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Identification of Ammunition from Gunshot Residues and Other Cartridge Related Materials—A Preliminary Model Using .22 Caliber Rimfire Ammunition

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ABSTRACT: The identification of the type of ammunition used during the commission of a crime is very often a critical aid to the investigation: for instance, matching a cartridge used in a crime to that found on a suspect, or the determination of which of two possible shooters fired the fatal shot. The physical differences of the cartridges and the chemical composition of the components should make it possible to differentiate ammunition using a number of unique factors.

A prototype database of both chemical and physical factors has been designed and established that can be searched easily to identify a cartridge. The composition of the gunshot residue, the projectile and the cartridge case indicators were analyzed and recorded. Because of its common use, .22 caliber ammunition has been investigated, however, the parameters and the principles of the database can be applied equally to other calibers.

KEYWORDS: forensic science, firearms identification, .22 caliber ammunition, gunshot residue, database, ammunition identification

The use of .22 caliber ammunition is widespread in Australia, and many other countries. However, little or no data on the chemical or physical make-up of .22 caliber ammunition is readily available to either the public or law enforcement agencies in a consolidated form. In recent years, .22 caliber ammunition has been used in a number of the country's most serious homicides in which identification of the brand and type of ammunition became critical in the investigations which followed.

In one of these cases, a victim was shot in the driveway of his home. Gunshot residue (GSR) was found on the side of the car indicating where the shot was fired from. GSR was also found on the back of the head of the victim and within the wound track giving an indication of distance (1) and confirming the distance estimated from the relative position of the gun with respect to the vehicle. Some unburnt propellant was also located around the wound. A spent cartridge case with a distinctive Ruger 10–22 firing pin impression was located at the scene. The headstamp on the cartridge indicated that it was manufactured by PMC in South Korea. The projectile had fragmented and was unrecognizable. The suspect vehicle was examined, and GSR was detected on the steering wheel and switches. In the boot of the vehicle, propellant grains were detected. This propellant was shown to be unique to one of the five types of .22 caliber PMC ammunition available in Australia at the time and also matched the material from around the wound.

There is thus a need for answers to the following questions: What factors can be used to characterize and identify .22 caliber or any type of ammunition? Which characteristics are common, which are unique or which combination of characteristics are unique?

Information gathered from crime scenes is compared to what is found on or about a suspect, i.e., a direct comparison. This is done by lengthy post-scene comparisons with reference material which is not ordinarily placed into any database.

Identification data on ammunition, other than headstamps and ballistic information which can be obtained from product information, e.g., Winchester product sheets, is not readily available. Some manufacturers make other information about cartridges available but not in a uniform format suitable for easy comparison. There are no databases available, which list both chemical and physical characteristics of cartridges from different manufacturers.

The objective of this work was to identify a set of parameters that uniquely identify an individual .22 caliber cartridge to its brand, batch or even its production run by combining both ballistic and chemical information in a single database which can be rapidly searched to give a timely indication of the brand, type and source of ammunition used. The techniques developed in this study should be applicable to ammunition of any caliber.

The chosen parameters are dependent on the physical and chemical characteristics of the cartridges and the explosion products on discharge.

The Cartridge—A typical .22 caliber cartridge consists of a cartridge case, a percussion primer, propellant and a projectile or bullet (see Fig. 1). The caliber of a cartridge refers to the bore diameter of the firearm used: Magnum, Long or Short, are variations designed for use in either rifles and pistols (2). This ammunition has a rimfire cartridge case in which the priming material is spun into the outer rim of the base of the cartridge making the rim shock sensitive. Propellant is placed in the cartridge case with the amount and type determining the speed of the projectile. On some projectiles a 'knife mark' is scored and wax lubricant is placed into this groove. 'Cannelures' are knurled marks which sometimes appear on either the projectile or cartridge case or both, and are used as a manufacturer's identifier (Fig. 1).

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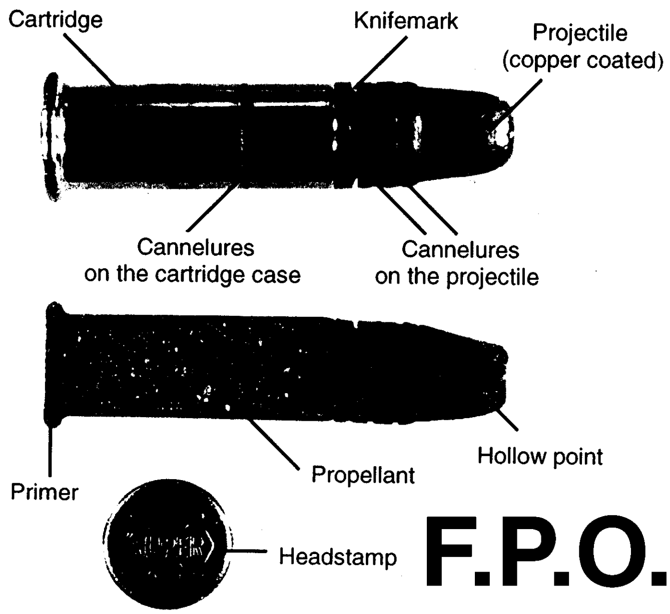


FIG. 1—*A .22 caliber rimfire cartridge showing physical characteristics.*

Cartridge Case—The cartridge case, which is often left at a crime scene, can be extremely useful, since it may be possible to match the cartridge case to the firearm. The spent cartridge case can exhibit firing pin impressions and ejector mechanism marks which may be used the identify the firearm, i.e., traditional firearm comparison. Since 1992, the Federal Bureau of Investigation (USA) has used, with some success, a recently developed automated capture and search database called 'Drugfire' (3) for firearms comparison evidence.

The material from which most modern .22 caliber cartridge cases are produced is 'Cartridge Brass.' However, copper cartridges and Russian-made iron cartridges have also been encountered. Unfortunately, the uniformity of modern brass cartridges does not enable easy differentiation, but coatings of nickel or nickel cobalt can aid in identification as the coating material can be incorporated into the GSR. GSR can also be extracted from spent cartridge cases and the base of the cartridge (4).

Headstamps are letters or symbols placed onto the back of the cartridge case as a brand or manufacturer's mark. The number and spacing of cannelures on either projectile or cartridge case can also identify the brand.

Projectile—The fired projectile is often used to identify the type of firearm (5) by way of impressions on the surface created by the 'lands' and 'grooves' as it is expelled from the barrel. The 'lands' and 'grooves' are the highs and lows of the rifling (6) (a number of spiral grooves cut into the inner surface of the barrel which impart a rotatory motion to the projectile and render its flight more accurate). The physical dimensions of the projectile, the shape, the cannelures, the shape of the hollow point, and the coating or identifying marks at the base of the projectile are all discriminators. GSR can also be recovered from the base of the fired projectile.

The projectile can be either a single solid object or a number of small spheres, as in birdshot. The projectile may be essentially pure lead, lead with antimony added as a hardener, jacketed or plated with either copper or brass. Trace impurities in the lead may be useful as an indicator in discriminating projectile fragments from one cartridge to another and also lead from other sources.

Propellant—The propellant is located inside and occupies the majority of the inner cartridge case. Propellants for modern .22 caliber cartridges are known as 'smokeless powder.' There are two main groups of 'smokeless powders': (a) Single based powders, which contain a elasticized nitrocellulose as the main explosive source. (b) Double based powders, which contain both nitrocellulose and a liquid explosive plasticizer such as nitroglycerine.

Propellants also contain binder, plasticizers, burn modifiers, stabilizers, and lubricants (7) which can be used as a discriminator. If the muzzle-to-target distance is less than a meter, discharged propellant is often detected surrounding the point of entry of the projectile. The propellant can also aid in identification of the cartridge since the physical characteristics of the propellant, such as size, shape, color and chemical composition, can be used as discriminators (see Fig. 2).

The Primer—All .22 caliber cartridges investigated for this database are known as rimfire ammunition. The exact composition of .22 caliber primers varies. Most however, contain an explosive, with fuels, oxidizers, fractionators, sensitizes and binders. Some of the compounds added have multi-purpose functions while other compounds are added which have a single function. The explosives are generally lead styphnate though lead or silver azides, mercury fulminates, and nitro compounds like TNT can also be used. Fuels are either antimony sulphide (stibnite) or calcium silicide, both which can also be used as a fractionator. The oxidizer is usually barium nitrate, however potassium chlorate, lead dioxide or lead nitrate can also be used. Fractionators are either antimony sulphide, calcium silicide or ground glass. If sensitizes are added, tetracene is usually used. The binders are organic gums and glues, for example sodium alginate, dextrin or gum arabic. The composition of .22 caliber primers varies greatly (8) (see Fig. 3).

Primer Covers—In some cartridges, lead/tin foils or waxed fibers have been used to protect the primer from moisture and dislodgment and these materials may be used as identifiers.

Gunshot Residue—When a gun is discharged, the resulting hot gases produced by the detonation and ignition of the cartridge are ejected from the muzzle and the breech in a dense cloud, and cool quickly. The vaporized materials within the gas condense and are deposited as particulate known as gunshot residue (GSR) or sometimes as firearm discharge residue (FDR). The GSR contains products of the decomposition of the propellant, primer, cartridge case, coatings on the cartridge case, projectile, the projectile coating, primer foils, and contamination from the barrel and even previous firings. Basu (9) describes the process in some detail.

Differences in composition of components of the ammunition may result in differences in the chemical composition of the residue produced. Such information, contained in the database, on the composition of each component of individual ammunition could be an indicator of elements expected in the GSR.

The source of GSR samples recovered from the crime scene can be the firearm, spent cartridge cases, the hands of the shooter (10), surfaces in close proximity to the discharged firearm and the wound site. GSR samples have been taken and used in the legal procedures following a crime for many years.

There are thus seven major components of each of the .22 caliber

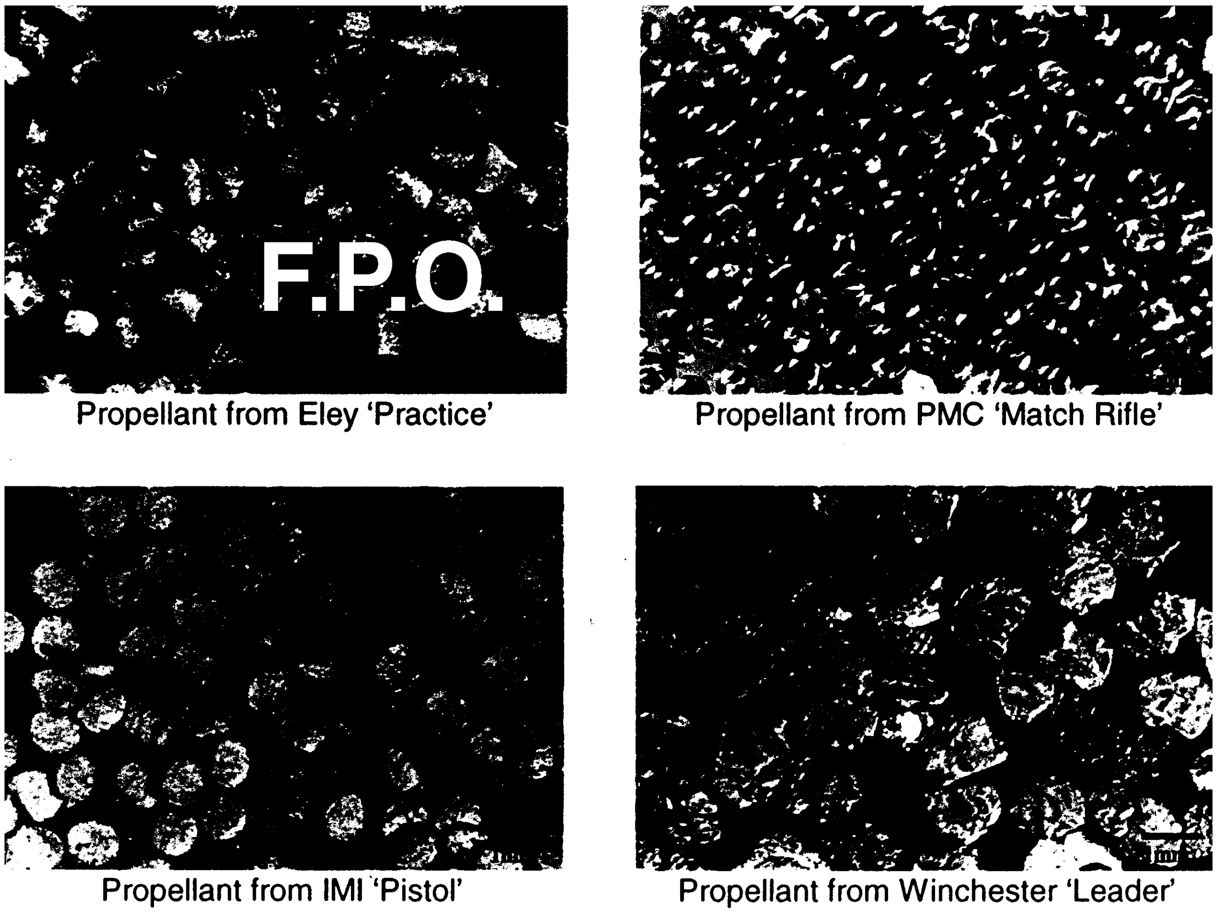


FIG. 2—*Examples of four distinctly different types of propellants found in .22 caliber rimfire ammunition.*

cartridges to be investigated. The database collects together a set of differentiating parameters in order to create a 'fingerprint' for each cartridge type (Table 1).

Materials and Methods

Unfired cartridges were obtained from commercial suppliers as well as police sources. Seventy types of .22 caliber ammunition were collected, representing 8 countries and 12 manufacturers. Some are produced in more than one country and it is recognized that there may be variations not recorded in the data thus far. Examples of .22 Magnum, .22 Long Rifle, .22 Short and .22 Shot ammunition were included.

The brand, batch number, and purchasing information for each cartridge was recorded, as was the caliber, type (e.g., long rifle or short), type of jacket and type of hollow point. The physical dimensions and distinguishing features, such as headstamps, projectile shape, number of cannelures on the cartridge case and/or the projectile and any other feature were recorded. Some manufacturers made ballistic and cartridge information available and, where applicable, this has been included in the database. The headstamps were also given a number to make searching within the database possible.

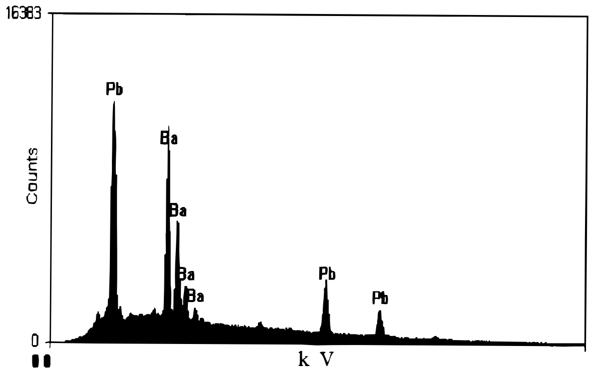
Each cartridge was mounted in a 'LECO' Varicut VC-50 diamond saw and sectioned along the axis of symmetry. This process is dangerous and may cause the cartridge to detonate. Lapua manufactured in Finland, has a waterproof wad over the primer, making cutting or disassembly without detonation very difficult. All 70 cartridges were cut in this manner and un-detonated sections of all the cartridges were achieved.

The sectioned cartridges were reconstructed to provide an internal section view, and then photographed using a Wild Heerbrugg microscope fitted with an Olympus OM-2 camera body at a magnification of 6 times, showing the internal characteristics, propellant, the shape of the projectile and hollow point.

The individual components, i.e., propellant, primer, projectile and cartridge case were separated. The propellant was photographed with the same microscope at 12 times highlighting the shape and color of the propellant grains. A description of the propellant size, shape and color was included.

The primer was carefully removed from the cartridge and placed onto a 1/2 in. diameter aluminum stub coated with a layer of carbon conducting cement. Analysis of an area approximately 3 mm $\times$ 2 mm was achieved in a Camscan Series IV Scanning Electron Microscope (SEM) fitted with a Tracor Northern 5500 Energy Dispersive X-Ray Analyzer (EDX). The conditions for analysis were identical to the Camscan gunshot residue analysis program (11). A working distance of 31 mm, an accelerating voltage of 25 kV, a count rate of 300 seconds live time and an X-ray detector take-off angle of 35° were used in all analyses.

Prior to analysis the surface of the cartridge case, projectile and primer foils were each gently scraped with a cleaned hardened steel machining tool removing any surface contamination. Any projectile coating was cleaned in the same way and analyzed in situ. All samples were mounted and analyzed in the same manner.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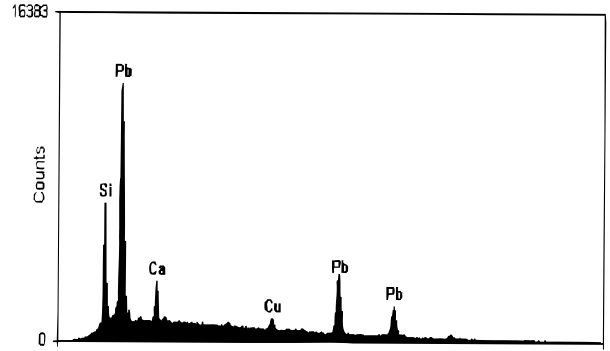
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This database has already proven valuable in casework, however, the limitations must be kept in mind. Like any database, the information must be current, complete and accurate. Furthermore there is always the possibility of an unknown type of cartridge being used or the manufacturer may modify the composition of a cartridge at anytime.

Discussion

The purpose of the database is to identify .22 caliber ammunition using both chemical and physical characteristics. This has been done for 70 types of .22 caliber ammunition to demonstrate the validity of the concept. The database of qualitative SEM/EDX analysis and physical characteristics, can be directly, compared with material obtained from crime scenes.

For example, consider the possibilities in the case of a cartridge case found at a crime scene. The head stamp identifies the manufacturer as CCI, the cartridge case itself is found to have a nickel coating, there is a cannelure on the cartridge case 13.5 mm from the base and analysis of the primer residue within the cartridge reveals the elements lead, barium, and silicon. These factors are consistent with only the type 'Stinger,' manufactured by CCI and no other type of ammunition within the database.

If no cartridge case is located at the crime scene, other material which can be obtained can still be used to uniquely identify the ammunition, or at least limit the number of possible types. For example: a .22 caliber hollow point projectile is removed from the deceased. The projectile consists of lead and antimony, and it has a brass coating. The primer residue sampled from in and around the wound contains lead, barium, antimony and silicon. These factors are consistent only with 'High Impact' ammunition manufactured by Stirling and no other ammunition within the database.

There are many characteristics, either in combination or individually that can identify either the manufacturer, or the type of ammunition. For example, 50% of the projectiles contain antimony and the others do not. While the projectile composition is probably less important than the primer, 43% contain both lead and antimony, and only one has tin. Forty-six percent of the projectiles contain no copper, all the others are plated or jacketed, with brass (92% copper and 8% zinc) or just copper.

Primer composition strongly influences the composition of the GSR particles and could be conclusive. It is often reported that the primers of .22 caliber ammunition do not contain all of lead, barium and antimony, the three elements which combine to make GSR unique. In this database, 16% of the cartridges contain primer with the three elements and all three elements in the GSR from some of these cartridges have been observed. The manufacturers are Federal (USA), Lapua (Finland), Niton (Poland), Remington (USA), and Stirling (The Philippines). Further work is underway to investigate the relationship between the elemental composition of the cartridge components, and the GSR particles produced.

Forty-four percent of all the cartridge primers in this database contained calcium, but only one cartridge contained both calcium and antimony, making 'Pistol' by Stirling unique in this aspect. Another unusual example which is unique is IMI's "Pistol" with silicon, calcium, iron and sulfur in the primer, as well as the expected lead and barium. Seven percent of the primers have no barium, and potassium appears in only 14%. Only one manufacturer places a sheet of tin/lead foil over the primer and another uses a waxed wad.

Almost 13% of the cartridge cases were coated with nickel and cobalt, which can appear in the associated GSR. However, not all cartridges are unique. Some manufacturers may market the same cartridge under different brand names as dictated by their marketing strategies. Within the database there are three brands of cartridge produced by the same manufacturer that cannot be separated by their physical or chemical composition.

While the journal monochrome reproduction of the images is adequate for demonstration or reporting purposes, it should be remembered that the high quality full color images as seen from the actual database on a quality computer monitor are superior as color itself can be a differentiator. Hence there are a large number of combinations which will enable the type of ammunition to be identified.

Even though it is somewhat limited, the existing database has been useful for the timely identification of cartridges from crime-scene-related material, either in the verification or elimination of ammunition type.

Acknowledgments

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