CASE REPORT

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Detection of Bone and Bone-Plus-Bullet Particles in Backspatter from Close-Range Shots to Heads

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ABSTRACT: A victim was shot in the head with a 9-mm Smith & Wesson pistol using Winchester Silvertip® hollow-point ammunition. Of interest in this case was the distance from the muzzle of the weapon to the victim's head, since the wound characteristics were equivocal for firing distance. Two other handguns (revolvers) were involved in this shooting, in addition to a revolver owned by the victim. The handguns were sampled using tape lifts, and the casings were sampled by washing them in distilled water, followed by vacuum filtration of the washing water through 0.2-μm-pore Nuclepore filters. These materials were examined by scanning electron microscopy/energy-dispersive X-ray analysis. Calcium-phosphorous (bone) particles were detected on the 9-mm Smith & Wesson pistol, on two casings found at the scene, and on one of the revolvers. Two of the calcium-phosphorous particles on the casings had associated bullet fragments.

Test shots on live pigs destined for slaughter showed that bone particles are a feature of backspatter from close-range shots to heads. Contamination of nearby surfaces by bone fragments and bone-plus-bullet fragments, as well as other organic debris, appears to be quite heavy.

KEYWORDS: criminalistics, wound ballistics, ballistics, microscopy, backspatter, X-ray analysis, SEM/EDXA

A disagreement between four armed individuals in a rugged, nonagricultural area, lead to an exchange of shots. One of the individuals was killed by a shot to the head by a Smith & Wesson 9-mm pistol. The bullet, a Winchester Silvertip® hollow point (STHP), did not exit from the victim's head and was recovered at autopsy. The scalp defect showed a small amount of tearing similar to a stellate pattern. A number of forensic pathologists examined the defect and were divided in their opinions as to whether the shot was fired at near contact or at a distance. The question of the distance of the shot had to be settled by other means, such as evidence of a bloody backspatter or alternative evidence of backspatter.

Stephens and Allen [*1*] report that backspatter is common with contact or near-contact shots to heads. A close-range cranial shot forces propellant gases between the scalp and the skull (which causes the scalp to tear in a stellate pattern) and into the cranium.

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Closure of the secondary cavity [2] in the cranium probably causes other tissue (bone and brain fragments), in addition to blood, to be propelled back toward the gun. Stephens and Allen [1] did not consider that tissue other than blood might be associated with backspatter, but Stephens (personal communication, 1987) states that the presence of bone fragments in the backspatter from a close-range shot to a head is "a very logical step."

In another study, Pex and Vaughan [3] provide an explanation to what they call "high-velocity bloodspatters" where they suggest that the cause is "the result of kinetic energy transferred from the hot gases entering the wound after the projectile and expanding the surrounding tissue. This expansion and subsequent contraction creates secondary projectiles (a bloody aerosol) traveling back toward the weapon and the supporting hand." Pex and Vaughan [3] did not report the presence of bone fragments in backspatter. Two elements of bone (phosphorus and calcium) can be detected using the scanning electron microscope (SEM) with energy-dispersive X-ray analysis (EDXA). The use of SEM/EDXA for the identification of bone fragments on bullets that have passed through bone has been reported [4].

The presence of bone particles as a component of backspatter has never been empirically tested. This paper also reports the results of experiments conducted on pigs to document bone fragment association with cranial backspatter.

Materials and Methods

The Shooting

A problem with the shooting was that more than five months had elapsed before the weapons involved were sampled by tape lift. If the victim was killed by a close-range shot, and bone fragments became associated with the gun, then most these fragments may have been rubbed off by the handling of the weapons. However, areas at the base of the gunsight, as well as other similarly protected areas, may escape all but the most careful cleaning.

The weapons involved were the following:

Weapon 1—A Smith & Wesson 9-mm pistol, Model 39-2, identified as the weapon that killed the victim. The evidence was sampled by tape lift.

Weapon 2—A Smith & Wesson .357 Magnum revolver owned by an individual wounded by the victim's weapon. The evidence was sampled by tape lift.

Weapon 3—A Smith & Wesson .357 Magnum revolver, sampled by tape lift.

(A Smith & Wesson .38 Special revolver owned by the victim was unavailable for sampling.)

Squares of double sticky tape (3M No. 666 Double Sticky Tape) were pressed into the grooves of each weapon with the blunt end of a Dumont No. 5 forceps. The squares were then mounted on 24-mm carbon disks, carbon coated, and viewed at 20 kV in an ETEC scanning electron microscope after having been mounted on aluminum stubs. A control tape sample was handled and mounted during the sampling and processing of the weapon/tape samples.

The casings from Weapon 1 were washed in approximately 5 mL of 0.2-μm-filtered distilled water. This was followed by filtration onto a 0.2-μm Nuclepore filter. The 24-mm Nuclepore filters were mounted onto carbon disks by colloidal carbon. The carbon disks were then attached to SEM stubs. The uncoated surface of each filter was viewed at 30 kV in the scanning electron microscope.

The degree of electron backscatter was used to select particles for further analysis. When a particle with a likely backscatter density was found, the beam was focused on the particle, and its elemental composition was determined by a Kevex Model 5100 energy-dispersive X-ray analyzer. When calcium-phosphorus particles were found, secondary and backscatter micrographs were made, and elemental dot maps were made of calcium and phosphorus of the same image. A maximum of 100 particles was examined from each sample (fewer if calcium-phosphorus particles were found).

Pig Experiments

A Smith & Wesson 9-mm automatic pistol (Model 39-2) and Winchester 9-mm STHP ammunition, similar to that which killed the victim, were used. Seven live pigs, all destined for slaughter, were killed, each by a single frontal shot. The shots were carried out by a person licensed to perform livestock slaughter. The distances from the muzzle of the gun to the pig's heads were approximately 150 cm, 76 cm, 40 cm, 37 cm, loose contact, and contact (two shots).

Prior to each shot, the pistol was thoroughly cleaned with lint-free linen cloth (No. 812, Ted Pella, Inc, Redding, California) by vigorous rubbing over all the surfaces that were to be sampled. The cleaning was followed by tape lifts around the muzzle. In order to eliminate the possibility of the pistol being contaminated by handling, the person who fired the shot wore a new surgical glove for each shot which was carefully put on just prior to the shot. Tape lift samples were taken from the pistol's muzzle after each shot.

Results

The Shooting

All the samples from the guns of the shooting were heavily laden with particles, most of which were aluminosilicates, lead, and typical gunshot residue (lead, antimony, and barium). The control tape was not. Two of the weapons and two of the 9-mm casings from the Smith & Wesson pistol had associated calcium-phosphorus particles.

Weapon 1—After searching almost 40 particles, a particle was found (Fig. 1) that was made up of calcium, phosphorus, and a small amount of lead. The element dot maps (Fig. 1, *bottom*) show that the calcium and phosphorus regions overlap.

Weapon 2—One hundred particles were analyzed; these showed the backscatter density that would be expected of a particle made up of calcium and phosphorus. All were aluminosilicates of one sort or another.

Weapon 3—In one part of the tape lift, an area was found that was heavily laden with calcium-phosphorus particles (Fig. 2). Many of these particles were less than 0.5 μm in diameter. Calcium and phosphorus maps (Fig. 2, *bottom*) of the area shown in Fig. 2, *top*, reveal that the many small particles are composed of calcium and phosphorus.

Casings from Weapon 1—Five calcium-phosphorus particles were detected from two of the eleven 9-mm casings collected from the scene of the shooting. One of these particles (Fig. 3) consisted of a core of lead with a small amount of copper and zinc partially surrounded by the calcium-phosphorus material. A second particle appeared to be composed of calcium and phosphorus with copper-zinc associated (Fig. 4). The remaining calcium-phosphorus particles had no other elements associated.

Pig Experiments

A white mist appeared to emanate from the wound for the contact and near-contact shots, which formed a cloud about 1 m in diameter several seconds after the shot. The cloud was not noted for shots more distant than the near-contact shot.

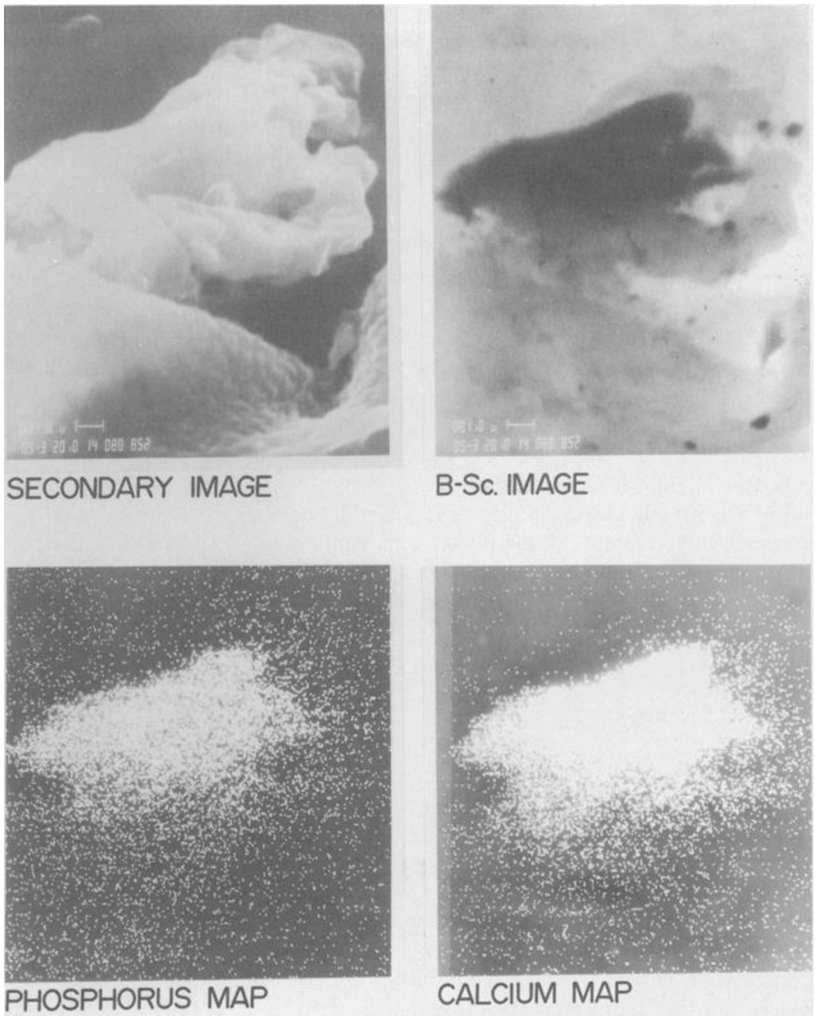

FIG. 1—(Top) *Secondary and electron backscatter images of a calcium-phosphorus particle from Weapon 1.* (Bottom) *Dot maps of phosphorus and calcium from the same region, showing that the particle was made up of calcium and phosphorus. Scale bar = 1 μm.*

Observations by SEM/EDXA of the tape lifts (Fig. 5, *top*) from the pig experiments establish that calcium-phosphorus particles associated with backscatter occur at a muzzle distance from contact to 37 cm from the pig's head. No determination of the number of calcium-phosphorus particles versus distance was made.

In addition to the calcium-phosphorus particles, a number of particles were observed that were a combination of bone (calcium-phosphorus) and components of bullets (Fig. 5, *bottom*). The bullet components of these particles appear as either "veins" or small pieces of heavy backscattering material and are combinations of lead, nickel, copper, and zinc. Lead usually dominates the bullet components in these particles.

Discussion

The results from the pig experiments show that bone (calcium-phosphorus) fragments are a feature of cranial backscatter for pigs, and very likely for humans. Unique particles

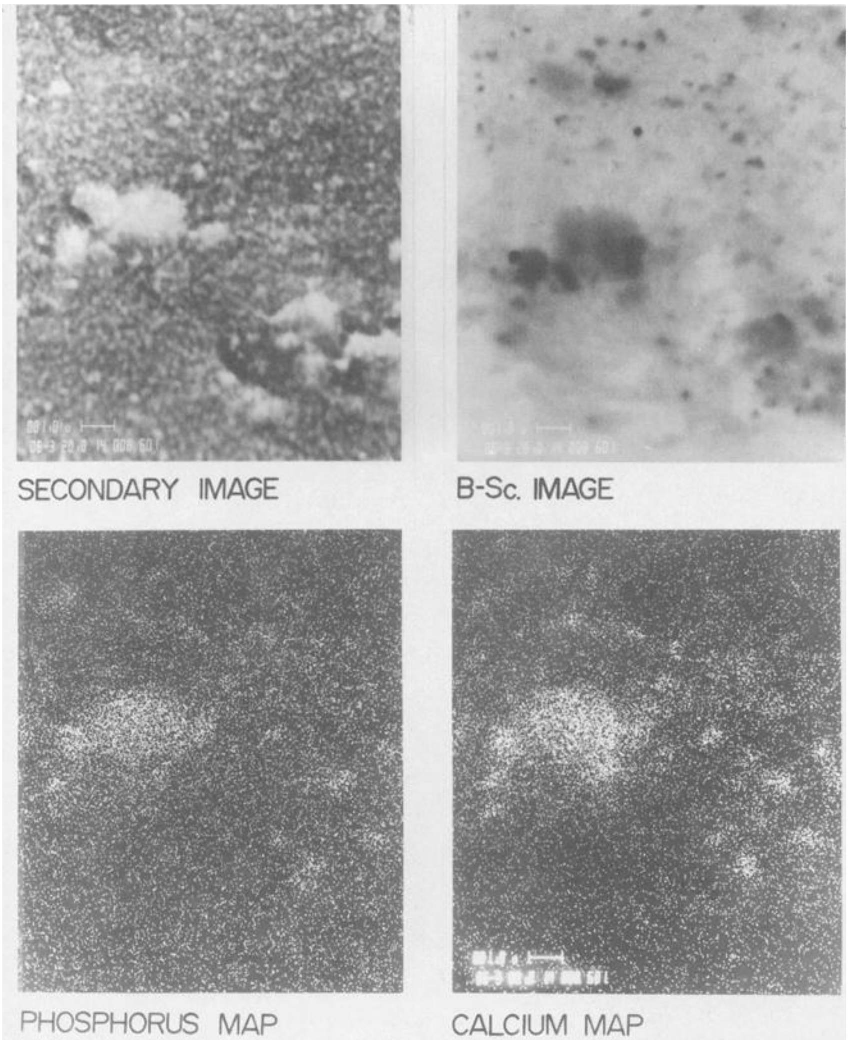

FIG. 2—(Top) *Secondary and backscatter images of a calcium-phosphorus particle from Weapon 3.* (Bottom) *Dot maps of phosphorus and calcium from the same region, showing that the particle was made up of calcium and phosphorus. Scale bar = 1 μm.*

(bone mixed with bullet fragments) are also generated. Such unique particles, when found on a weapon or associated objects have strong evidentiary value.

The experiments show that, for pigs, a cranial shot from contact to as much as 37 cm from the pig's head will have backspatter, with bone and bone-plus-bullet particles associated. It must be noted, however, that the pig skull is quite different from that of the human, and these results should be interpreted with caution.

The finding of possible backspatter components on Weapon 3 and on two of the 9-mm casings was initially surprising. The owner of Weapon 2, who was wounded in the firefight, was more than 10 m from the other individuals when he was shot. Thus, it is unlikely that any backspatter from him got on Weapon 3. Weapon 3 was not the source of the bullet that killed the victim. How did this presumed bone get on the weapon and the 9-mm casings?

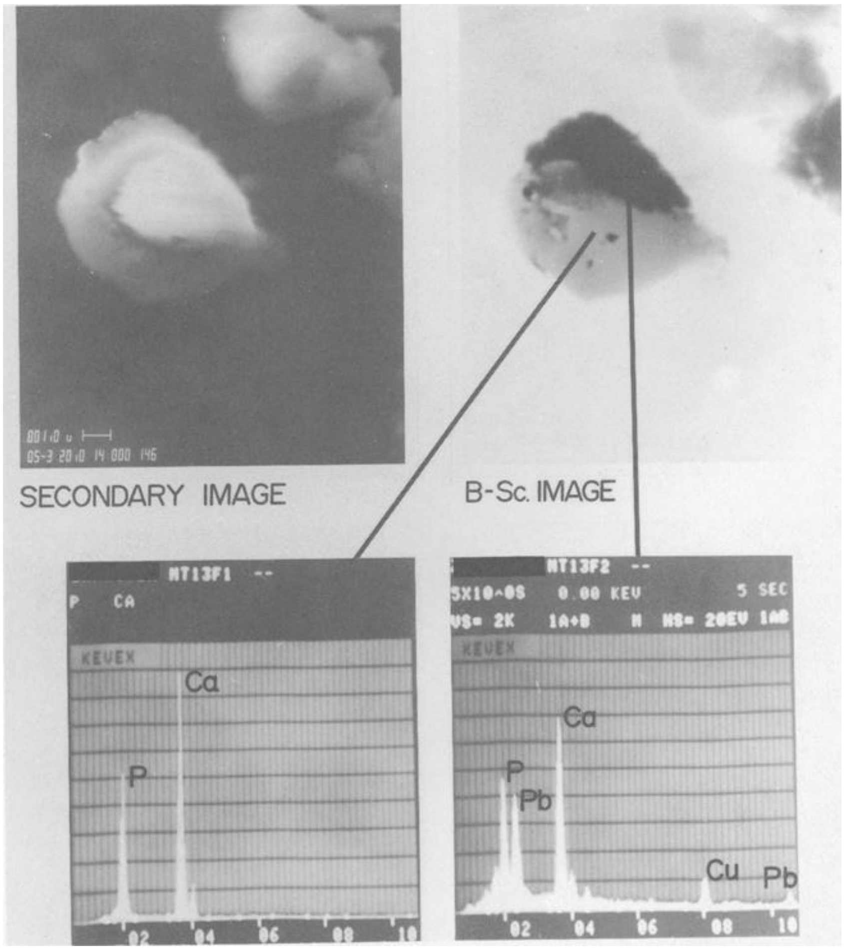

FIG. 3—(Top) *Secondary and electron backscatter images of a calcium-phosphorus particle with associated bullet material (mostly lead) from one of the casings of Weapon 1.* (Bottom) *Spectra from two different regions of the particle. Scale bar = 1 μm.*

Are the calcium-phosphorus particles on the weapons and casings a natural mineral (hydroxyapatite) and not biologically produced? If so, one may theorize that these particles have no significance on these weapons. However, the mineralogy department of the local natural history museum had no specimens of hydroxyapatite, nor were there any reported from the region in the museum's records.

Another possibility is that the weapons were contaminated by bone fragments from a source other than the victim's head. Bonemeal is often a component of fertilizer in urban and agricultural areas. Weapons 1, 2, and 3 were in use both before and after the shooting and could have been exposed to another source of bone fragments. However, it would be unlikely that such contamination would get on the 9-mm casings, since the location of the shooting was rural and nonagricultural. Furthermore, neither the nonbiological nor the fertilizer explanation accounts for bullet material in association with bone-like material.

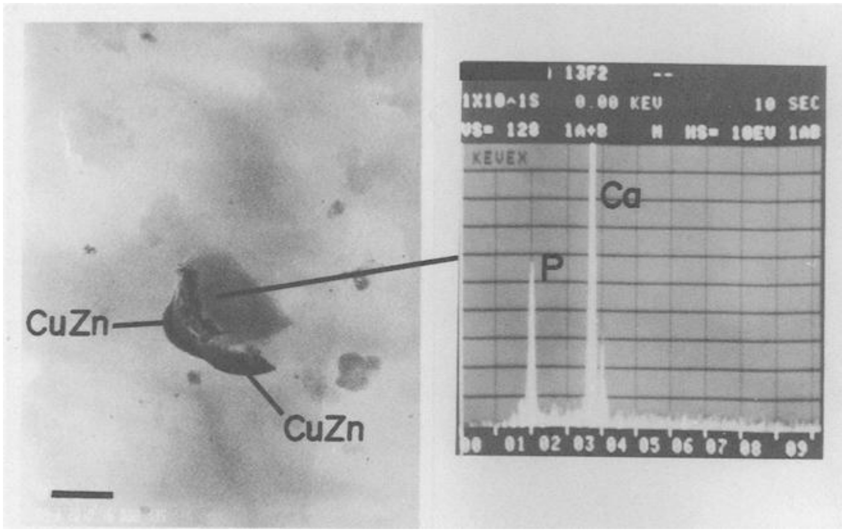

FIG. 4—*Backscatter image of a calcium-phosphorus particle with associated bullet-jacket material (copper-zinc) from one of the casings of Weapon 1. Scale bar = 1 μm.*

Serological testing of the materials associated with the shooting was never attempted. Certainly, showing that there was human tissue on these weapons would add to the impact of this SEM/EDXA study.

There is little doubt that objects associated with this shooting were contaminated with the products of backspatter from a close-range shot to the head of the victim. Backspatter material could have been on the clothing of the victim as well as on Weapon 1. Handling of the evidence by the investigating criminalist probably contaminated Weapon 3 and the two casings. It is also possible that Weapon 1 could have been contaminated from the hands of the criminalist by a previous handling of the victim's clothing.

The scenario that the killing shot was fired from a distance and the observed products of backspatter were transferred to other objects from the victim's clothing is unlikely. Stephens and Allen [*1*], as well as Pex and Vaughan [*3*], describe backspatter as a feature of close-range shots. Injection of the propellant gases into the bullet wound and consequent closure of the temporary cavity [*2*] has been proposed as the reason for backspatter [*3*].

The presence of bone and especially bone-plus-bullet fragments on objects close enough to be exposed to backspatter from a cranial close-range shot should be considered by the investigating criminalist in such cases. A discovery of bone fragments on such objects will support the hypothesis that either the shot was fired at close range (as in the case reported here) or that of the spattered objects were close to the victim when the shooting occurred. Considering the magnitude of the backspatter shown by the pig experiments, it is possible that protected areas on the assailant, such as those found around a belt buckle or in the interstices of jewelry as well as on the weapon (as in the case reported here) may provide a long-term record of a shooting.

Acknowledgment

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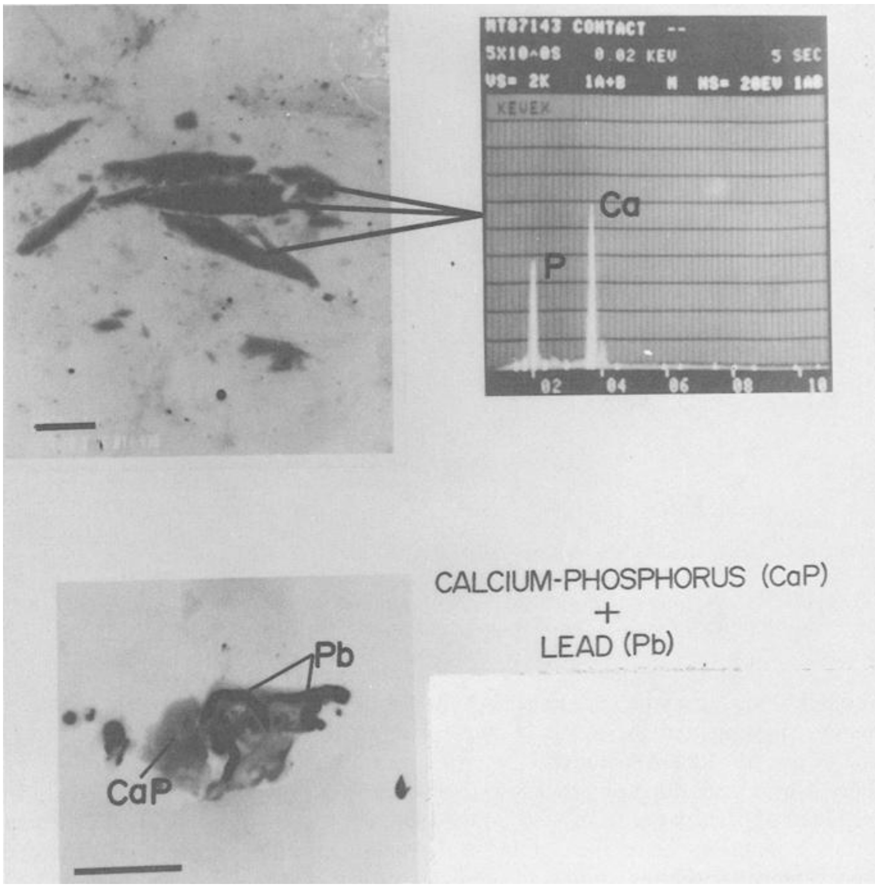

FIG. 5—*Material from the pig experiments.* (Top) *Backscatter image of calcium-phosphorus particles (bone) on the surface of the tape lift taken from the test pistol (near-contact shot). Scale bar = 1 μm.* (Bottom) *Calcium-phosphorus (bone) plus bullet fragments (lead) in intimate association from one of the near-contact tape lifts. In this particle, the lead appears as veins within the bone matrix. The longest dimension of the particles is about 5 μm.*

References

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