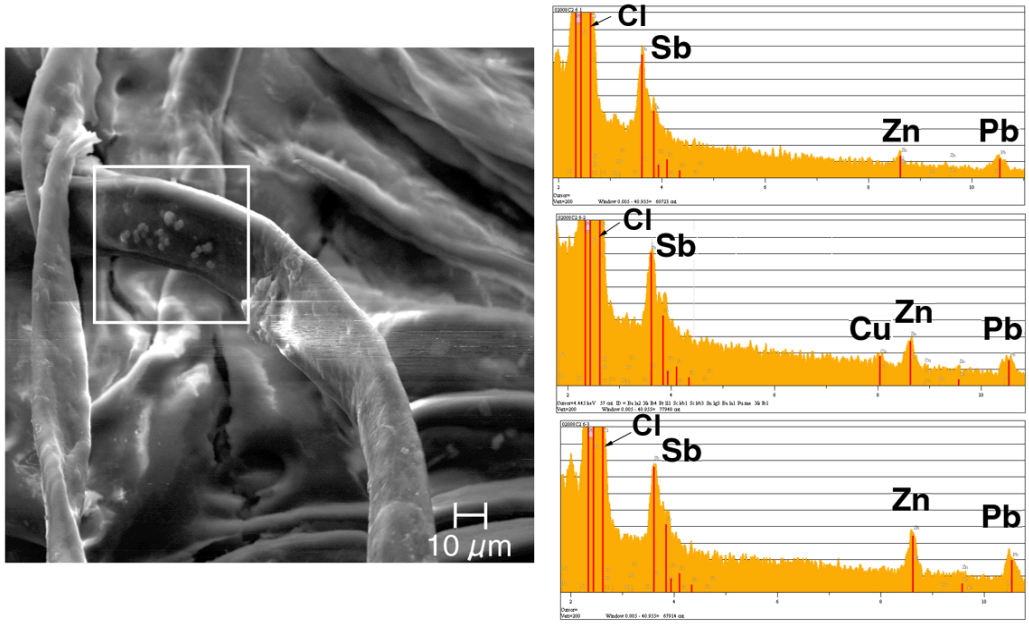

Figure 19. Secondary electron image of dress fibers with associated metaliferous gunshot residue with spectra of three of these particles.

The brass bullet coating of the Remington/Peters ammunition exhibits a behavior when fired that often deposits zinc-rich particles in the bore of the weapon. One sample (bore sample, series 4, Fig. 8A), 29% of the gunshot residue particles contained zinc without detectable copper. Copper from the brass coating appears to be preferentially concentrated in the target samples and some samples from the cylinder gap (Table 3). For example, the target sample from series 4 (Fig. 8B) appears to be enriched with copper. McVicar (2003) noted that zinc is preferentially depleted from the inside of cartridges in center-fire ammunition and gunshot residue with high zinc has been observed. It is apparent that a separation of copper from zinc occurs with the brass coating on the .22 bullet where copper tends to enrich in the target gunshot residue samples and the zinc the bore. There is, however, some variability (Table 3). The cylinder-gap samples are even more variable in copper-zinc and copper levels than the target samples. The low percentage of zinc-associated gunshot residue particles (i.e., copper not detectable) in the cylinder-gap samples corresponds to that of the target samples (Table 3).

Why does it generally appear that brass or copper coatings of .22 bullets have much more of a propensity to show up in the gunshot residue particles than bullet-derived antimony (despite the uncertainties with the antimony origin)? The diameters of the bullets from seven different batches of .22 cartridges are plotted in Fig. 16. The diameters of the copper- and brass-coated bullets are generally larger than that of the uncoated bullets. Figure 16 also shows some bullets that lack brass or copper coatings are within the size range of the brass-coated bullets. It certainly is no stretch of the imagination to propose that the diameter of a bullet influences the degree with which the surface of the bullet is ablated during firing. Perhaps those bullets without a copper or brass coating that have a diameter in the high range (> 5.62 mm, Fig. 16) also provide more than usual antimony bullet-surface material to the gunshot residue particles.

A "dirty" gun. An issue that was not anticipated in this series of experiments was the effect of apparent accumulation of bullet and primer components on parts of the gun over the duration of these experiments. In other words, the revolver became increasingly fouled with gunshot residue with each firing of the weapon. In retrospect, this should not be at all surprising (Basu et al. 1984). The magnitude of gunshot residue contamination (as measured by barium levels in shots from cartridges with lead-only primers) by previous shots generally increases with each shot (Table 2). Thus, the gauge of a "dirty" weapon is the increase in contamination of the current gunshot residue population from elements generated by previous shots.

Gunpowder. Inspection of the fabric from the housedress in the scanning electron microscope showed apparent partially burned gunpowder amongst the fabric fibers (Fig. 18). There were metaliferous gunshot residue particles associated with this material (Fig. 18B, red arrows). Metaliferous gunshot residue associated with gunpowder has been previously observed (e.g., Burnett 1989B). Apparently, the unconsumed or partially consumed gunpowder flakes as they travel down the bore of the gun, intercept molten metaliferous gunshot residue. Gunpowder fragments completely covered with metaliferous gunshot residue (Fig. 21A, white arrows) are observed. Other flake surfaces are partially covered (Fig.

Table 5. A listing of the elements silicon (Si) and calcium (Ca) associated with the metaliferous gunshot residue particles on five samples of gunpowder flakes from four different ammunitions and housedress samples. Primer: the metal primer composition of the particular ammunition. Total #: the number particles analyzed with energy dispersive X-ray spectroscopy.

		FEDERAL POWER-FLITE	FEDERAL LIGHTNING	WINCHESTER WILDCAT	PETERS GOLDEN B.	PETERS GOLDEN B.	HOUSEDRESS
PRIMER		PbSbBa	PbBa	PbBa	Pb	Pb	—
TOTAL #		120	120	119	112	120	113
Si	%	7	24	59	97	89	32
	$\bar{X}$	30	168	146	375	344	30
Ca	%	2	—	—	96	73	85
	$\bar{X}$	43	—	—	62	83	33

TOTAL# - The number particles analyzed with energy dispersive X-ray analysis
% - Percent of particles that has this element
$\bar{X}$ - Average element CPS

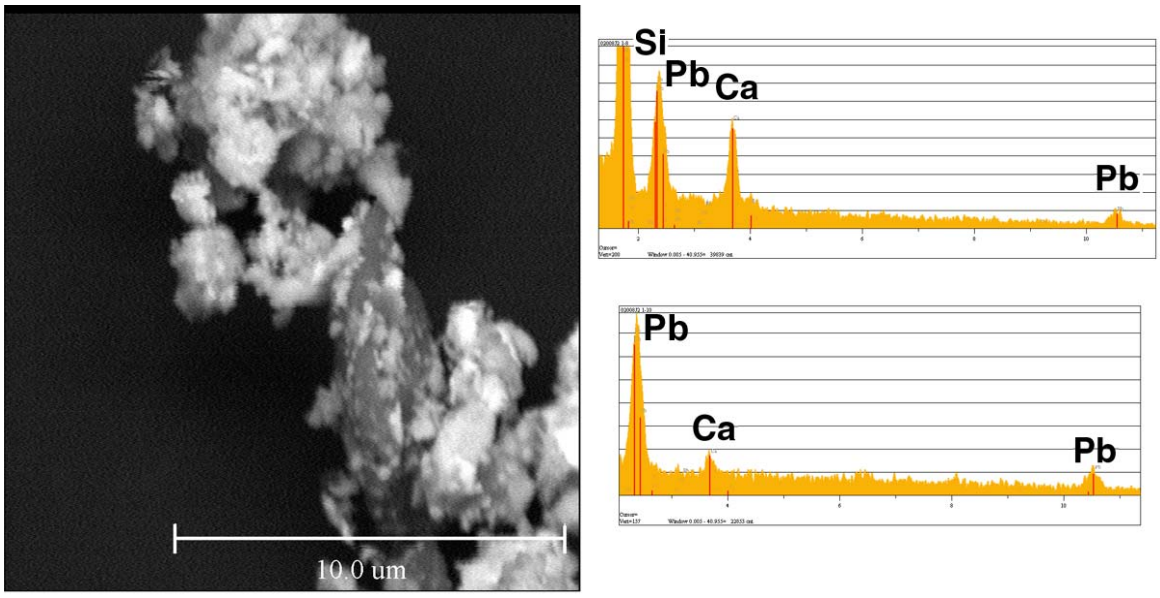

Figure 20. Secondary electron image of primer material with two example spectra of this material.

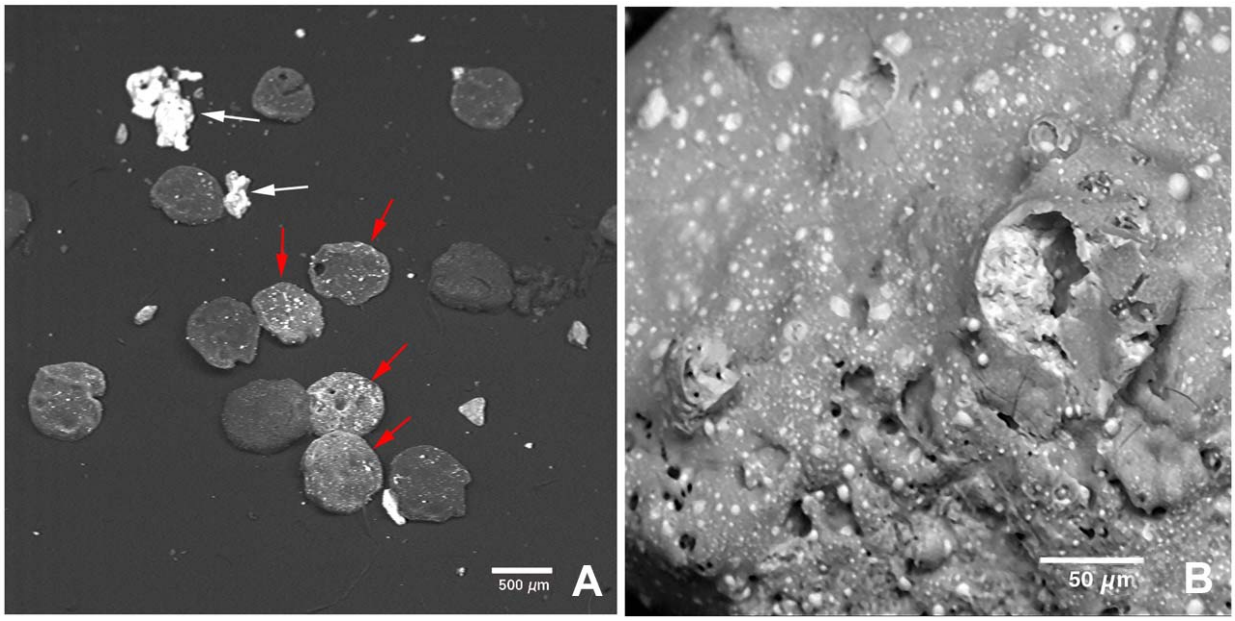

Figure 21. Backscatter electron images of fired gunpowder. A: Low magnification image of gunpowder flakes from a Peters Golden Bullet cartridge. Heavy backscattering objects (white arrows) are the metaliferous gunshot residue particles that are covering the flakes. Red arrows, lower density metaliferous gunshot residue on powder. B: Higher magnification of a gunpowder flake from a Federal Lightning cartridge showing the metaliferous gunshot residue (white blebs) scattered over its surface.

21A, red arrows) or have only scattered metaliferous gunshot residue particles. Some have none at all. The metaliferous gunshot residue particles appear on many of the flakes as pox-like blebs (Fig. 21B) and the results of the analyses of these gunshot residue particles on gunpowder flakes are presented in Fig. 22 for four different brands of ammunition.

Noteworthy is the consistency of the compositions of the metaliferous gunshot residue particles on the flakes with that of the primer for each cartridge brand tested. There appears to be no contamination from previous shots for these metaliferous gunshot residue populations. Antimony was found on these gunpowder flakes only when it was a part of the primer composition (Fig. 22A). The Federal Lightning (Fig. 22B) and Winchester Wildcat (Fig. 22C) ammunitions both had bullets with an antimony layer, but antimony was not observed on flakes from either ammunition. However, for both the Peters shots (Figs. 22D and 22E), the metaliferous gunshot residue on the gunpowder flakes had a substantial number of particles showing either copper-zinc or copper.

The apparent conservation of the primer metaliferous composition on the flakes may also apply for other elements such as silicon (Si) and calcium (Ca). Both silicon and calcium are found in the Peters primer (Fig. 20). These elements are also part of the metaliferous gunshot residue on the gunpowder flakes (Table 4) but were rarely observed in the other gunshot residue samples (bore, target and cylinder gap) from the Peters gunshot residue samples.

CONCLUSIONS

The purpose of this paper is to provide a meaningful analysis of the gunshot residue evidence in the case of People v. Aceves. Until this study it was not known which primer type was used in the assailant weapon for the two .22 Remington/Peters shots fired at the victim nor was it known what effect of previously-used ammunition of a different primer composition have on bore, target and breech gunshot residue samples. In order to explore these issues, a variety of different ammunitions (Table 1) were fired prior to two shots of Remington/Peters cartridges (experiment series 7 through 11, Figs. 11 through 15) in a revolver of the same model (S&W .22 revolver, Model 18) as the alleged weapon used in the assault.

The amount of antimony and barium in the bore wipe of the Aceves S&W revolver are suggestive that the last shot or shots fired were from ammunition with a three-metal (lead-antimony-barium) primer. This supports the defendant's father's contention that he last fired Federal ammunition in the Aceves S&W revolver. However, barium and antimony contamination from previously fired ammunition as well as a contribution of antimony

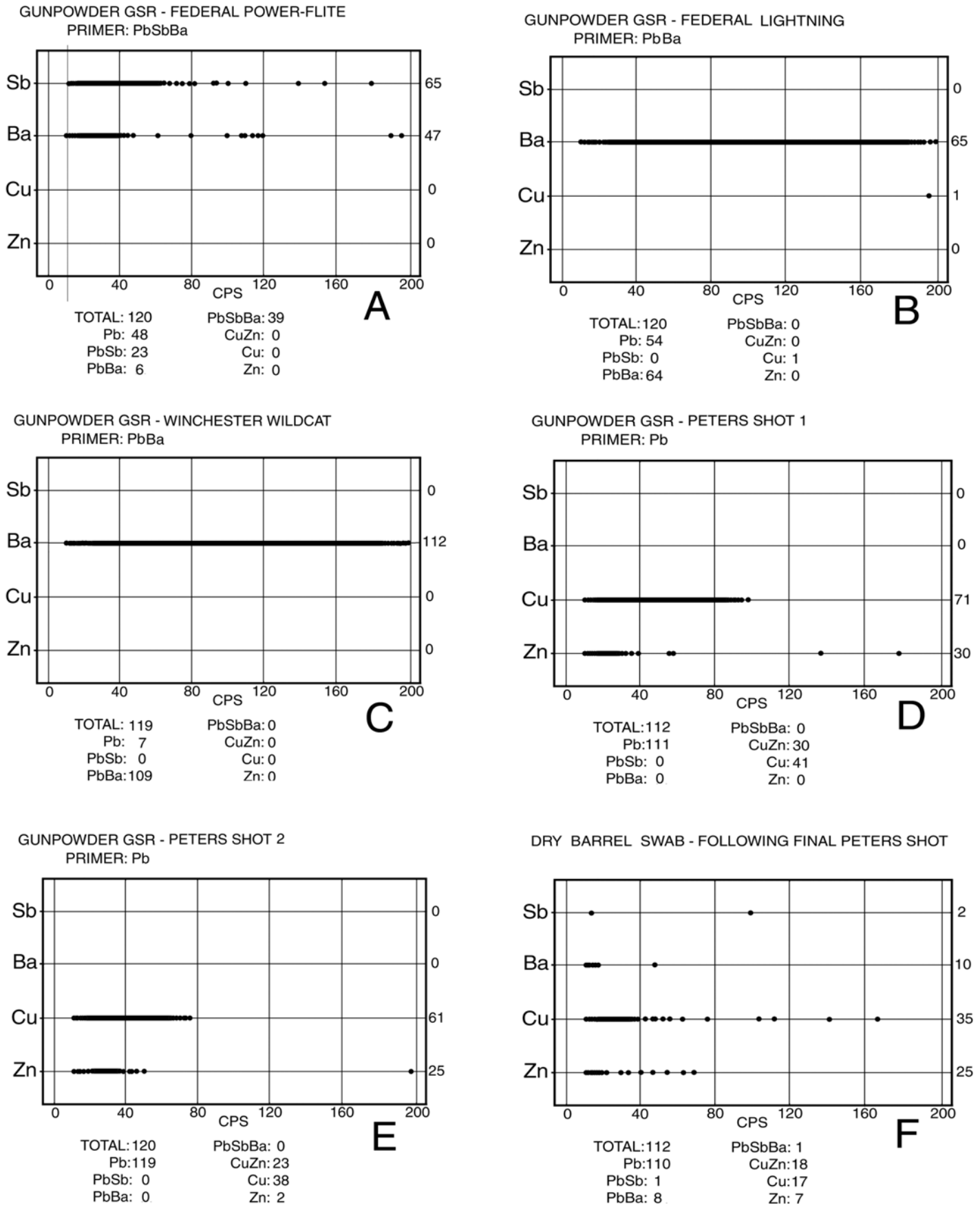

Figure 22. Summary of the elemental analyses performed on the metaliferous gunshot residue on the gunpowder flakes from four different ammunitions. A: Federal Power-Flite (primer: lead-antimony-barium). B: Federal Lightning (primer: lead-barium), C: Winchester Wildcat (primer: lead-barium). D & E: Peters Golden Bullet (Primer: lead). F: Bore wipe following these shots.

from the bullet may be possible (but unlikely) in this bore sample. All the test firings of Peters .22 bullets that were coated with brass showed zinc either with copper or by itself in the bore wipe that followed the shots. The high copper level (without zinc) in the bore of the Aceves S&W revolver indicates that the last bullet fired in this weapon was likely copper coated. Thus, the lack of zinc as well as the high levels of barium and antimony in the bore sample of the Aceves S&W revolver means it is quite unlikely that the last two cartridges fired in this gun were Remington or Peters cartridges with brass-coated bullets and a single-metal (lead) primer.

The gunshot residue deposited on the housedress was from one or more cartridges that had a primer composition of Lead. Calcium was a component of the gunshot residue deposit on the housedress. Observations of the metaliferous gunshot residue on gunpowder fragments produced by test-fired Peters ammunition show lead and calcium. Thus, the gunshot residue deposited on the housedress was likely from single-metal (lead) primer Remington/Peters ammunition.

The bore sample from the .22 revolver that was found in ivy patch indicates that the last fired cartridge in this weapon contained a primer composition of lead (i.e., a Remington or Peters cartridge). The primer composition also had calcium and, therefore, the gunshot residue deposited on the victim's housedress was likely from this type of cartridge.

The lead, lead-antimony and lead-barium particles found on the blue shirt and surgical glove that were from the defendant's apartment are problematic. The high percentage of antimony (64%) with these particles matches more gunshot residue from a lead-antimony-barium primered firearm that has fired multiple shots prior to this alleged gunshot residue breech sample (Table 3, sample series 11) than with the unknown-make revolver firing Remington/Peters ammunition. One could make a case for these particles coming from the Aceves S&W revolver that has fired cartridges with a primer of lead-antimony-barium (as originally proposed by the prosecution expert, Fig 2). But, considering sample series 7, 8 and 10 (Table 3, cylinder gap column), these particles are not likely to be from Remington/Peters lead-primer cartridges. Moreover, it cannot be ruled out that the single barium-containing particle may have been from a different source than the rest of the particles. It must be pointed out, however, that this sample size is quite small (i.e., sampling error may explain the composition makeup of these particles).

The results of the .22 test shots indicate that the generation of gunshot residue, especially from the cylinder gap, is unpredictable if the gun was previously used with different ammunition. In addition, likely bullet antimony accumulates on breech components, which adds additional uncertainty in any attempt to predict breech gunshot residue composition based on the primer composition of the last cartridge fired. Such an unpredictability of gunshot residue composition was also observed for a semi-automatic .22 pistol (Burnett 2003A) and center-fire weapons (Zeichner et al. 1991; Basu et al. 1997). Release of gunshot residue inconsistent from the current primer composition may increase, as the gun becomes fouled with gunshot residue from previous shots. Burnett (2003C) identified gunshot residue buildup locations on the same revolver used in the empirical part of this study.

As noted above antimony is problematic in that it is found both in primers of some .22 ammunitions (Wrobel et al. 1998; Burnett 2003A) and on the surface of most modern .22 bullets (Wrobel et al. 1998; Zeichner et al. 1997; Burnett 2003D). Data presented here suggest that bullet antimony may have a major contribution (> 10%) to gunshot residue composition in some gunshot residue samples. The claim that bullet antimony has limited involvement in the formation of gunshot residue (Wrobel et al. 1998; Zeichner et al. 1997) is likely incorrect for some .22 caliber shootings.

If gunshot residue matching is to be attempted in a case, it will behoove an investigator not only to obtain a gunshot residue sample from the bore of the weapon, but also from the breech components. In addition, recovery of unburned or partially burned gunpowder from the shooting may provide important data. Such information would likely explain a gunshot residue composition on hands of the shooter that does not correspond to the primer composition of the ammunition used.

Coumbaros et al. (2001) recently examine the composition of .22-generated gunshot residue on the hands of shooters from .22 ammunition with a primer composition of lead-barium. This study's results are inconsistent with the results presented here and may be due to the larger particles examined by these authors. The particles examined in the present study were approximately 1micron with an estimated plus/minus of 0.10 microns.

Burnett (1989B) and Neantimonyitt, et al (1976) reported metaliferous gunshot residue on the surface of partially consumed gunpowder. These authors did not attempt to relate metal-coated gunpowder residues to the origin primer compositions. From the limited sample size used in this study, the metaliferous gunshot residue coating the surface of some of the fired gunpowder flakes appear at least for .22 ammunitions to be more reflective of their origin primer compositions than that of the gunshot residue particle samples from the bore, target or cylinder gap. Additional experiments are certainly needed for perhaps an important new approach to gunshot residue analysis.

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Bryan Burnett
Meixa Tech
P.O. Box 844
Cardiff, CA 92007

brburnett@meixatech.com

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