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Trajectory Reconstructions I: Trace Evidence in Flight

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ABSTRACT: This paper reviews the use of trace evidence recovered from spent bullets in helping to establish trajectories. The use of information derived from such trace evidence combined with that from geometrical techniques of trajectory reconstruction and other data is discussed. Five cases are reviewed in which the analysis of trace evidential materials adhering to bullets was used to help reconstruct the event.

KEYWORDS: criminalistics, ballistics, trace evidence

This paper and a companion paper, to appear later, are designed to deal with two areas of trajectory reconstructions which are in need of more attention from forensic scientists. Four general areas of physical evidence from which information may be drawn in trajectory reconstructions can be identified: (1) weapon-associated class and individual markings on projectiles (and, at times, those on cartridge cases); (2) residues and residue patterns around putative bullet holes and impact points, including those caused by secondary projectiles from intermediate targets; (3) target-specific markings on and trace evidence from bullets; and (4) holes and markings amenable to geometric techniques for ascertaining and demonstrating trajectories. All of these are fully complementary and should be considered in trajectory reconstruction work. It is our observation that the latter two areas have not received the degree of attention from criminalists that the former have enjoyed. For this reason, this paper and its companion to come will focus on the latter two areas, but will emphasize the importance of integrating information from all four sources, when it is available, in reconstructing trajectories.

The crucial role played by trace evidence in associating people, places, and things involved in crimes, in reconstructing the scenes of crimes, and in establishing the details of the event itself has enjoyed a long-standing, high level of appreciation in the forensic science community [*1–25*]. Despite this, trace evidence remains underexploited. The importance of target-specific markings and trace evidence on bullets with respect to trajectory reconstruction has been discussed earlier [*26–29*]. As pointed out in a recent article, potentially valuable trace evidential material present on spent bullets collected at the scenes of crimes, or at autopsy, is often unknowingly destroyed during standard processing by many pathologists [*30*]. In the collective experience of the authors of the

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present paper, such unknowing destruction of evidence is also sometimes done by other forensic personnel, such as crime scene technicians and firearms examiners. Discharged bullets often interact with intermediate targets, thereby making it possible for many different types of foreign material to be present on the recovered projectiles. The range of materials we have encountered is similar to that recently reported by Di Maio *et al.* and includes such evidence as blood, tissue, bone, paint, plaster, glass, wood, fibers, and hair [*30*]. A more complete listing of trace evidence we have encountered is presented in Table 1.

It is gratifying to see concern for the handling of bullet evidence to safeguard trace evidence being raised and expressed in wider forums. More generally, we are pleased to see the potential value of trace evidence on bullets receiving increased recognition. Another recent paper illustrates this point by describing a case in which the fortuitous discovery of trace evidence in the recess of a hollow-point bullet was instrumental in resolving a question concerning a shooting involving a reentry wound [*31*]. Over the course of several years, the authors of the present study have worked with trace evidential materials trapped within or adhering to spent bullets. In order to further emphasize the importance of bullets as valuable sources of contact trace evidence which should not be overlooked, we will discuss the role that trace evidence from bullets can play, as well as some of our experiences and observations from casework involving trace evidential material obtained from spent bullets. It is difficult to assess the frequency of identifiable trace evidence being present on bullets because, typically, only a small fraction of evidence bullets are handled properly and examined for trace evidence. Certainly, it can be anticipated that some bullets will not bear identifiable trace evidence or target-specific markings despite profound interaction with intermediate targets and careful handling by forensic personnel. However, it is clear, that there is a need for increased awareness on the part of such personnel.

Methods and Materials

After recovery and receipt of the spent bullet or bullets at the laboratory, the projectiles are examined with the aid of a stereomicroscope. If foreign material is present, the bullets are photographed. Next, depending on the material or materials attached to the bullet,

TABLE 1—*The various types of trace evidence actually found on spent bullets obtained in casework.*

Fibrous Substances	Particulate Matter
Hair	Blood crust
animal	Bone fragments
human head	Cinder
Synthetic	Concrete
acetate	Foams
acrylic	polyester
nylon	urethane
polyester	Glass chips
Mineral	Human skin
glass	Linoleum
slag	Metallic flakes
Vegetable	Paint chips
cotton	Paint smears
wood	Plaster chips
	Plastic fragments
	Quartz fragments
	Silver metal smear

various types of analyses are performed. Polarized light microscopy (PLM) is most often utilized because of its nondestructive nature. PLM in the hands of an experienced microscopist, affords the criminalist/microscopist with the widest range of identifying capability of any form of scientific instrumentation. When necessary, other complementary forms of analyses are utilized, for example: micro-Fourier transform infrared spectrophotometry (micro- FTIR or FTIR microscopy), X-ray diffraction, scanning electron microscopy/energy-dispersive X-ray analysis, and so forth.

Discussion

The authors have both encountered significant trace evidence on bullets received as evidence over the course of a number of years. One (NP) has maintained useful statistical data for trace evidence casework undertaken since 1980. A review of these casework records for the period from 1980 to the present involving trace evidence recovered from spent bullets revealed several interesting observations. First, it was noted that trace materials are usually encountered on bullets made of lead as opposed to metal-jacketed bullets. In fact, out of 27 spent bullets found to have trace evidence adhering to their surfaces, only 6 were metal jacketed and half of these were semijacketed. Second, from Table 1 it is apparent that the trace material found on spent bullets can be in the form of most any substance. Next, the type of matter adhering to or otherwise attached to the spent bullets can be useful in reconstructing the events of the crime, and in associating the people, places, and things involved in the crime. Finally, the position or layering of trace material on the spent projectile can be utilized in helping to establish its trajectory. This information can then be integrated with information derived from additional physical evidence. The cases described below will help to illustrate these observations.

Case 1

A young male Hispanic was found dead in bed with an apparent bullet wound to the left side of his head. Later, a single .38 caliber deformed lead bullet was recovered from inside the pillow under the deceased. At autopsy, no other spent bullets were recovered from the body. Consequently, the medical examiner wanted to confirm that the bullet which was recovered from the pillow was the one that caused the fatal wound. The trace evidential material present on the questioned bullet made this confirmation rather trivial and provided more information than was actually required.

As shown in Fig. 1, the bullet (B) was covered with a large tuft of white fibers (F) and several dark hairs (H). Close scrutiny of the trace material adhering to the questioned bullet revealed four distinct layers of trace material. The outermost layer of white fibers was identified with PLM as polyester fibers which were the same type of polyester fibers as those used to fill the pillow. The next layer was identified by PLM as being composed of fragments of white cotton threads which were similar to the textile material utilized in the pillow's casing. The third layer was composed of brown human head hair and bone fragments. The final layer was composed of brown human head hair. Some blood and soft tissue were also mixed in with the inner layers. The questioned human head hair fragments recovered from the bullet were found to be "consistent" in all microscopic characteristics with the known head hair specimen taken from the decedent at autopsy. Figure 2 shows some of the trace materials found on the bullet.

The trace evidence obtained from the questioned bullet made it apparent that this was indeed the bullet which caused the young man's death—first entering and exiting his head and then entering the pillow under his head. Confirmation by physical evidence was probably not necessary in this case, but the case does illustrate how the sequence of targets through which a bullet has passed can sometimes be learned from an examination of the layers of trace evidence on it.

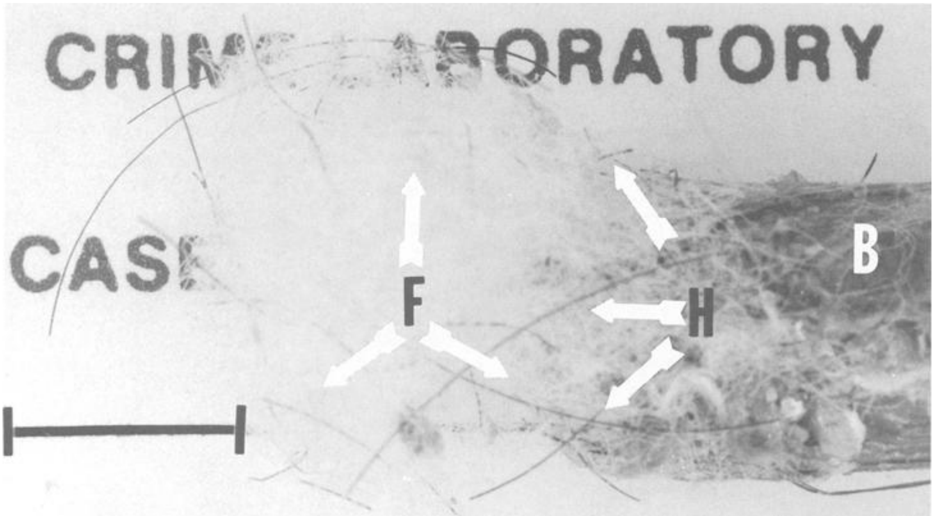

FIG. 1—*Deformed lead bullet with a tuft of white polyester fibers and several brown head hairs embedded on its surface. The black bar equals 55 mm.*

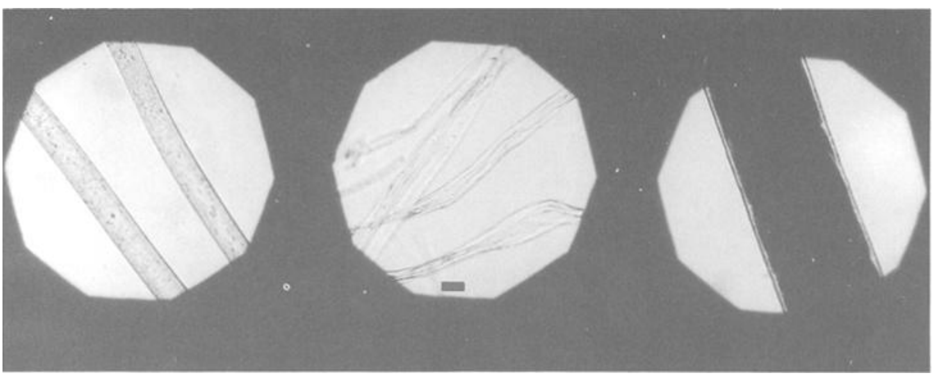

FIG. 2—*A photomicrograph depicting,* (left) *the outermost layer of polyester fibers found on the spent bullet,* (middle) *some of the cotton fibers taken from the second layer of trace material found on the bullet, and* (right) *one of the questioned head hairs found nearest the bullet's surface. The black bar in the photomicrograph equals 20 μm.*

Case 2

During the commission of a burglary in an apartment, a young man was shot once by the resident of the apartment while he was entering the premises through the living room window. After being shot, the perpetrator fled on foot and sought medical treatment at a local hospital. A search of the crime scene produced one deformed .38 caliber lead bullet in the rear courtyard, directly under the complainant's living room window. The bullet was observed to have several tufts of blue fibrous material embedded on its surface (see Fig. 3). A suspect was apprehended at the hospital after the police had been notified by hospital authorities that they were treating a man with a gunshot wound. Upon arrest, the defendant, who matched the complainant's description, was wearing a blue jacket. A specimen of the defendant's jacket was forwarded, along with the questioned bullet, for examination and comparison purposes.

FIG. 3—*A spent deformed bullet* (B) *with several tufts of fibers* (F). *The scale equals 1 in. (2.54 cm).*

The questioned blue fibers from the bullet were identified by PLM as consisting of a mixture of two distinct types and colors of blue acrylic fibers. Blue polyester and acetate fibers were also found on the bullet. Examination by PLM of the cloth specimen from the jacket revealed it was composed of a blend of two distinct types and colors of blue acrylic fibers. Microscopic, instrumental, and microchemical comparison of the acrylic fibers from the bullet and the jacket revealed that they were indistinguishable. On this basis it was concluded that the questioned acrylic fibers from the bullet could have originated from the suspect's jacket. These data made possible the association of the suspect, who was subsequently arrested at a hospital, with the scene of the crime. Lengthy testimony about the fiber evidence was given at trial. The suspect was convicted of burglary.

Case 3

The complainant, a male Caucasian, was shot twice in the head and once in the abdomen while patronizing an uptown Manhattan social club. Three .45 caliber Armament Control Panel (ACP) semijacketed lead bullets were recovered during a search of the premises. Two of the bullets were hollow point and one was a soft point. Two of the bullets were recovered from the walls inside the premises; both were severely deformed and contained minute traces of paint and plaster embedded on their surfaces. The third bullet, a hollow point, was found lying on the floor inside the club. A quantity of wood was embedded inside this bullet (Fig. 4). One of the wooden tiles comprising the hardwood floor inside the club was found to have what appeared to be a bullet hole traversing its entire thickness. This tile was removed and inexplicably forwarded directly to the property clerk. Two years later, a suspect was apprehended and charged with this crime. The gun used in the

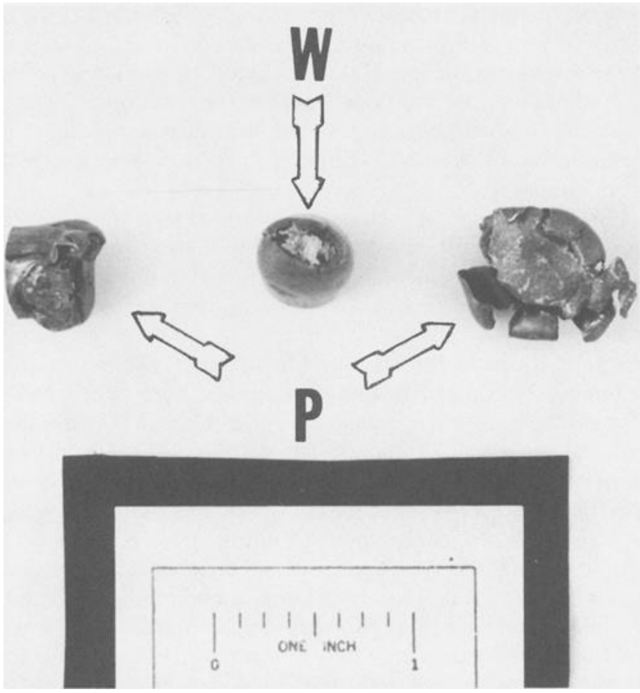

FIG. 4—*Three copper-jacketed bullets recovered from the social club. Two contained minute traces of paint and plaster* (P), *and one contained a quantity of wood* (W).

assault was never recovered. At the trial it became important to know if the bullet found on the floor of the premises caused the hole in the floor tile.

The wooden tile was obtained from the property clerk's office, where it had been stored for almost two and a half years. The bullets were obtained from the ballistic section's file. Upon examination, the floor tile was found to be constructed of slats of red oak with a cushion of polystyrene foam glued to its base. Traces of copper metal were found around the perimeter of the hole in the wooden floor tile. Microscopic examination of the wood recovered from the bullet disclosed it to be mahogany. No traces of polystyrene were found adhering to the wood obtained from the hollow-point bullet. However, when the top layer of wood was removed from the hollow-point bullet, fragments of blue cotton denim threads were found underneath. At the time of the shooting, the victim was known to have been wearing a blue denim shirt and pants outfit. These data suggested that the questioned bullet found on the floor was not the one that caused the hole in the wooden floor, but was in fact the bullet that struck the victim's abdomen, and that it then, after exiting the victim, struck a different wooden object, perhaps the bar. (A known sample of wood from the bar was not made available.) This information also indicated that another copper-jacketed bullet (never recovered) made the hole in the floor tile. Whether this hole was made during the commission of this crime or another event remained unknown. This information was reported to the district attorney for use at the trial.

Case 4

While executing a search warrant at a suspected illicit narcotics-processing location (a residential apartment), one of the police personnel taking part in the raid was struck and killed by a projectile that had passed through the door leading into the only bedroom in the apartment. A search of the crime scene produced five .38 caliber deformed lead bullets. One of the questioned bullets (Q1) was found on the living room floor at the end of a hallway leading from the bedroom. Three of the questioned bullets (Q2 through Q4) were found inside the bedroom proper. The fifth questioned bullet (Q5) was discovered in the bedroom closet. A sixth .38 caliber deformed lead bullet (Q6) was removed from the officer at autopsy.

Stereomicroscopic examination of each of the deformed lead bullets revealed the presence of trace evidential material embedded on each of their surfaces (Figs. 5 and 6). During the investigation of the incident, it became crucial to know the trajectory of each of the questioned projectiles. The trace material present on each bullet made these determinations possible.

Analysis of the paint found on the two questioned bullets Q1 and Q6, and the known paint specimens removed as standards from the bedroom door (which had two apparent bullet holes) revealed the presence of numerous colors of paint which were consistent in physical and chemical properties (Table 2). The data in Table 2 help to show that the two questioned bullets Q1 and Q6 did in fact go through the bedroom door. Figure 7 depicts FTIR spectra of one of the specimens of questioned paint removed from Q1 and one of the specimens of known paint removed from the door K2.

Stereomicroscopic examination followed by PLM, chemical, and instrumental analysis of the various colors of paint found on the two questioned bullets Q2 and Q5, and the known paint specimens removed from the bedroom walls helped to prove that Q2 and Q5 did strike said walls. Q2 then ricocheted to the floor, where it was found, and Q5 passed through the bedroom wall into the bedroom closet, where it was found (Table 3).

Instrumental, chemical, and microscopic analysis and comparison of the trace evidential material present on the deformed lead bullet Q4, and the known floor covering obtained from the bedroom floor made it apparent that Q4 was fired directly into the bedroom floor (Table 4 and Fig. 8).

Finally, PLM and X-ray diffraction analysis of the trace evidential material present on

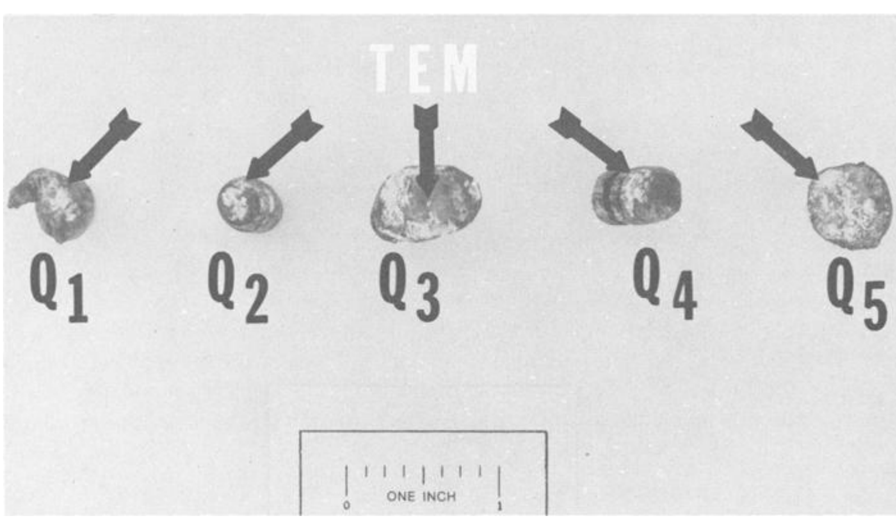

FIG. 5—*Five deformed lead bullets found at the crime scene: Q1 in the living room, Q2 through Q4 in the bedroom, and Q5 in the bedroom closet. All had trace evidential material embedded on their surfaces.*

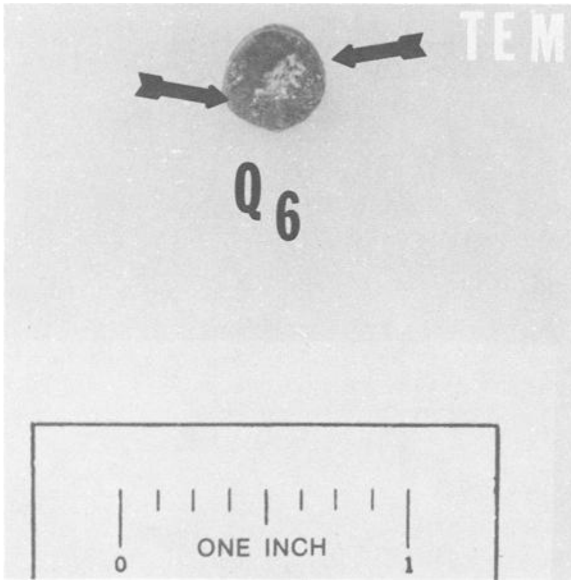

FIG. 6—*One deformed lead bullet (Q6) removed by the medical examiner at autopsy which contained trace evidence material embedded to its surface.*

TABLE 2—*The various colors of similar paint found on both Q1 and Q6 and the known paint specimens removed from the bedroom door.*

Known Paint (layering)	Q1 Paint (smeared)	Q6 Paint (smeared)
White (top)	. . .	. . .
Tan	. . .	+
Medium blue	+	+
Light blue	+	+
Blue-green	. . .	+
White	+	+
White	+	+
White	+	+
Tan	+	+
Base wood (bottom)	+	. . .

the questioned bullet Q3, and the known material composing the bedroom ceiling made it apparent that the deformed lead bullet Q3 struck the bedroom ceiling, ricocheted, and fell to the bedroom floor, where it was recovered by the crime scene officer (Table 5). Lengthy testimony was given at the trial concerning the bullet trajectories.

Case 5

Two police officers responded to a radio run "shots fired." Upon arriving at the scene, the police officers observed a male Caucasian, in front of the reported location. The man, who was apparently acting in an irrational manner, approached the officers with a

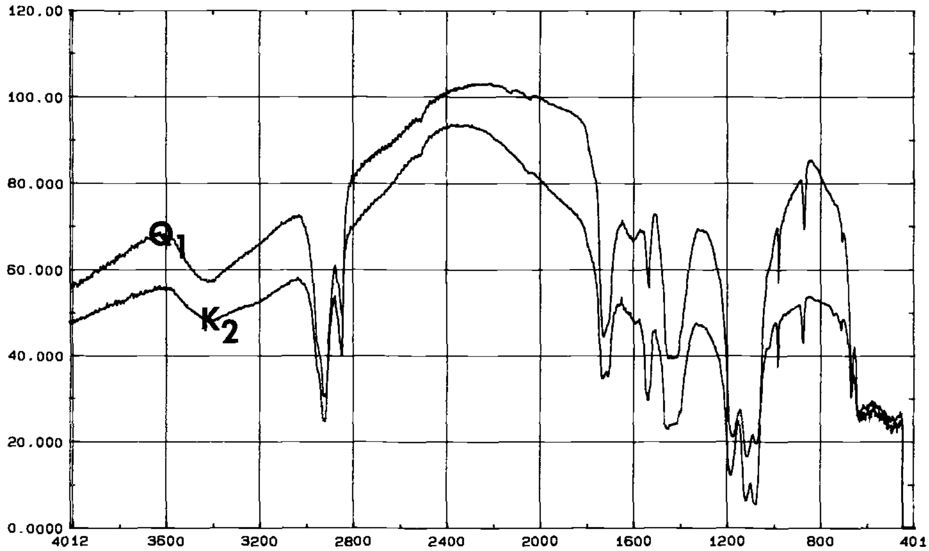

FIG. 7—*FTIR spectra of one of the specimens of tan paint removed from Q1, and one of the specimens of tan paint removed from the known door* (K2).

TABLE 3—*The various colors of similar paint found on both Q2 and Q5 and in the known paint specimens from the bedroom walls.*

Known Paint (layering)	Q2 Paint (smeared)	Q5 Paint (smeared)
White (top)	+	+
Yellow	+	+
White	+	+
Medium blue	+	+
Light blue	+	+
Blue-green	+	+
Rose	+	+
Pink	+	+
Green	+	+
Light green	+	+
Tan	. . .	+
White plaster	. . .	+
Gray concrete plaster	. . .	+
Wood lath (bottom)	. . .	+

TABLE 4—*Trace material found on Q4 and the known floor covering from the bedroom floor.*

Known Floor Covering	Q4
White/yellow vinyl floor covering	+
Metallic flakes	+
Wooden subflooring	+

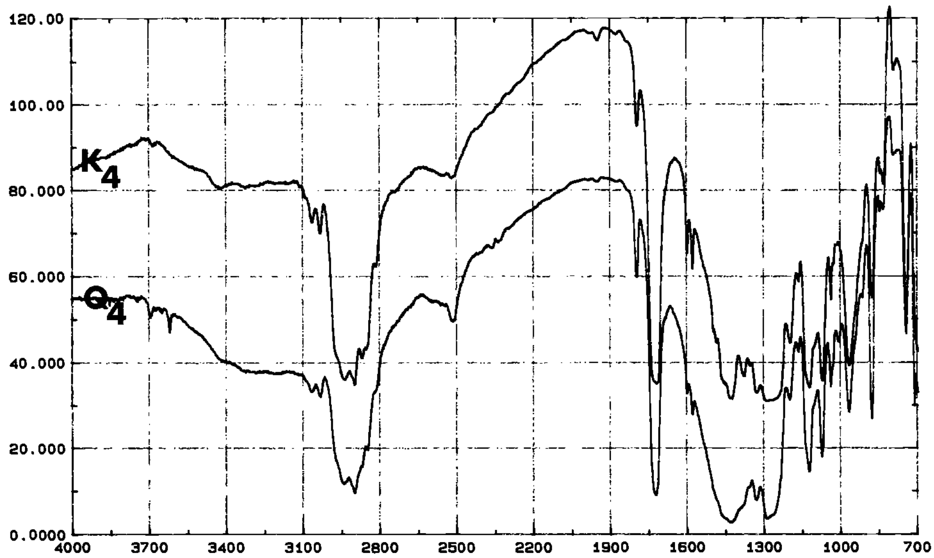

FIG. 8—*FTIR spectra of the known floor covering from the bedroom K4, the floor covering from the bedroom K4, and one of the questioned specimens of suspected floor covering obtained from the bullet Q4.*

TABLE 5—*Similar materials found on Q3 and composing the bedroom ceiling.*

Known Ceiling (layering)	Q3 (layering)
Clear resin (top)	+ (bottom)
Tan paint	+
Plaster of Paris	+
Gray concrete plaster (bottom)	+ (top)

shiny object in one of his hands. One of the officers ordered the subject to stop. However, the man kept coming towards them. At this point one of the officers drew his revolver and fired one shot in the direction of the subject. The subject fell to the ground. A knife was found in the man's right hand. The man, who was apparently suffering from a gunshot wound, was removed to the local hospital, where he was pronounced dead. The police officer who fired in the direction of the subject did not believe that the shot he discharged struck the subject.

During the subsequent investigation, the crime scene unit found bloodstains inside the reported location. This and other circumstantial information indicated that the subject was actually shot inside the building by a female occupant. The crime scene officers searched the location for the spent bullet fired by the officer. A deformed lead bullet was found in the alleyway adjacent to the building. A bullet impact mark (BIM) was found on the side of the same building. A portion of the brick which contained the BIM was removed from the building. Both the questioned bullet and the brick were forwarded to the laboratory for examination.

The spent bullet and the brick fragment containing the BIM were examined with a stereomicroscope. No traces of clothing fibers, blood, or any other tissues were found on the bullet or on the brick. A portion of the brick contained a mark which was found to contain lead, and which was the same shape as the nose of the deformed lead bullet. A chevron-shaped piece of cinder was found embedded in the nose of the spent bullet. A piece of cinder with an identically shaped cross section was also found on the exposed surface of the brick within the central area of the BIM (Fig. 9). The spent round, although damaged, bore class rifling characteristics similar to those observed on test (exemplar) bullets fired from the officer's weapon. This is the only case we have had in which an absolute physical match between the BIM and the bullet was possible. However, this fortuitous experience suggests that such opportunities should be consciously sought by other examiners.

Conclusions

We are convinced that only a very small fraction of the bullets bearing potential trace evidence have been directed to our attention in our casework. In order for the potential of trace evidence on bullets to be realized, some changes in the way in which firearms evidence is normally handled are in order. Crime scene personnel and pathologists must be sensitized to the potential value of trace evidence on bullets and in the areas from which bullets are recovered. Changes in evidence packaging are also of concern so that traces that are dislodged from the projectiles during transportation to the laboratory are retained. This is also true of evidence submission and routing policy. Bullets should be examined routinely for adherent trace evidence prior to preparation for traditional bullet comparison work.

The potential of finding valuable trace evidential material or materials on spent bullets, which could be used to associate the people, places, and things involved in the crime or used to reconstruct the event, has been clearly demonstrated by these five cases, as well as others for which only summary data are supplied here. It is the authors' hope that this report will further encourage the utilization of this often untapped source of trace evidential material on a routine basis for obtaining information for use at both investi-

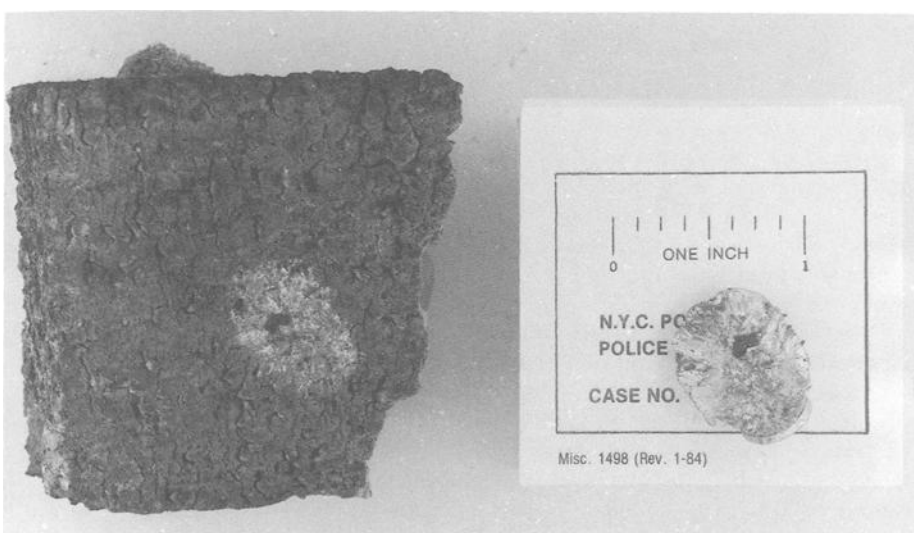

FIG. 9—*Portion of brick bearing a bullet impact mark* (left) *and deformed lead bullet with imbedded chevron shaped cinder* (right).

gative and adjudicative stages of a case. Information concerning the occurrence of trace evidence on bullets remains anecdotal. Not unexpectedly, we find it most frequently on unjacketed and soft-nosed bullets as opposed to fully jacketed bullets. However, it is clear that more reviews of casework experience, combined with experimental research, will be necessary to make it possible to know what kinds of trace evidence to expect and under what conditions it may be expected.

Summary

The use of trace evidence materials adhering to bullets in trajectory reconstruction has been discussed. Data reflecting the true frequency of the occurrence of such evidence on bullets are not available. We believe that only a small fraction of the bullets received as evidence in investigations is examined for trace materials. Thus, the true frequency of occurrence would be much higher that our experience would indicate. Data from our experience are presented, along with details from five selected illustrative casework examples. Recommendations for increasing the utilization of such evidence are given.

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