Errors in gunshot residue assessment by scanning electron microscopy/ elemental analysis in criminal cases: III. Friction-brake particles assigned as "highly specific" gunshot residue particles

By Bryan Burnett

"To make valid inferences about a population from a sample, we must be reasonably certain that the sample is representative of the population" Byrkit, 1987.

Abstract. Automated scanning electron microscope analyses of gunshot residue samplers are being performed by many crime laboratories all over the world. Often the criminalist-technician operators of these instruments do not have adequate training for the interpretation of spectra generated by energy dispersive X-ray spectroscopy (parts I and II of this series) and distinguishing gunshot residue from similar composition particles from an environmental source (this article). In this case, gunshot residue-like particles were found on samplers from the hands of the defendant. The criminalist-technician called many of these particles "highly specific of gunshot residue." The presence of prominent iron with small copper and zinc peaks in almost all these "highly specific of gunshot residue" particle spectra indicate an automotive friction-brake origin. Gunshot residue from the victim and witness (bystander) samplers do not have associated iron, copper and zinc.

Introduction

The previous two articles of this series (Burnett, 2005A and 2005B) dealt with errors made by criminalist-technicians in the interpretation of element spectra. This third article of this series will deal with the misassignment of apparent friction brake-generated particles as "highly specific of gunshot residue" particles.

The homicide occurred at a residence inside an attached garage that was converted to a bedroom. The victim was shot four times with a 9 mm pistol at a distance where gunshot residue (soot/powder debris) was not visually noted on the victim. The witness to the shooting (who may have been the shooter) claimed the defendant was with him and the victim. For no apparent reason, according to the witness, the defendant shot the victim. The witness also claimed he was standing approximately ten feet from the victim when he was shot. The defendant then allegedly ran out of the room through a side door to his car and drove away. The pistol was not recovered.

Materials & Methods

Tape-lift samples were taken from the victim (left hand back and right hand back, 2 samplers) the witness (left hand back and right hand back, 2 samplers) , the defendant (left hand, palm and back and right hand, palm and back, 4 samplers) and the defendant's car (steering wheel and gear shift knob, 2 samplers). The witness's hands were sampled about 1.5 hours after the shooting and the defendant's hands were sampled more than eight hours after the shooting. An automated scanning electron microscope examination was performed on each sample by a prominent southern California crime laboratory.

That crime laboratory's procedure (Anon., 1997):

1. The gunshot residue samplers are placed within the SEM and the samplers are automatically scanned for GSR candidate particles.
2. The SEM-associated computer records the position of particles of interest. When the automatic run is completed, the analyst goes back to the particles of interest and performs a confirmation elemental analysis for each.
3. The analyst summarizes the data and records by handwritten notes as well as acquiring spectra and particle images.
4. A report is then written by the analyst that summarizes the analysis results as well as providing a conclusion.

The results of these analyses will be examined through the handwritten notes as well as the spectra and images.

Results and Discussion

The victim. A number of "highly specific" gunshot residue particles were identified by the analyst (Fig. 1). All of the particles where spectra and images were taken had compositions of lead, antimony and barium (Figs. 1A through 1E). One particle (Fig. 1A) not only had lead-antimony-barium, but also nickel, copper and zinc. The analyst noted additional lead-antimony-barium composition particles ("add PbSbBa", Fig. 1F), but did not provide a number. He also reported "many PbSb" as well as "Pb only" (Fig. 1F) and again did not provide numbers.

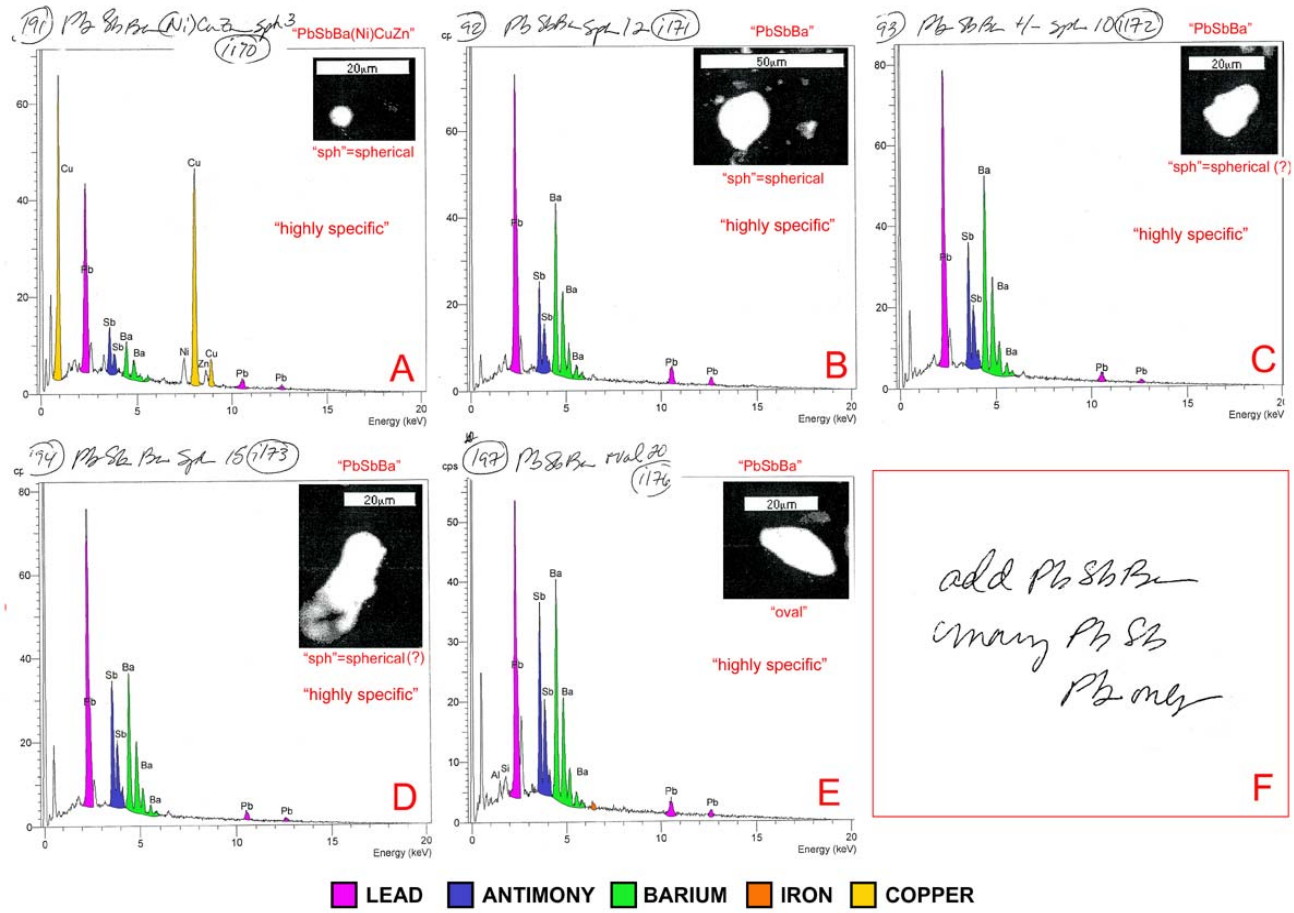

Figure 1. *Spectra, particle images and handwritten notes for the particles on the gunshot residue samplers from the victim. The handwritten note concerning each particle is at the top of each particle's spectrum and image. To the right of the handwritten note is the elemental composition that that note indicates for that particle. Below the image of each particle is the interpretation of the analysts particle shape (a (?) applied by the author for those shapes that seem to be at odds with the description). In the middle-right part of each spectrum is gunshot residue type, "highly specific," that the analyst has assigned to each of these particles. A through E: Particle spectra, images and interpretations. F: Handwritten notes of other particles observed by the analyst in this sample series.*

The witness. Spectra and particle images from the tape lifts from this individual's hands are shown in Fig. 2. These particles appear to show more diversity in composition than the particles found on the victim's samplers. Some of the particles from the witness were, according to the analyst, "highly specific," that is, these particles were composed of antimony-barium (Figs. 2A and 2B) and lead-antimony-barium (Fig. 2E). Matching the analyst's handwritten notes with the spectra, there are two misidentified spectra. A small amount of antimony is associated with one particle's spectrum (Fig. 2D) and the analyst misidentified another particle's prominent antimony peak, as barium (Fig. 2F).

The analyst's handwritten notes for the analyses performed on the samplers from the witness are shown in Fig. 3. In Fig.3A (highlighted area) shows entries that involve two particle types: the first "CuZn many" is problematic in that this analyst never defines what he means by "many." The second particle entry involves two lines. The first line: "114" is the spectrum number, "BaSbS"

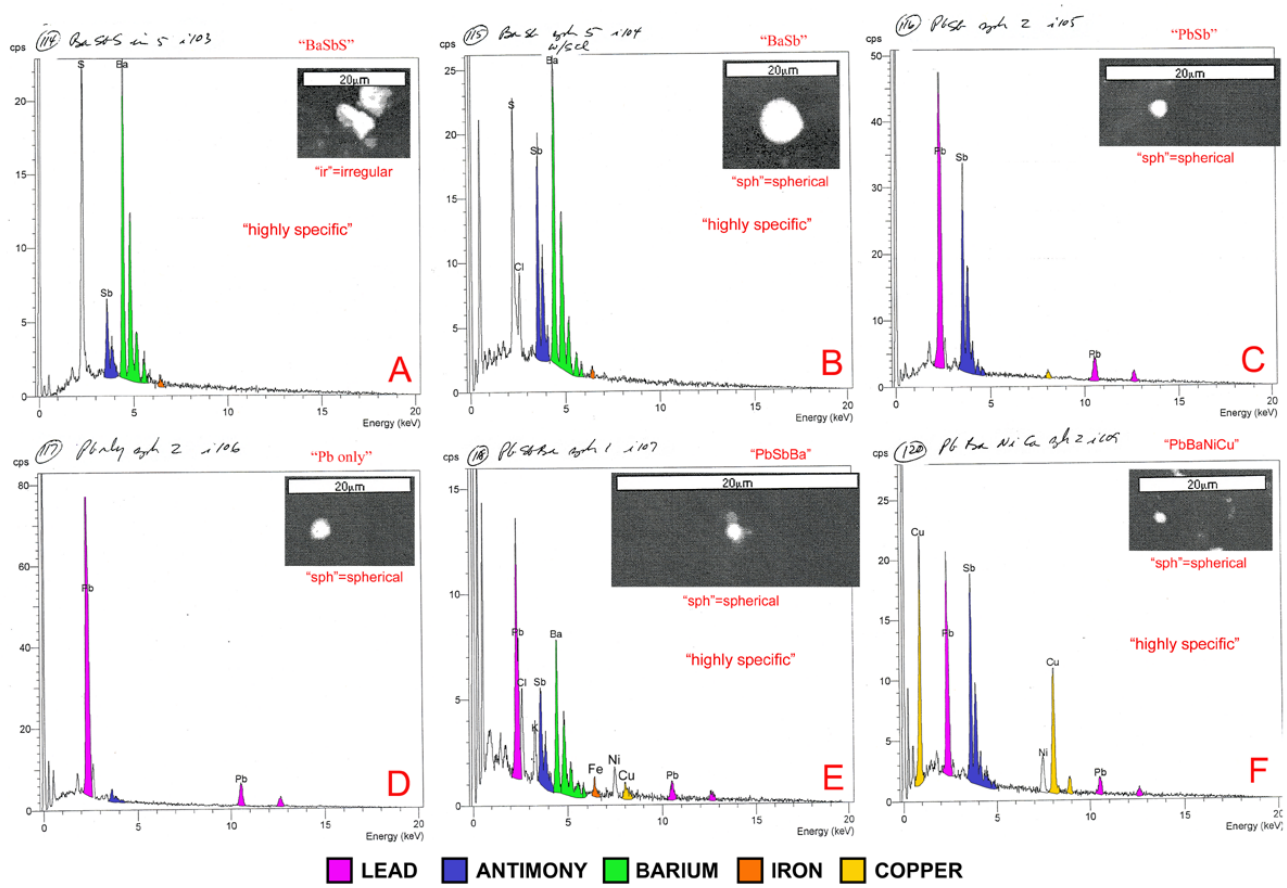

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Figure 2*. Spectra, particle images and handwritten notes for the particles on the gunshot residue samplers from the witness. The handwritten note concerning each particle is at the top of each particle's spectrum and image. To the right of the handwritten note is the interpretation of elements that that note indicates. Below the image of each particle is the interpretation of the analysts particle shape (a (?) applied by the author for those shapes that seem to be at odds with the description). In the middle-right part of each spectrum is gunshot residue type, "highly specific," that the analyst has assigned to the particle. Particles that do not have an assignment associated with the spectrum are "consistent" with gunshot residue.*

barium-antimony-sulfur, "ir"= irregular particle, "5" = size of particle in microns, "i103"=image 103. The second line, apparently for particle "114" is confusing – the first word appears to be "heterogeneous," "w/sb" (which apparently means "with antimony") and the last word is not legible. The highlighted B area of Fig. 3 appears to be "PbBaCrCa(?)K ClSi" and the last part of the line is illegible. Lead-phosphorus (PbP) is the entry for Fig. 3C – this is likely a particle that originated from soil (Cao et al., 2001). The entry "Z add Pb only" (Fig. 3D) is also meaningless to everybody but the analyst. What does "sev. add SbBa" mean? For the "few Sb" (Fig. 3E) entry, how many does "few" mean?

In these notes (and notes from other cases) the analyst's handwritten "Ca" (calcium) is often indistinguishable from "Cu" (copper).

The defendant. These samples were taken from the defendant's hands <u>eight hours</u> after the shooting. The particles identified as "highly specific" to gunshot residue from the defendant's hands are shown in Fig. 4. Notable is that only two of the particles have lead (Pb) and most have high iron as well as copper-zinc as part of the particles at issue. The particles shown in Fig. 4 were compiled from the results of four samplers: two from the hand backs and two from the hand palms.

The defendant's car. The defendant was driving a Ford Thunderbird. The gear shift as well as the steering wheel of this vehicle were sampled by tape lift. Some of the particle images and spectra are shown in Fig. 5. Of all the particles analyzed in these two samples, only one was found that had lead, antimony and barium (Fig. 5A) and, thus, the designation of "highly specific" was applied to this particle. The rest of the particles had compositions of either lead (Figs. 5A, 5B and 5C) or lead-antimony (Figs. 5E and 5F). These samples also showed lead and lead-antimony particles with tin (Figs. 6A, 6B and 6C).

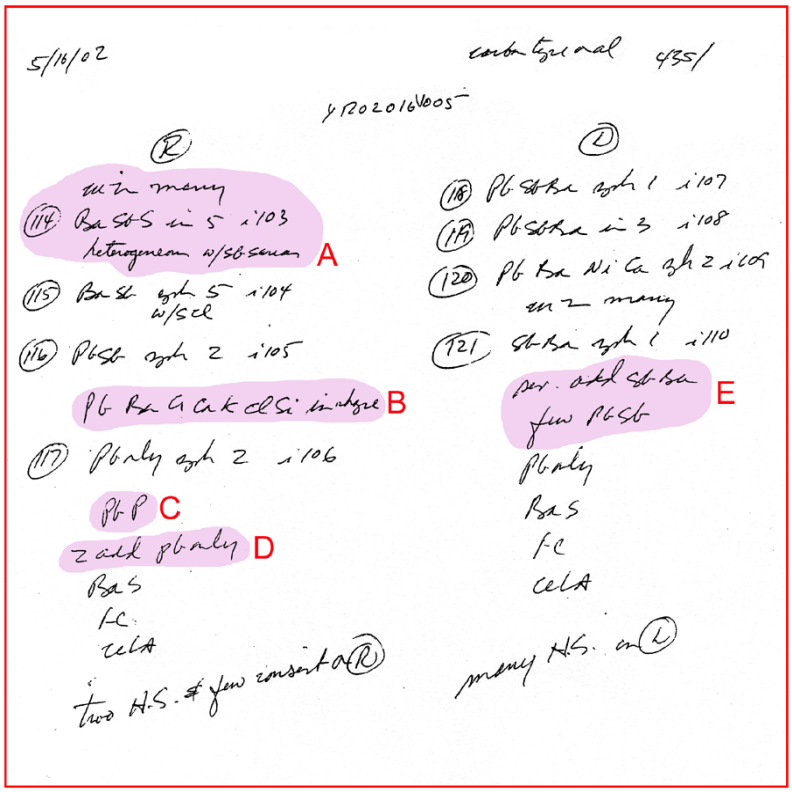

Figure 3. *The hand written notes from the analyst made after the automated analysis of the two samplers from the witness. Results of the right hand are on the left and from the left hand on the right. A through E: notations of the analyst referred to in the text.*

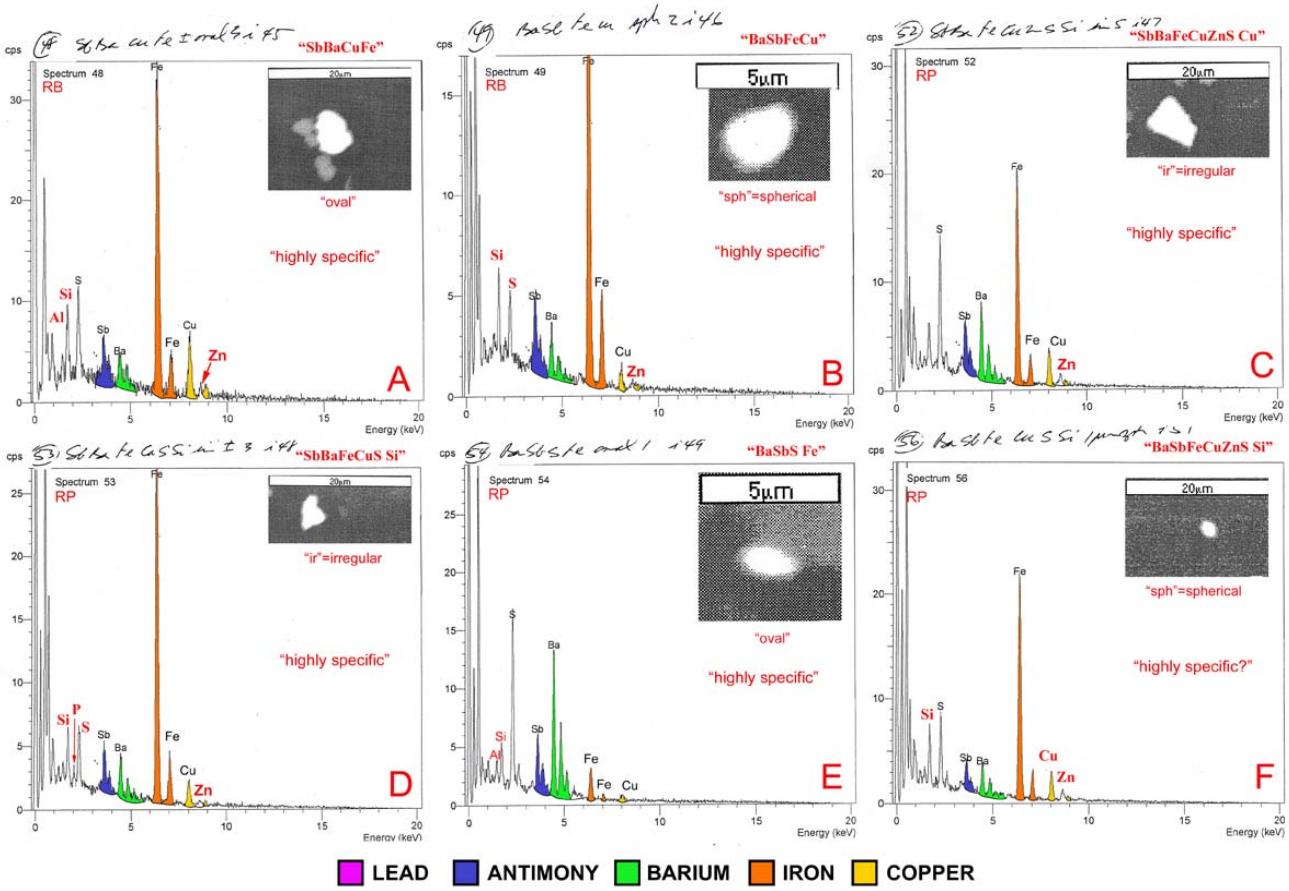

Figure 4. *Spectra, particle images and hand notes of six particles from the defendant's hand samplers. See Fig. 1 for details.*

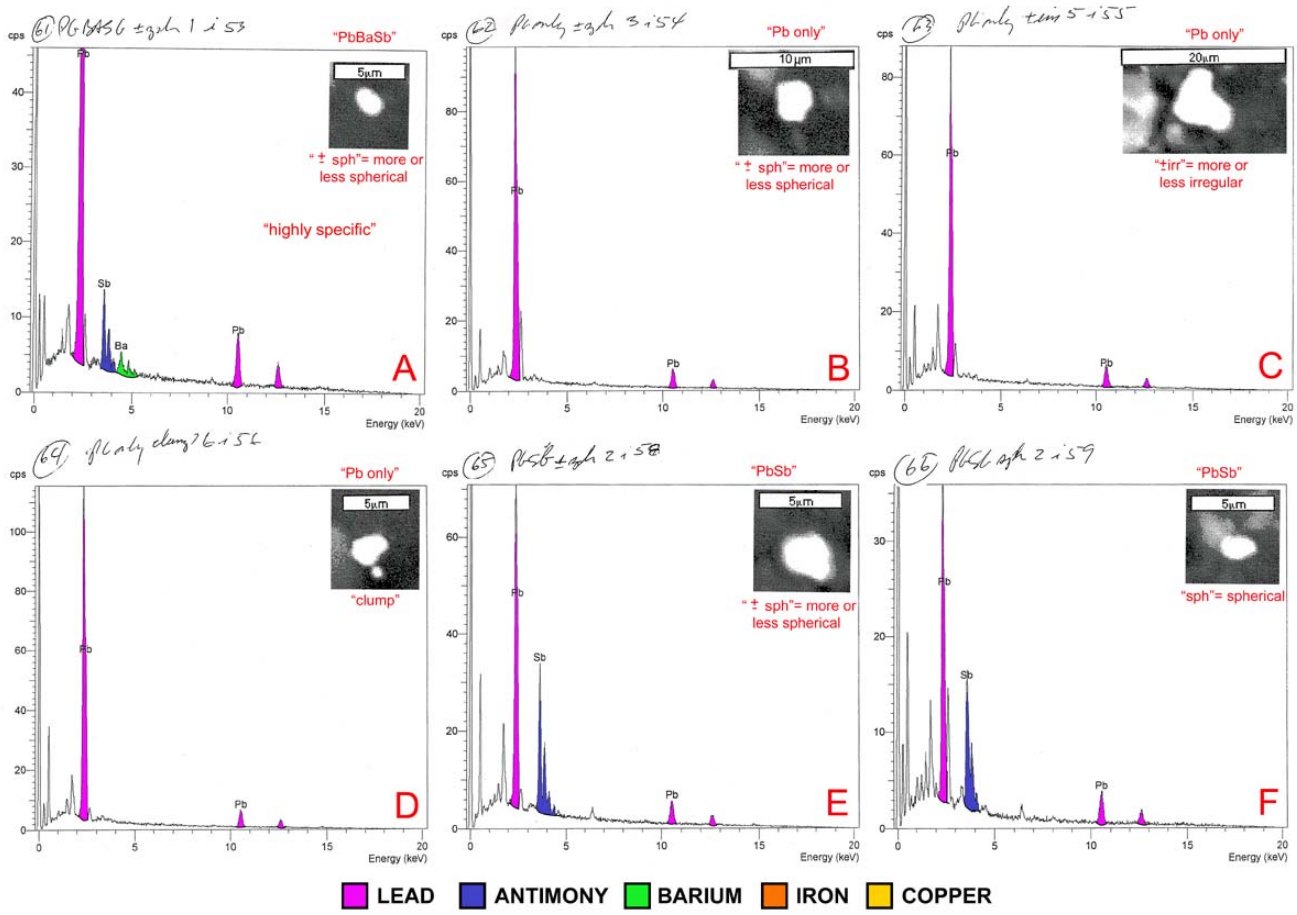

Figure 5. *Spectra, particle images and hand notes of six particles from the defendant's Ford Thunderbird samplers. See Fig. 1 legend details.*

Conclusions

As noted above, the samples from the defendant's hands were taken eight hours after the shooting. It is well established that gunshot residue on a shooter's hands usually does not persist longer than three hours after deposition (Wolten et al., 1977; Zeichner and Levin, 1995; Mastruko, 2002; Jaegar, 2004). The rate of gunshot residue loss depends on the activity of the shooter (ibid.). Most, if not all of the so-called gunshot residue particles found on the defendant's hands are unlikely to have originated from the shooting at issue on this basis alone. The defendant claimed that he occasionally drove to rural areas to hunt. There may be a contribution of GSR from this source on samplers of his car as well as from the defendant's hands.

The Aerospace Group (Wolten et al., 1977) studied gunshot residue by scanning electron microscopy and energy dispersive X-ray analysis. In that text, on page 58, these researchers noted, "The presence of substantial numbers of inconsistent particles overrules the evidentiary significance of particles consistent with gunshot residue." This rule is still valid, even though significant technical advances (e.g., backscatter electron detection, automated sample processing etc.) have occurred since the Aerospace Report was issued. Torre, et al. (2002) reported that automotive friction products (i.e., brake pads) produced by a number of manufacturers will generate gunshot residue-like particles with combinations of lead, antimony and barium. There is a diversity of these particles that are made up of these metals from this source. When found on a sample, these brake-origin particles could be and have been (this article) mistaken for gunshot residue. As a result, Torre, et al (2002) propose a corollary to Wolten's Rule: "…before judging a sample as positive, the type of ammunition fired in the investigated crime must always be taken into consideration: only by comparison between the sample and the ammunition's particles is it possible to attain a decisive answer." Giacalone (2002) has expressed this same position. In this case, we have the gunshot residue from the victim and the apparent gunshot residue on the witness for comparison.

Most of the particles that the analyst reports as "consistent" or "highly specific" in the samples from the defendant have a moderate to large contribution of iron (Fe) (Fig. 4). Also associated with these particles are small amounts of copper (Cu) and zinc (Zn). The presence of iron, copper and zinc distinguishes these spectra from the spectra of particles from the victim, the witness and defendant's car (Table 1). The majority of the particles identified as "highly specific" that were found on the defendant's gunshot residue samplers are likely from a friction brake source as defined by Torre et al. (2002). A supportive opinion of this interpretation of the

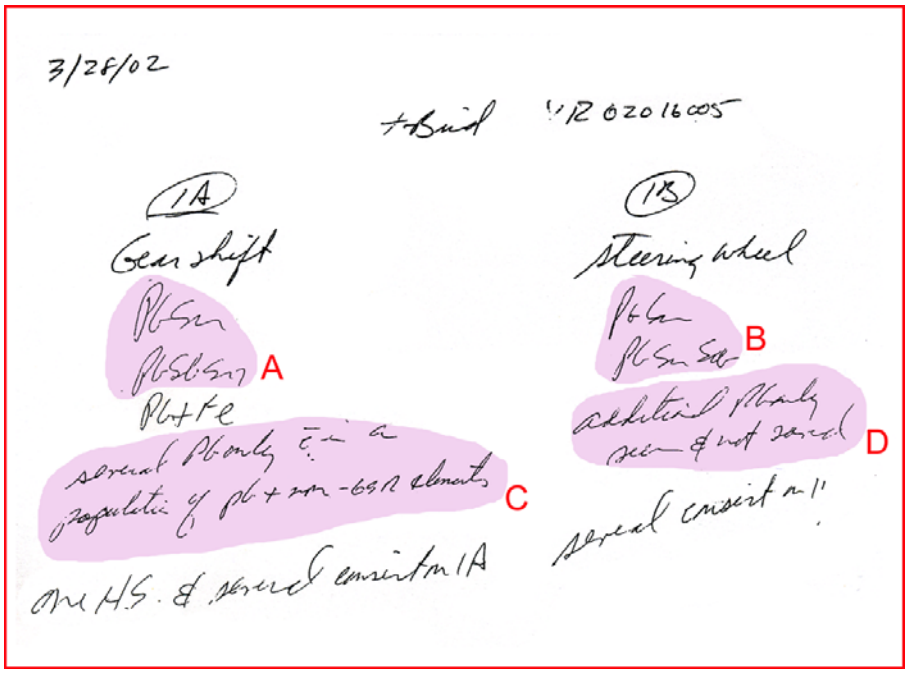

Figure 6. *Extracts of the handwritten notes from the analyst made after the automated analysis of the two samplers from the defendant's Ford Thunderbird. Results of the gear shift sampler are on the left and from the steering wheel on the right. A through D: notations of the analyst referred to in the text.*

Forensic Laboratory
Analysis Report

Agency: Riverside County Sheriff
Case#: YR02016005
Subject:

Microanalysis: Gunshot Residue

Specimen: One properly sealed GSR kit.

Purpose: Determine by Scanning Electron Microscopy / Energy Dispersive Spectroscopy (SEM/EDS) analysis if any gunshot residue particles are present.

Results: SEM/EDS analysis revealed:
Right Back – Two highly specific particles and one consistent particle of gunshot residue.
Left Back – No particles of gunshot residue.
Right Palm – Several highly specific particles of gunshot residue.
Left Palm – One highly specific particle of gunshot residue.

Therefore, the subject may have discharged a firearm or had his hands otherwise in an environment of gunshot residue.

Date of Analysis
3/27/02
File: R0205HC

Figure 7. *The report submitted to the court on the results of the analysis from the defendant's four samplers.*

Table 1. *Listing of the elemental composition of the particles of interest in this case from the analyst's handwritten notes and spectra. The analyst's tendency to skip or misreport elements inserts some uncertainty into this table. The likely high variability due to small sample sizes may be the reason for the differences between the witness and the victim samples. The lack of iron-containing particles for the witness, victim and defendant's car samples suggest a source of particles on the defendant's samplers different from these other samplers.*

		SAMPLE			
		DEFENDANT	WITNESS	VICTIM	DEFENDANT'S CAR
PRIMARY PARTICLE COMPOSITION	Pb	1	2	2	>13*
	PbBa	-	1	-	-
	PbSb	-	4	5	2
	PbSbBa	1	2	>10*	1
	SbBa	7	7	1	-
	Sb	2	-	-	-
	Ba	-	-	-	-
	BaCa	5	-	-	-
	BaAl	2	-	-	-
	BaCaAl	1	-	-	-
ASSOCIATED ELEMENTS	Fe	13	-	-	-
	Cu	9	1	1	-
	Zn	6	-	-	-
	Ni	-	2	1	-

* Actual number is uncertain due to undefined terms such as "many," "several" and "few"

spectra from the defendant's samples was kindly provided by John Giacalone (2004, personal communication).

Another issue in this case is the small sample sizes for all the analyses. It would have been appropriate to provide numbers for the various particle types rather than "few," "many" etc. With such numbers a more reliable analysis of the particle types from these sources could be performed.

It is apparent in all of these analyses that the analyst did not consider that a comparison of the elemental compositions of particles between samples might be important in this case. That analyst issued a report (Fig. 7) for the defendant's sampler analyses that alone can be interpreted as inculpatory. However, examination of the foundation material (handwritten notes and spectra) reveals that most of the particles the analyst is calling "highly specific particles of gunshot residue" likely are not. It is ironic that this analyst recently shifted from identifying particles with lead-antimony-barium or antimony-barium "unique to gunshot residue" to "highly specific to gunshot residue." This terminology shift was apparently based on the Torre et al. (2002) and Giacalone (2002) observations.

References

Anon. 1997. Procedure: GSR Interpretation. Microanaylis Section, Department of the Coroner, Los Angeles County, . . (A policies and procedures document).

Burnett, B.R. 2002. Observations on the composition of breech gunshot residue from a .22 pistol. International Association for MicroAnalysis. 4(1):12-15.

Burnett, B.R. 2005A. Errors in gunshot residue assessment by scanning electron microscopy/elemental analysis in criminal cases: I. Arsenic/sulfur mistaken for lead. Post on website, meixatech.com/articles/

Burnett, B.R. 2005B. Errors in gunshot residue assessment by scanning electron microscopy/element analysis. II. Missed tin (Sn) and

antimony (Sb) in an unusual, non-gunshot residue population of particles containing phosphorus (P). Posted on website, meixatech.com/articles/.

Byrkit, D. 1987. Statistics today. A comprehensive introduction. Benjamin/Cummings Publishing Co., Menlo Park, California 859pp.

Cao, X, Ma, L.Q., Singh, S.P. Chen, M. Harris, G.W. and Kizza, P. 2003. Field demonstration of metal immobilization contaminated soils using phosphate amendments. Final Report. Florida Institute of Phosphate Research. FIPR Project 97-01-148R.

Giacalone, J.R. 2002. Distinguishing characteristics for the determination of forensic microtrace origination. International Association for MicroAnalysis. 3(2):8-10.

Jaeger, L. 2004. The value of primer gunshot residue (p-GSR) evidence: A pilot study regarding p_GSR contamination. Scanning, Proceedings. 26(2)67-68.

Mastruko, V. 2002. Forensic applications of an ESEM. International Association of MicroAnalysis 3:(1):4-7.

Torre, C., Mattutino,G., Vasino, V. and Robino, C. 2002. Brake linings: A source of non-GSR particles containing lead, barium and antimony. Journal of Forensic Sciences 47(3):494-504.

Wolten,G.M.; Nesbitt,R.S.; Calloway,A.R.; Loper,G.L.; Jones,P.F. 1977. Final Report on Particle Analysis for Gunshot Residue. Aerospace Corporation. 197 p.

Zeichner,A. and Levin, N. 1995. Casework experience of GSR detection on samples from hands, hair and clothing using autosearch SEM/EDX system. Journal of Forensic Science. 40(6)1082-1085.

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Comments Appreciated!

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