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The Detection of Gunshot Residue (GSR) Particles on the Bottom of Discharged Bullets

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ABSTRACT: The well-established method of gunshot residue (GSR) particle detection using scanning electron microscopy/energy dispersive spectrometry (SEM/EDS) is generally employed in both the examination of the suspect and the target area. In the present work, it was demonstrated that GSR particles can be consistently found on the bottoms of discharged bullets, including those severely deformed on impact or having undergone other severe conditions. In addition, a proposed mechanism for this finding was investigated. Because this phenomenon is found useful in several types of cases, it should be well remembered by criminalistic related examiners that the bottoms of discharged bullets contain valuable information not to be overlooked.

KEYWORDS: criminalistics, ballistics, gunshot residues, chemical analysis

Scanning electron microscopy employed with energy dispersive spectrometry (SEM/EDS) is a widely known method used for the detection and classification of gunshot residue (GSR) particles [*1-4*].

The pioneering works published regarding this method concentrated on the identification of GSR particles found on the hands or clothes of the suspects [*5-11*]. Other works dealt with attempts at identifying particles found around the bullet's entrance hole in cases of firing from short distances [*12*]. Because of the proximity of the fired weapon to the target, a direct physical transference of GSR particles to the target was the proposed explanation for this occurrence.

Another work, by Ravreby, reported the finding of GSR particles around the bullet entrance hole in cases of long-range firing distances [*13,14*]. Here, the proposed explanation was that the GSR particles attach themselves to the fired bullet and fall off when the bullet penetrates the target. To substantiate this explanation, the author examined bullets after they had been fired into wood targets, and indeed found that it is possible to discover GSR particles on the bottoms of the discharged bullets.

The finding of GSR particles on the bottoms of discharged bullets is found to be important and useful in several types of cases:

1. Generally, the preferred method used for a meaningful identification of GSR particles is to compare the particles found on the suspect to those of the ammunition used in the

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related incident. Here, whenever no cartridge cases are found, one could use for this comparison the bottoms of the recovered bullets.

2. Often, in cases where bullets recovered are severely deformed (and again, no cartridge cases are present), GSR particles may be a useful tool for determining the type of ammunition that was fired. Thus, the finding of a certain type of ammunition might point to a terrorist related incident as opposed to a criminal one.

3. In a case where more than one weapon was fired and it is uncertain from which weapon the fatal shot originated, the identification of GSR particles could be helpful in discriminating between distorted bullets that are recovered but cannot otherwise be related to a particular weapon.

While Ravreby's work reported on the presence of GSR particles on the bottoms of discharged bullets [*13*], here, this presence was more extensively studied to demonstrate that:

1. The bottom of a discharged bullet is one of the most natural places to find GSR particles.
2. It is possible to find GSR particles on the bottoms of bullets in spite of the deformation and other "hardships" the bullet experienced between its firing and examination.
3. One can substantiate the suggested explanation [*13*] for the transference of GSR particles around the bullet hole in long-range firings.

Experimental Procedure

Ammunition was chosen to include various types of primer and bullet compositions. Table 1 lists the types of ammunition used.

The bullets examined were collected from two main sources:

1. The Division's firing range, where fired bullets were removed from sand traps and antifragment pads.
2. Cases that were received in the laboratory through the course of day-to-day work. Among these bullets were those removed from building walls and from the skull of a murder victim.

The bottoms of the bullets were examined in three stages:

1. Examination of the bottom as is, without prior treatment.
2. Examination of the bottom after being treated in an ultrasonic acetone bath.
3. Same as 2, but evaporation coated with graphite before examination, using a Polaron SEM Model E 500 coating unit.

The bullets' bottoms were examined and analyzed using a Cambridge Scanning Co. Camscan III S scanning electron microscope, equipped with a backscatter detector and a Tracor Northern TN 5500 X-ray analyzer.

Results and Discussion

GSR particles were found on the bottoms of all the untreated, discharged bullets appearing in Table 1 that were examined. These GSR particles matched those of their respective cartridges both in morphology and composition. Figures 1 to 3 depict representative photographs and spectra of the bottom of a discharged bullet, a GSR particle found on this bottom, and GSR compositions, respectively.

The compositions of bottoms of bullets can be classified into two main categories, lead and nonlead. This composition affects the ease with which GSR particles are recognized. Where the bullet's bottom is either brass-copper, nickel, or steel, the GSR particles are readily recognized because of their brightness observed in the backscatter image (BEI)

TABLE 1—*Types of ammunition examined.*

Type of Ammunition Examined	Composition of Bullet	Composition of Bullet's Bottom	Characterizing Elements of Primer Particles/GSR
1. 7.65-mm WW	copper jacketed lead	lead	Pb. Ba, Sb
2. 9-mm short WW	copper jacketed lead	lead	Pb, Ba, Sb
3. 7.65-mm GFL	nickel jacketed lead	nickel	Pb, Ba, Sb
4. .22 LR Federal	lead	lead	Pb, Ba, Sb
5. .38 Special S & W	lead	lead	Pb, Ba, SB
6. .357 Magnum manufacturer unknown	copper with lead nose	copper	Pb, Ba, Sb
7. 7.62 × 39 USSR	copper washed steel	steel	Sb, Sn, Hg
8. 9-mm Makarov	copper jacketed lead	lead	Sb, Sn, Hg
9. 7.65-mm SBP	nickel jacketed lead	lead	Pb, Sn, Ba
10. 9-mm parabellum IMI	copper jacketed lead	lead	Pb, Sb, K, Cl

(Figs. 4 and 5). This contrast arises from the substantial difference in atomic number between the elements constituting the GSR particles (lead, barium, and antimony) and the bottom of the bullet (copper, nickel, and iron).

However, with lead bullets, one cannot rely on the SEM's backscatter image (BEI) to enhance the brightness of the GSR particles. Instead, it is the particle's morphology that aids in its recognition. Figures 2 and 6 are secondary electron images (SEI) of GSR particles on a lead bottomed bullet.

Note that in many cases the GSR particles were found not only on the bottom of the core of open jacketed bullets, but also on the perimeter of the jacket itself that is situated inside the cartridge (Fig. 1).

FIG. 1—*General view of the bottom of a WW 7.65-mm copper jacketed bullet. Bottom of the lead core and copper margines are shown. Magnification:* ×*20.*

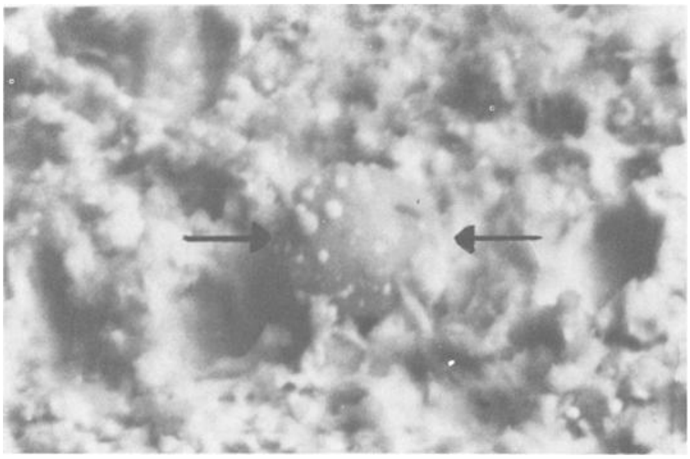
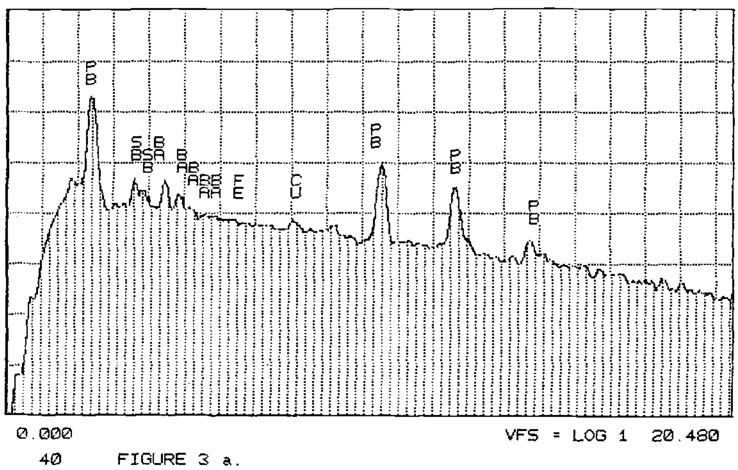


FIG. 2—*A GSR particle on the bottom of a WW 7.65-mm bullet. Magnification: ×3200.*



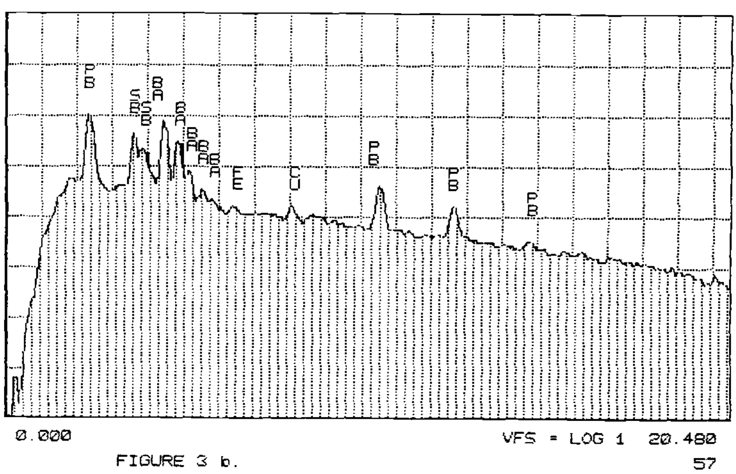


FIG. 3—(a) *Energy dispersive X-ray analysis (EDXA) of a GSR particle found on the bottom of a WW 7.65-mm bullet.* (b) *EDXA of a GSR particle sampled from a discharged WW 7.65-mm cartridge case.*

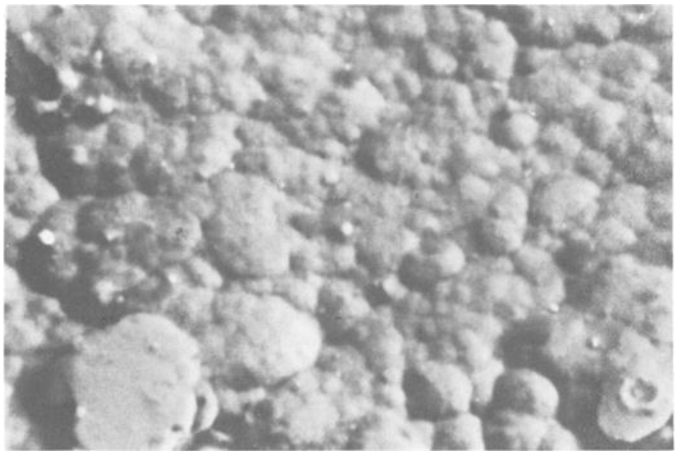


FIG. 4—*Backscatter electron image (BEI) of GSR particles (bright, round spots) on a copper bottomed .357 Magnum bullet. Magnification:* ×*2140.*

FIG. 5—*Backscatter electron image (BEI) of GSR particles (bright, round spots) on a nickel bottomed GFL 7.65-mm bullet. Magnification:* ×*2340.*

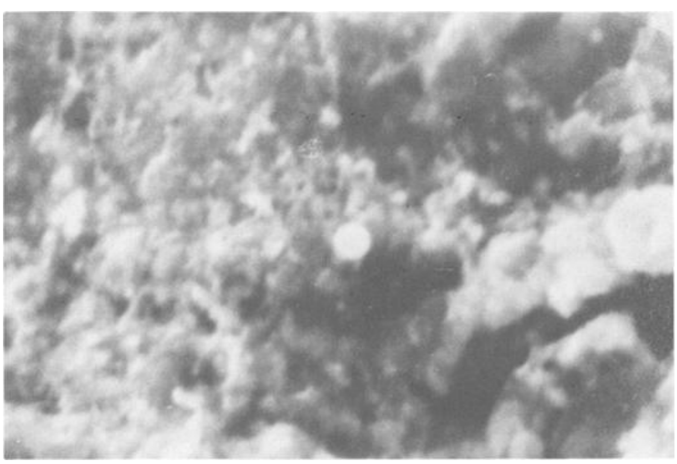


FIG. 6—*Secondary electron image (SEI) of a GSR particle on the bottom of a Makarov 9-mm lead bottomed bullet. Magnification:* ×*6470.*

GSR particles were also found on the bottoms of discharged bullets that had impacted into various media such as sand, concrete, and skull bone. This fact demonstrates that the GSR particles are embedded or even fused to the bullet's bottom. This is further demonstrated by the finding of the GSR particles on bullets that were treated in an ultrasonic bath for up to 20 min. An added advantage of treating the bullets in an ultrasonic bath before their examination in the SEM is that this insures the removal of any "loose" GSR particles, thus preventing possible contamination of the SEM sample chamber.

While it was possible to identify the GSR particles without graphite evaporation coating the bottoms of the bullets, coating the bottoms enhanced the image received.

In Ravreby's study [*13*], the emphasis was placed on the looseness of the GSR particles on the bottoms of bullets to explain the "transference" model of these particles to the target. Here, however, it is the strong adherence of the particles which is of interest to the examiner and enables one to discover these particles consistently. This adherence can be explained by the high temperatures and pressures developed during the combustion processes of the primer and gunpowder. These conditions result in the fusion of a substantial quantity of GSR particles to the bottom of the bullets.

Added support to this explanation is given by the fact that, often, the GSR particles were found in or near crater-like holes on the bullets' bottoms (Figs. 7 to 9). While these crater-like holes were not found on the bottoms of unfired bullets, they were found in varying sizes and quantities on the bottoms of fired ones.

The phenomenon of particle indentations on the bottoms of bullets has been reported in the past [*4,15*]. These indentations were explained to be a result of powder grains propelled against the base of the bullet, thus accounting for their shape and relatively large dimensions. In addition, these indentations were reported [*4*] to be found on lead or open jacketed lead core bullets. In this study, the crater-like holes observed ranged from less than 1 μm in diameter to about 30 μm; this being about the same range as the size of GSR particles [*5*]. Another feature of these GSR crater-like holes is that they appear not only on lead bottomed bullets, but even on the bottoms of steel, copper, and nickel based bullets (Figs. 10 and 11).

To verify that these "GSR holes" are formed independently from the "powder holes," the bottoms of bullets discharged using only the primer (without powder) were examined and compared to those discharged with powder. The similarity in shape and size between the crater-like holes on the bottoms of normally discharged bullets (Fig. 12), and those of the

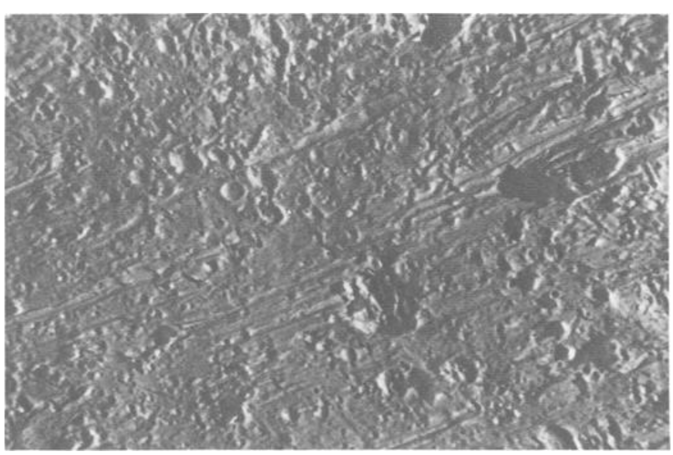


FIG. 7—*Crater-like holes on the bottom of a S&W .38 Special lead bottomed bullet. Magnification: ×500.*

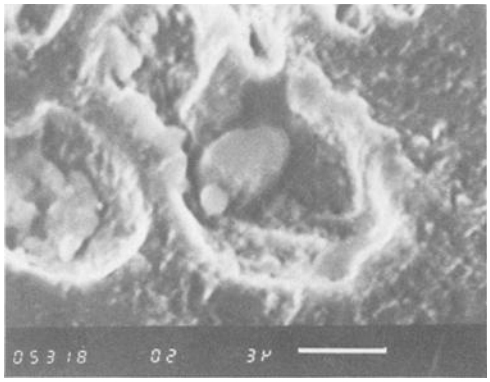


FIG. 8—*A GSR particle inside a crater-like hole on the bottom of a lead bottomed S&W .38 Special bullet. Magnification:* ×*6600.*

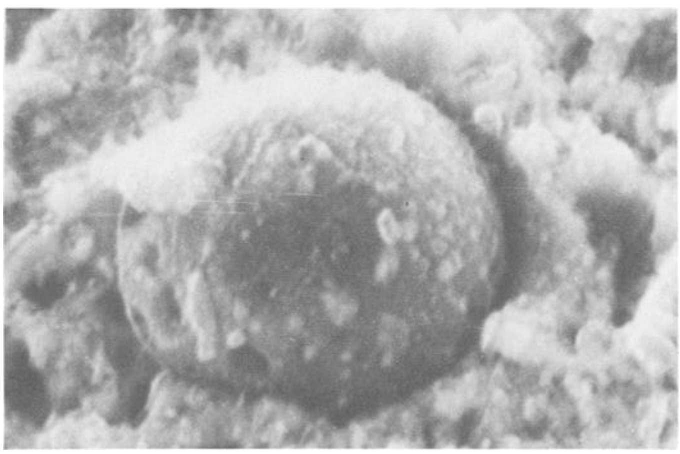


FIG. 9—*A GSR particle filling a crater-like hole ("egg in the nest") on the bottom of a lead bottomed SBP 7.65-mm bullet. Magnification:* ×*6900.*

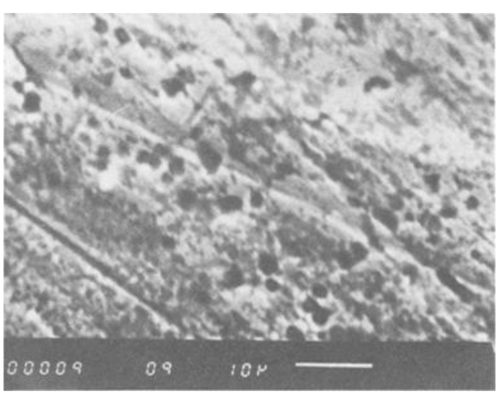


FIG. 10—*Crater-like holes on the bottom of a steel bottomed 7.62- by 39-mm (USSR) bullet. Magnification:* ×*2000.*

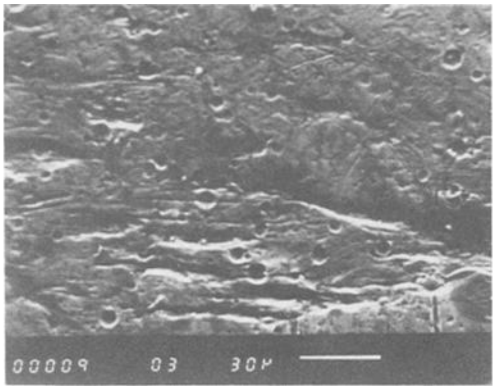


FIG. 11—*Crater-like holes on the copper margines of a HP 9-mm bullet. Magnification: ×640.*

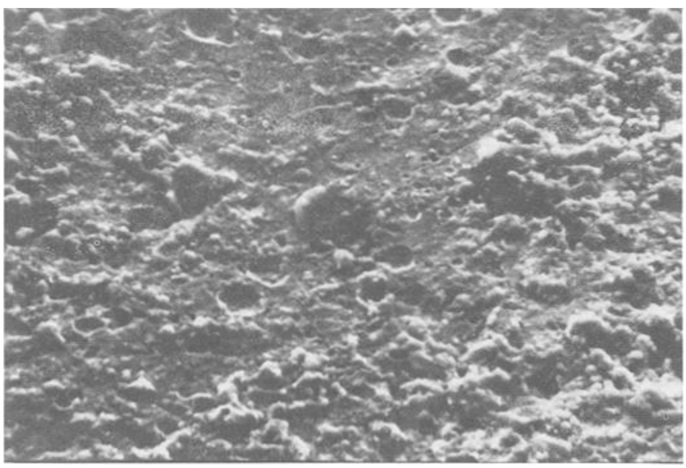


FIG. 12—*Crater-like holes on the bottom of a lead bottomed WW 7.65-mm bullet which was normally discharged. Magnification: ×710.*

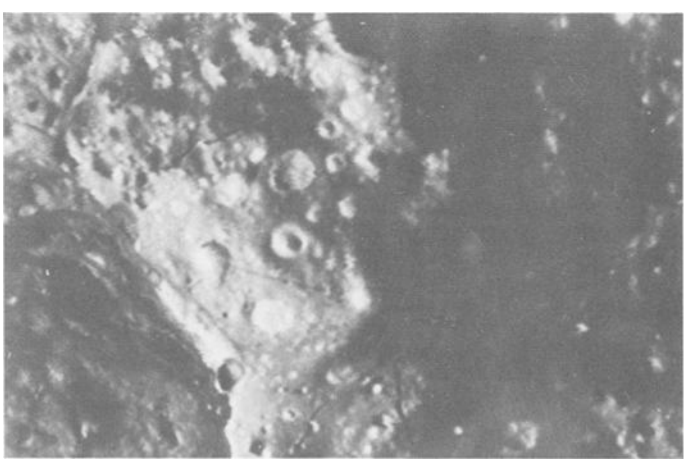


FIG. 13—*Crater-like holes on the bottom of a lead bottomed WW 7.65-mm bullet which was discharged using primer only (without powder). Magnification: ×710.*

"primer only" discharged bullets (Fig. 13) leads one to conclude that these holes are formed by the GSR particles.

In the light of these findings, it should be well remembered by criminalistic related examiners that the bottoms of discharged bullets carry GSR particles. This valuable information should not be overlooked.

Conclusion

In the present work, it was demonstrated that GSR particles can be consistently found on the bottoms of discharged bullets, including those that had been severely deformed on impact or undergone other severe conditions. It was also found that in addition to indentations caused by powder particles, GSR particles form crater-like holes on the bottoms of the bullets.

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