Chapter 1
A Brief History of Forensic Science and Crime Scene Basics

The word *forensic* in this context means "the application of scientific methods and techniques to the investigation of crime" and encompasses a wide range of endeavors, from gathering and analyzing evidence to offering expert testimony in a court of law (Forensic, 2001). Forensic specialists exist in an almost endless variety of scientific disciplines, including anthropology, biology, entomology, chemistry, serology, psychology, and, of course, geology. An associated term is *criminalistics*, which is the "application of scientific techniques in collecting and analyzing physical evidence in criminal cases" (Criminalistics, 2011).

There is no consensus as to exactly when science first entered the realm of law enforcement, though it was certainly in use in some areas of the world long before it became a recognized field of study. In the Western world, there were initially large social barriers between the shady world of the Bow Street Runners (London's first professional police force, founded around 1749) and the rarified ivory towers of the gentleman scientist. Most early scientists were independently wealthy and often of high social rank. The early history of law enforcement, on the other hand, was unfortunately rife with tales of corruption, incompetence, and even murder. It is no wonder that the scientists of the time would have considered it well beneath them to even speak to a "copper," much less work with or, goodness forbid, for them.

The birth of the modern science of geology is usually linked to the 1785 presentation of a paper entitled *Theory of the Earth* by Scotsman **James Hutton** (1726–1797) to the Royal Society of Edinburgh. Based on years of observations of geological processes in action and the layering of exposed rock (stratigraphy), Hutton explained that the Earth must be much older than previously thought.

An Introduction to Forensic Geoscience, First Edition. Elisa Bergslien.

He hypothesized that there had to be several cycles of deposition, uplift, deformation and erosion, in order to form the sequence of rock layers exposed, and each of these cycles must have occurred slowly, as demonstrated by the geological processes in action today; therefore, the Earth must have an extremely long history. In 1795, Hutton published his two-volume *Theory of the Earth*, expanding on his previous work and presenting one of the fundamental principles of geology: *uniformitarianism*. Uniformitarianism is the concept that the geological processes at work today, shaping the Earth, are the same processes that have been active throughout geologic history. This concept is often referred to using the phrase "the present is the key to the past." Thus, the surface of the Earth has not been shaped by random, unknowable events but, for the most part, by processes that we can see in action right now. This concept also establishes a link between geologists and the world of forensics, where scientists in both are using clues from the past to work out a sequence of events to determine what happened.

One of the first criminal cases to mention geologic evidence occurred in 1786 in Kirkcudbright, Scotland. A couple returned home to find their adult daughter lying dead on the floor, her throat slashed. It was established that she did not commit suicide and that her attacker was left-handed. The only other clues to the identity of the murderer were footprints found in boggy ground near the family's cottage. Plaster casts were made of the footprints, and the boots of all the men who attended the young woman's funeral were examined. None matched. Eventually, the authorities did find a boot that matched the plaster casts. It belonged to a laborer named Richardson. He was left-handed and had several scratches on his face.

Initially, Richardson appeared to have an alibi, since he had been at work with two other men that day. Additional questioning, however, revealed that Richardson left the other men to go to the blacksmith's and that he had been gone for much longer than expected. When he returned, Richardson had scratches on his cheek and muddy feet. During a search of his cottage, investigators found stockings that were bloodstained and covered in mud that was identical to the mud near the farm cottage of the victim. Apparently, the mud contained a significant amount of sand and was unlike the soils found elsewhere in the area. It turned out that the young woman was pregnant and that Richardson was her lover. He was found guilty of her murder and confessed before execution. While this case is more famous for its precedent-setting use of plaster casts, forensic geology also played an important supporting role.

In 1810, **Eugene Francois Vidocq** (1775–1857) was appointed the head of the new French *Brigade de la Sûreté*, or Sûreté for short, the world's first plain-clothes investigative police agency (Figure 1.1). Vidocq, a former criminal himself, is credited with creating the first police files (a card-index system where the physical appearance of apprehended criminals was recorded), being a pioneer in the field now known as *criminology* (the study of criminals and crime as a social phenomenon) and with introducing the science of ballistics into police work. He is also credited with being the first to make plaster casts of foot and shoe impressions, though that is apparently not quite true, and he was a master of disguise and surveillance. Vidocq recognized that sometimes an expert from outside law enforcement might be of some assistance in solving crimes. Vidocq served as the inspiration for some of the famous detectives in literature, including Edgar Allan Poe's French sleuth Auguste Dupin.

Figure 1.1 Portrait of Eugène François Vidocq by Achille Devéria.

An important development for both geology and forensic science occurred in 1828, when **William Nicol** (1770–1851), a Scottish physicist/mineralogist and lecturer at the University of Edinburgh, invented the polarizing light microscope, one of the key tools for identification of geological materials (Figure 1.2). He developed the *Nicol prism*, using a rhombohedron of "Iceland spar," which is a very clear, well-formed calcite crystal, first by bisecting the crystal in a plane passing through its obtuse angles (those > 90°) (see ABCD on Figure 1.3a) and then cementing the halves back together again with Canada balsam, a transparent resin. When light (S) enters the resultant structure, it is split into two polarized rays (light waves in which the vibrations occur in a single plane). One of these rays (O ray) undergoes total internal reflection at the balsam interface and is reflected to the side of the prism. The other ray (E ray) is not reflected at the interface and leaves through the second half of the prism as plane polarized light (Figure 1.3b). Nicol also developed a method for preparing geologic samples by cementing the sample to a glass slide and then grinding the rock down until it was thin enough to see through so that the inner structures of geological materials could be examined. While Nicol was not involved in any criminal cases, the descendants of his microscope are found in crime laboratories around the world.

Dr Mathieu Joseph Bonaventure Orfila (1787–1853) is considered the father of forensic toxicology. A Spanish-born scientist, he became a professor of medical jurisprudence (1819) and of chemistry (1823), in France, and in 1813 he published the first scientific book on everything known about poisons at the time, *Traité des poisons tirés des règnes mineral, végétal et animal, ou toxicologie générale: Considérée sous les rapports de la physiologie, de la pathologie et de la médedine légale* (often called *A Treatise of General Toxicology*). It included information about methods of detecting

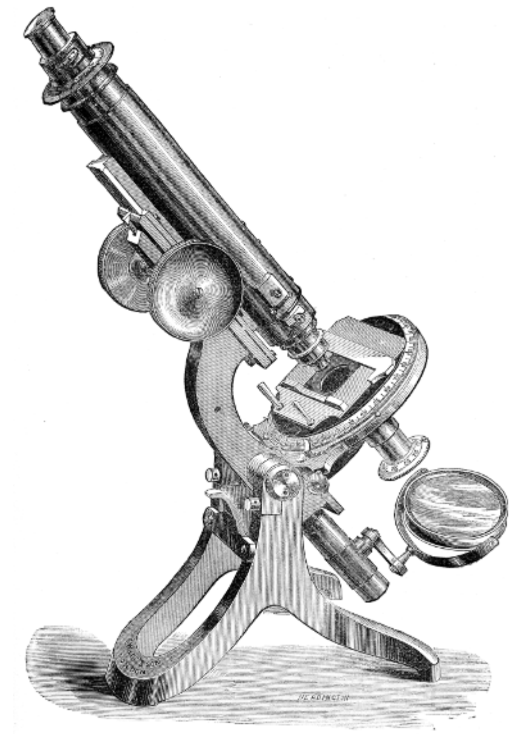


Figure 1.2 Swift and Son Petrological microscope with Nicols prism attachment.
Source: 1882 copy of *Practical Micropscopy* by George Davis.

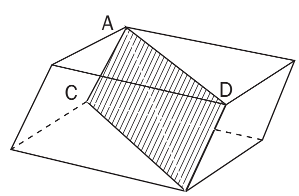


Figure 1.3a Plane of bisection through a crystal of Iceland spar.
Source: 1882 copy of *Practical Micropscopy* by George Davis.

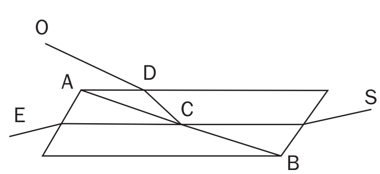


Figure 1.3b Path of light rays through a Nicol prism.
Source: 1882 copy of *Practical Micropscopy* by George Davis.

poison, but he found the methods in use at the time to be unreliable. Much of Orfila's fame came from his work to refine detection methods in order to achieve greater accuracy. However, in the case of arsenic, another scientist got there first.

James Marsh (1794–1846), an Englishman, invented a process that could detect the presence of the gas arsine, which is produced when arsenic is heated. The method of arsenic detection that existed at the time, called the *Rose method*, after its inventor, was complex and somewhat unreliable. Marsh decided to improve the method and to make it more demonstrative so that a jury would be able to understand the results. He placed the suspected samples into a closed flask, dissolving them in a solution of arsenic-free zinc and weak sulfuric acid. If arsenic is present, arsine gas forms and is led through a long drying tube to a glass tube in which the gas is heated (Figure 1.4). Heated arsine gas decomposes into arsenic and hydrogen gas, which is ignited at the end of the tube. Arsenic is deposited as a "mirror" just beyond the heated area, on any cold surface held in the burning gas emanating from the jet. A black mirror of arsenic is formed when a glazed porcelain dish is held in the flame (air deprivation). A white mirror of arsenic is formed on a black plate held over the flame (excess air). A more refined form of the Marsh test is still used today. This method is so sensitive that it can be used to detect minute amounts of arsenic in foods or stomach contents. The case that made the Marsh test, and Dr Orfila, known to the public was that of Marie Lafarge, in 1840.

Marie Lafarge was a pretty, young widow of 24, whose husband, Charles Lafarge, had apparently died of cholera (Figure 1.5). However, Marie was known to be unhappy with her arranged marriage, and Dr Lespinasse, the attending physician, told Charles' mother that he suspected her son had been poisoned. The doctor interviewed the servants and was told that Marie had been observed

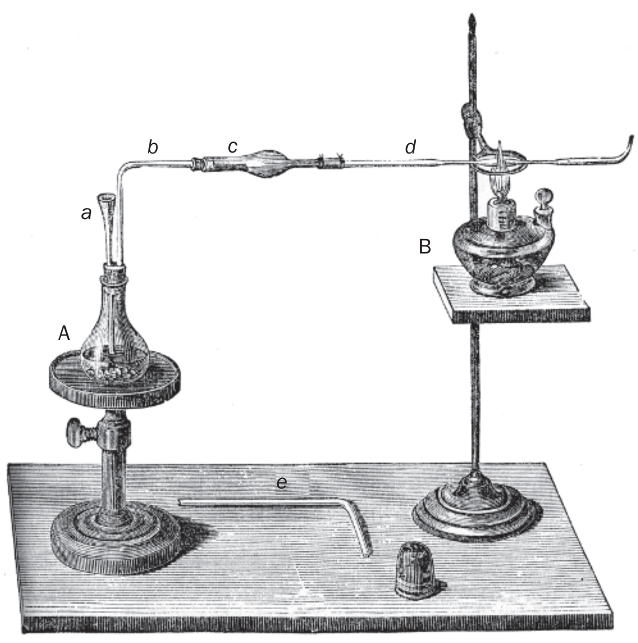


Figure 1.4 Apparatus for the application of Marsh's arsenic test.
Source: 1867 copy of *Micro-chemistry of Poisons* by Theodore G. Wormeley, MD.

Figure 1.5 Image of Marie Lafarge(?). *Source:* Frontispiece of the 1841 translation of the *Memoirs of Madame Lafarge*, published by Carey & Hart.

sprinkling a white powder over Charles' meals, including a cup of eggnog she had given him just hours before his death. Marie had purchased large amounts of arsenic in the months preceding her husband's death, ostensibly for killing rats, a common enough practice at the time. Dr Lespinasse directed the police to seize the glass Charles had been drinking from and to transport his body for autopsy. A local pharmacist tested the eggnog and found arsenic. There was clearly a large body of circumstantial evidence against Marie; however, the prosecution would also need to prove that there was arsenic inside of Charles.

Marie Lafarge's trial was reported worldwide by sensationalist newspaper articles. By all accounts, Charles had been a disagreeable character who owned a rat-infested forge on the brink of bankruptcy, and Marie had been forced unwillingly into the marriage. Because the experts brought in by the prosecution were unable to demonstrate the presence of arsenic in Charles' stomach contents, the public was divided over her guilt or innocence. Midway through the trial, Mathieu Orfila was brought in by the prosecution and asked to test for arsenic using Marsh's method. Orfila examined the work done by the previous experts and found that they had performed the tests incorrectly. Not only did he establish the presence of arsenic in Charles Lafarge's body, he also proved that it had not originated from the soil surrounding Lafarge's coffin. Arsenic, like formaldehyde, was commonly used to preserve bodies, and many old cemeteries have high levels of arsenic in the soil even now. Based on Orfila's results, Marie was found guilty of murder and spent the rest of her life in prison.

What might be the first use of a microscope in a murder case occurred during the Praslin Affair in France in 1847. This story was so sensationalized at the time that it is hard to separate fact from invention, and the storyline was further distorted by the fictitious version presented in Rachel Field's 1938 book *All This, And Heaven Too*, which was made into a movie starring Bette Davis in 1940. An outline of the tale is roughly as follows.

Charles Laure Hugues Théobald, the Duc de Choiseul-Praslin, married Altarice Rosalba Fanny Sébastiani, in 1824, when he was 19 and she only 16. Fanny was the independently wealthy daughter of one of Napoleon's generals, and she bore Charles nine children. Initially, the marriage was reported to be a happy one, though as the years passed there was greater and greater discord. One point of conflict included a governess named Henriette Deluzy-Desportes, who was eventually dismissed without a reference at the duchess's insistence. In alternate versions of the story, the duchess was upset either because Henriette was her husband's mistress or because Henriette came between the duchess and her children. Whatever the case, Charles continued to call on Henriette even after she had been dismissed and the whole situation was the subject of much gossip in Parisian society.

In some versions of the story, the duchess declared, in June 1847, that she was going to seek a divorce, a scandalous and expensive endeavor that could separate the duke from his children. Alternately, the duke was attempting to force his wife to write a letter of recommendation for Henriette so that she could secure a post at a nearby school. Whatever the reason, things shortly came to boiling point.

On the morning of August 18, servants heard screams and the bell to the duchess's bedroom beginning to ring. The sounds of crashing and more screams were heard through the door, which was locked or wedged shut. Some of the servants ran outside and looked up at the windows to the bedroom. At one point, the shutter opened and they could see a man that looked like the duke. Believing that the duke was fighting off intruders, the servants rushed back to the bedroom to find the door open and the duchess dead. Her throat had been cut, her face battered and she might have been stabbed, though she was not hacked to death or chopped up with a saber.

At this point, the duke walked into the room and screamed. He said that he had only just been awoken by the noise. The police were summoned and an investigation headed by M. Allard, Vidocq's successor, began. The duchess's jewelry was untouched, which indicated that burglary could not have been the motive. Under a sofa in the room, they found a pistol, which turned out to belong to the duke, covered in blood. At this point, the duke's story apparently changed, and he claimed that he heard his wife's calls for help, rushed to her room and found her covered in blood. He dropped the pistol when he picked his wife up and, seeing she was dead, he went back to his room to wash. The inspectors followed a trail of blood to the duke's room, finding within a bloodstained handkerchief, a bloodstained dagger hilt, and a piece of bloodstained bell-pull rope. The severed end of the bell-pull was found under the duchess's body and the duke was arrested for murder.

There were several lines of evidence gathered against the duke, but the one of interest here began with the question of whether you could tell that the pistol had been dropped in a pool of blood or if it had been used to beat the duchess. The esteemed pathologist **Auguste Ambroise Tardieu** (1818–1879) examined the pistol under a microscope and discovered chestnut hair and fragments of skin tissue both near the butt of the pistol and near the trigger. His microscopic investigation confirmed that the duchess had been battered with the pistol. Based on this and other evidence, the duke was clearly linked to his wife's murder. Before being taken to prison, the duke swallowed poison and died three days later, still proclaiming his innocence. Several newspapers of the day, though, suggested that the duke's death was a masquerade and that his connections to the royal family allowed him to be spirited safely away.

While the Marie Lafarge trial brought the public its first experience with forensic chemistry, a fictional character is most responsible for popularizing the idea of using science to solve crime. Sherlock Holmes, a character created by **Sir Arthur Conan Doyle** (1859–1930) was introduced in *Beeton's Christmas Annual* in 1887 with *A Study in Scarlet*. The literary detective was a composite of Conan Doyle's medial school professors and based chiefly on a Dr Joe Bell. The exploits of Eugene Vidocq probably also played a role as well, though this was apparently denied by Conan Doyle. Published from 1887 into the 1920s, the coldly logical Holmes and his companion Dr Watson solved seemingly inexplicable crimes using observation, deductive reasoning, and scientific experimentation.

> "For example, observation shows me that you have been to the Wigmore Street Post-Office this morning, but deduction lets me know that when there you dispatched a telegram."
>
> "Right!" said I. "Right on both points! But I confess that I don't see how you arrived at it. It was a sudden impulse upon my part, and I have mentioned it to no one."
>
> "It is simplicity itself," he remarked, chuckling at my surprise – "so absurdly simple that an explanation is superfluous; and yet it may serve to define the limits of observation and of deduction. Observation tells me that you have a little reddish mould adhering to your instep. Just opposite the Wigmore Street Office they have taken up the pavement and thrown up some earth, which lies in such a way that it is difficult to avoid treading in it in entering. The earth is of this peculiar reddish tint which is found, as far as I know, nowhere else in the neighbourhood. So much is observation. The rest is deduction."
>
> "How, then, did you deduce the telegram?"
>
> "Why, of course I knew that you had not written a letter, since I sat opposite to you all morning. I see also in your open desk there that you have a sheet of stamps and a thick bundle of postcards. What could you go into the post-office for, then, but to send a wire? Eliminate all other factors, and the one which remains must be the truth."
>
> (From *The Sign of Four* by Arthur Conan Doyle, published 1890)

Sir Arthur Conan Doyle actually became involved in a few real criminal cases, and though he achieved some positive results he was profoundly angered by the corruption and racism he found in the judicial system. Conan Doyle was a firm believer in overturning false convictions, and his work was partially responsible for the establishment of the Court of Criminal Appeal. In one case in 1906, he applied forensic geology, along with many other lines of evidence, to argue that an English solicitor, George Edalji, accused and convicted of mutilating farm animals, was not guilty. The soil on the shoes that the solicitor wore on the day of the crime was a black mud, quite dissimilar to the yellow sandy clays of the crime scene.

Despite Doyle's evidence, Edalji ended up with only a partial clearing of his name. He was found innocent of cattle mutilation, but still considered guilty of writing anonymous letters about the crimes. The commissioners appointed to consider the case decided that because Edalji might have "brought his troubles on himself" he should be awarded no compensation for the three years he served in prison. Conan Doyle called the whole affair a blot on the record of English justice. "What confronts you," he wrote, "is a determination to admit nothing which inculpates another official, as to the idea of punishing officials for offences which have caused misery to helpless victims, it never comes within their horizons" (Womack and Hines, 2001).

Johann (Hans) Baptist Gustav Gross (1847–1915) is widely regarded as one of the founders of modern criminalistics and even credited with coining the term *criminalistics*. A criminalist, according to Gross, was someone who studies crime, criminals, and the scientific methods of their identification, apprehension, and prosecution. He was a public prosecutor and judge in Graz, Austria and in 1893 published the first treatise describing the application of scientific disciplines to the field of criminal investigation, *Handbuch für Untersuchungsrichter als System der Kriminalistik* (published in English in 1907 under the title *Criminal Investigation*) a groundbreaking text that was used all over the world. It detailed the types of assistance that could be expected from the fields of microscopy, chemistry, forensic medicine, toxicology, mineralogy, botany, serology, ballistics, anthropometry, and fingerprinting. Gross wrote in his *Handbook* that "dirt on shoes can often tell us more about where the wearer of those shoes had last been than toilsome inquiries" (Murray and Tedrow, 1992: 3).

Georg Popp (1867–1928), a forensic scientist who ran a laboratory in Frankfurt, Germany, may be one of the first scientists to use geologic evidence in a criminal case. In October 1904, a seamstress named Eva Disch was found murdered in a bean field. At the crime scene, a dirty handkerchief was found that contained bits of coal, snuff, and grains of the mineral hornblende. This information was used to locate a suspect who worked part-time at both a coal-burning gasworks and in a quarry where the mineral hornblende was abundant. He also used snuff. In his pants' cuffs were two layers of dirt. The lower layer matched the soil at the crime scene, while the upper layer, which contained crushed grains of the mineral mica, matched the soil found on the path between the crime scene and the suspect's home. Confronted with this and other evidence, Karl Laubach confessed.

In 1908, Popp again highlighted the utility of forensic geology with the Margarethe Filbert case. The decapitated body of a woman, eventually identified as Margarethe Filbert, was found in a state forest near Rockenhausen, Bavaria. The body had clearly been dragged to the location where it was found, and investigators were initially at a loss for a motive or suspects. It was unclear whether the attack was sexual or a robbery. The victim's skirt and petticoat were thrown back over her head and her left glove had been removed. Eventually, witnesses placed the owner of an adjacent field near the site on the day of the crime. The suspect claimed to have been inspecting his other fields that day, far away from the crime scene, and his wife supported him. The situation reached an impasse. The local district attorney, Sohn, aware of the Eva Disch case sought out Popp's assistance.

Georg Popp studied the available evidence, including soil encrusted on the dress shoes of the suspect, a farmer named Andreas Schlicher. It had been established that Schlicher's wife had cleaned his dress shoes the night before the murder and that he had only worn them once, on the day of the murder. Schlicher claimed that he was nowhere near where the crime took place, so Popp collected soil samples from various locations around the crime scene and the suspect's land for study. Assisted by a geologist named Fisher, Popp found that the ground around the suspect's home was covered with green goose droppings, and the suspect's fields had a soil that contained fragments of porphyry, milky quartz, and mica, while the soil around the crime scene contained decomposed red sandstone, angular quartz, and iron-rich red clay. He also took samples at a castle where evidence linked to the crime had been found. There the soil contained coal, lots of brick dust, and broken pieces of cement from the crumbling castle walls.

The area in front of the heel on the suspect's dress shoes was thickly caked with mud, and Popp applied a variant of the geologic *law of superposition* (though he probably didn't think of it that way) by reasoning that, since the shoes were only worn for one day, the layers of soil in the mud would correspond in sequence to the places that Schlicher visited on the day of the murder. By carefully removing the layers of soil, Popp uncovered the following stratigraphic layers: first a layer of goose dropping directly in contact with the shoe, followed by a layer containing fragments of red sandstone. Next came a layer that contained coal, brick dust and cement fragments. Clearly, the suspect had not been walking in his own fields, as no porphyry, or milky quartz, was found. Just as clearly, the suspect had been at the scene of the crime, and then hidden evidence at the castle. Helping to clinch matters, reddish-brown wool fibers, like those from the dress of the victim, were found in the soil layer with the decomposed sandstone.

Schlicher was found guilty and apparently confessed after sentencing. Based on her clothing, Schlicher had assumed that Margarethe was rich and had decided to rob her. In reality, she was almost penniless and, in a rage, Schlicher cut off her head and hid it. It was finally recovered after his confession. Following this success, Georg Popp went on to make other contributions to the field of forensic science, including expanding the use of botanical identification in forensic investigation.

Edmond Locard (1877–1966) also put the ideas of Hans Gross and Sherlock Holmes into practice. A great fan of both, Locard stated, "I hold that a police expert, or an examining magistrate, would not find it a waste of time to read Doyle's novels . . . If, in the police laboratory at Lyons, we are interested in any unusual way in this problem of dust, it is because of having absorbed ideas found in Gross and Conan Doyle" (Locard, 1929: 277). Born in 1877, Dr Locard studied medicine and law at Lyons, becoming the assistant of the pioneer criminologist Alexandre Lacassagne, professor of Forensic Medicine at the University at Lyons. In 1910, Locard established the first police crime laboratory with the Sûreté (Figure 1.6). Armed with only two rooms in an attic, two assistants, a microscope, and a rudimentary spectrometer, Locard soon became renowned to forensic scientists and criminal investigators throughout the world for his pioneering work. In 1920, Locard published *L'enquête Criminelle et les Méthodes Scientifiques*, a seven-volume work in which appears a passage that may have given rise to the forensic precept that "every contact leaves a trace," commonly referred to as *Locard's Exchange Principle*:

> Whenever two objects come into contact, there is always a transfer of material. The methods of detection may not be sensitive enough to demonstrate this, or the decay rate may be so rapid that all evidence of transfer has vanished after a given time. Nonetheless, the transfer has taken place. (Murray and Tedrow, 1992: 7)

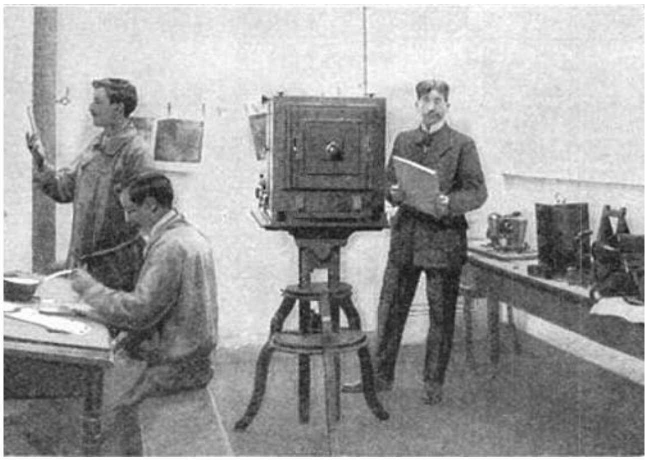


Figure 1.6 Edmond Locard, Director of the Laboratory of Police Technique at Lyon, France, next to an enlarging camera used to detect forged signatures.

One example of his work is the Emile Gourbin case. One morning in 1912, Marie Latelle was found strangled to death in the parlor of her parents' villa. Emile Gourbin, a bank clerk in Lyon, France, and Marie's fiancé, came immediately under suspicion of the murder. He was known to be jealous of Marie's flirting. Gourbin was arrested but produced what appeared to be a very strong alibi. According to the doctors, Marie died around midnight, but at that time Gourbin was at a friend's house playing cards. According to his friends, who lived miles away from the scene of the crime, they shared dinner with Gourbin, consumed a great deal of wine, and played cards into the night. They all went to bed around 1 o'clock in the morning.

Locard was called in and, after examining the scratches on the victim's neck, he took scrapings from underneath Gourbin's fingernails. Examining the scrapings under a microscope, Locard noticed a pink dust in the scrapings that turned out to be a powder consisting of rice starch, bismuth, magnesium stearate, zinc oxide, and an iron oxide used as a red pigment, commonly called Venetian red. Essentially, the skin cells collected from under Gourbin's fingernails were covered in pink face powder. Locard asked the police to search Marie's room for face powder. The box they recovered had powder of the same composition as that from the scrapings, and it turned out that the face powder had been custom-made for Marie by a Lyons druggist. This evidence led to Gourbin's confession. He had tricked his friends into thinking they went to bed at 1 a.m. when in reality Gourbin had gotten them drunk and turned their clock ahead. According to his confession, Gourbin flew into a rage after Marie refused to marry him. The jury found Gourbin guilty of premeditated murder, mostly because he had moved the clock ahead in order to sneak out to meet Marie.

An important American pioneer was **August Vollmer** (1876–1955) who, in 1905, was elected town marshal of Berkeley, California and, in 1909, was appointed as the City's first Chief of Police. It was the start of a highly distinguished career. Vollmer should probably be credited as the man who contributed the most to the professionalization of the American police force and for promoting the application of scientific principles to police work in the United States. In 1907, he established a police school within his department, which included instruction from university professors on subjects such as evidence procedures and applications of the law. It was the first school of its kind in the world. Based on the positive results from the departmental police school, in 1916 Chief Vollmer was instrumental in establishing the first School of Criminology at the University of California at Berkeley.

The same year, **Albert Schneider**, a professor in the College of Pharmacy at the University of California and part-time criminologist for the Berkeley police department, was apparently the first to use a vacuum apparatus to collect trace evidence. He also published articles on police use of the microscope. Through a series of steps, Vollmer and Schneider, among others, created the first police crime laboratory in the United States.

Edward Oscar Heinrich (1881–1953) is the most famous of the faculty associated with Vollmer's Cop College. Known as the Wizard of Berkeley, Heinrich is a remarkable figure in the history of the American justice system and credited with solving more than two thousand crimes. Also called the American Sherlock Holmes, an accolade he apparently disliked, Heinrich did remarkable work with trace evidence, including geological materials such as sand, soil, and paint pigments. Heinrich graduated from UC Berkeley with a degree in chemistry in 1908 and held a series of different jobs, including serving as the Chief of Police for the city of Alameda, California, before being appointed to the faculty at the University of California at Berkeley and opening a private laboratory in 1919.

One of his more famous cases was known as the Flapjack Murder. On the night of August 2, 1921, a stranger, dressed in a heavy overcoat with the collar turned up and wearing driving goggles, drove up to the Holy Angels Catholic Church. He rang the doorbell of the parish house and asked to speak with Father Patrick Heslin. The stranger explained that his friend (or relative) was dying and had requested the last rites. Father Heslin grabbed his religious paraphernalia and went into the night with the stranger.

When Father Heslin failed to return by the next morning, his housekeeper contacted the archdiocese. Shortly thereafter, the archdiocese received a ransom note demanding $6,500 for the safe release of the priest. The note said, "You will get instructions [for the delivery of the ransom] . . . about nine o'clock, perhaps tonight. Had-to-Hitt Him four Times And He is unconscious from pressure on Brain So Better Hurry and no fooling. Tonight at 9 o'clock" and warned against contacting the police. The second letter failed to arrive and the archdiocese contacted the police on August 5. A vast manhunt ensued, with no sign of Father Heslin. Edward Heinrich examined the ransom note and announced that the flowery style of writing meant that the letter's author was a baker and decorator of cakes. Apparently, this announcement was taken with a pinch of salt.

A week passed and Archbishop Hanna offered a reward for information leading to the missing priest. One of the people who showed up to claim the reward was William Hightower, a former baker, who claimed to have information about the location of the body. He told a somewhat confused story about how he found out about the body. Then he led a party of police and journalists toward a sign for Albers Flapjack Flour on Salada Beach. Hightower took the party directly to the body, which was buried only a couple of feet down in the sand. The priest had been shot twice and his skull crushed. In and around the impromptu grave, investigators also recovered some white cord, boards from a tent floor, a tent peg, and .45-caliber cartridges.

There were several lines of evidence linking Hightower to the murder of Father Heslin. For example, Heinrich examined Hightower's jackknife and found threads that appeared to match the white cord found with the body. He also recovered sand from several of Hightower's possessions that was similar to the sand where the body had been buried. Based on this and other evidence, Hightower was convicted and sentenced to life imprisonment in San Quentin. He was released in 1965 at age 86.

Edward O. Heinrich's most spectacular triumph was probably the D'Autremont attempted train robbery. On October 11, 1923, a Southern Pacific express train going southbound through the Siskiyou tunnel near the border between Oregon and California was stopped by three armed men. They ordered the engineer to halt the train at the far end of the tunnel, leaving the passenger cars in darkness. Shortly afterward, there was a large explosion as the bandits attempted to open the mail car. They used too much explosive, causing the entire car to burst into flames, killing the mail clerk inside. Upon hearing the explosion, the train's brakeman ran forward, only to be gunned down. At some point in these bungled proceedings, the bandits also shot the engineer and the fireman to death. The fire prevented the robbers from getting any loot and they fled the scene empty-handed. The sound of the explosion quickly brought rescue crews to the scene. After learning what happened, the rescue crews promptly turned into a posse that combed the area.

After a protracted search failed to turn up any sign of the bandits, the evidence collected from the scene was passed on to Heinrich. He examined a pair of overalls that had been recovered and announced that "the man who wore these overalls is a left-handed, brown-haired lumberjack not more than 25 years old, about 5 feet 8 inches tall, thickset, clean-shaven; he has recently worked in lumber camps in northwest Oregon or Washington." It was a seemingly amazing announcement, but Heinrich proceeded to explain the source of each of these pieces of information. For example, he found a couple of hairs on the overalls and, using a microscope, was able to discern both the hair color and approximate age of the suspect. Because the pockets on the overalls were more worn on the left side, he knew the suspect was left-handed. By examining spots of sap, wood chipping, and needles from the pockets, Heinrich knew the suspect was a lumberjack who had recently been cutting fir trees.

In addition to constructing a description of one of the suspects, Heinrich found one other clue that previous investigators had missed. Buried deep in one of the pockets was a small piece of paper that turned out to be a registered-mail receipt. He was able to tease the receipt number from the paper, and the Post Office traced it to one Roy D'Autremont of Eugene, Oregon. Roy fit the description Heinrich provided and had been missing since October 11, the day of the holdup. His two brothers were also missing and a massive manhunt ensued. It took almost four years for the D'Autremont brothers to be located and brought to justice.

During the 1930s, several important forensic laboratories were established and the application of scientific methods to investigate crime was becoming commonplace. In 1932, under the direction of J. Edgar Hoover, the **Federal Bureau of Investigation** organized a national laboratory intended to offer forensic services to all law enforcement agencies in the country (Figure 1.7). Its official birthday was set as November 24, 1932; the date was arbitrarily decided because the founding of the lab took place over several months. Forensic geology was in use at the laboratory as early as 1935 and by early 1939 heavy mineral separations and mineral identifications were standard practices for cases involving soils. There is an informative article on the history of the FBI laboratory on its website (http://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/oct2007/research/2007_10_research01_test4.htm). On April 10, 1935, the **Metropolitan**

Figure 1.7 Federal Bureau of Investigation laboratory scientist.
Source: Photograph courtesy of the FBI.

Police Forensic Laboratory opened at the Police College, Hendon, United Kingdom.

There have been several modern pioneers in forensic science; too many to include here. However, there are a few people worth a special mention. **Walter McCrone** (1916–2002) was a world-famous chemical microscopist, applying microscopy to a wide range of analytical problems, including forensic science. He published over 600 articles and was editor and publisher of the professional journal *The Microscope*. He is perhaps most famous for his work on the Shroud of Turin and the Vinland Map. McCrone taught microscopy and materials science beginning in 1944 at what is now the Illinois Institute of Technology. In 1956, he left to set up his own research company, McCrone Associates, in Chicago and developed the multi-volume *McCrone Particle Atlas*. His most lasting legacy is found in the skills of the literally thousands of forensic scientists throughout the world whom he trained.

In 1975, **Ray Murray** and **John Tedrow** published *Forensic Geology: Earth sciences and criminal investigation*, the first textbook in the field. The text outlines principles for the collection, examination, and evaluation of evidence, and discusses the conclusions that can be drawn for presentation in a court of law. The approach presented in this text still serves today and the book is found on the reference shelves of a number of crime laboratories.

Now that you have an understanding of the history of forensic geology, we can look at the procedures used at a modern…

Scene of the Crime

Arriving at the scene of a horrendous crime, the crime scene investigator surveys his surroundings. A brutal murder occurred here just hours before and, as everyone knows, the first 24 hours following a crime are critical. His steely gaze sweeps the room and he spots what may be a vital piece of evidence. It is most likely the one piece of evidence that will blow the case wide open and identify the murderer. He marches across the room, bends over and–

Unlike on the television shows, the last thing in the world a real crime scene investigator is going to do at this point is go tromping across the crime scene to pick up evidence. There are strict rules that must be followed in order to preserve the integrity of the evidence collected and to ensure that as much information as possible is collected at the scene of a crime. No one interested in solving a crime would risk compromising the scene the way they do on television. Classic unsolved crimes are often so because of improper crime scene procedures, leading to doubts about the quality or even legitimacy of the evidence collected. Was that bloody glove really found at the crime scene or was it planted? Who really dropped that cigarette? Once the integrity of a crime scene is lost, there is no getting it back.

Remember Locard's Exchange Principle, which can be paraphrased as "every contact results in an exchange of material"? Every person passing through a crime scene will leave something behind and will pick something up. This applies not only to the bad guys but also to everyone else. Each person passing through the scene following the crime will obscure or confuse matters to some degree. Thus, the number of people entering and leaving a crime scene must be strictly controlled, as must the conduct of each person at the scene.

The first officers to arrive are responsible for securing the scene. This means that they must do their best to ensure that everything stays exactly the way it was when they arrived. No one should be allowed to wander around the scene, no toilets should be flushed, no phones used, and no towels moved. The only exception to this is when life-saving measures must be taken. Not only does the evidence at the scene need to be preserved, nothing should be inadvertently added either. Random cigarette butts have led to no end of problems and it would be impossible to find the original footprints of a perpetrator if another dozen people have just wandered around the same ground.

Police agencies have detailed policies describing the duties of the first officer at the scene. The following is a general description of what will happen at the crime scene and is by no means authoritative, nor does it include all of the responsibilities of the police, such as ensuring that suspects are not still present. Instead, this description concentrates on the procedures necessary for the collection of trace evidence and does not necessarily even apply to the collection of biological evidence, which often requires special handling.

Technically, a crime scene includes not just the obvious location of criminal activity, a murder scene for example, but any areas where evidence may be collected. Sometimes "a" crime scene may actually comprise two or more discrete locations miles apart. For example, if a body is found dumped in one location, and the murder scene is somewhere else, both of those areas are part of the crime scene. If the car that was used to transport the body is also located, it too becomes part of the scene of the crime.

Each crime scene is different, which means that the initial responding officer must approach it carefully and be ready to adapt to the situation at hand. This officer is placed in the unfortunate position of having to accomplish several things at once. One of their initial duties is to secure the scene. This could mean something as simple as locking a door or stringing up rope or crime scene tape, or it could mean setting up barricades and chasing away sightseers. Not only should the visible crime scene be protected, but likely zones of the perpetrator's entry and exit should also be preserved. The routes leading to the crime scene may yield evidence just as important as what is found at the scene itself. If possible, there should be a buffer zone and enough area to create entry and exit pathways for investigators. Everyone working the scene would generally enter and leave along the same route to minimize their impact on the scene.

Another of the first responder's responsibilities is to take detailed notes, recording their precise time of arrival, information about the condition of the scene and creating a chronological record of when additional personnel arrived and what was done. It can sometimes be vital to know which lights were turned on or off, what doors were open, if any telephones were off the hook or if there were any distinct odors. Obviously, if injured people are at the scene, the administration of first aid takes priority over protection of the crime scene, but if at all possible the exact location of the victims should be noted, photographed, and/or sketched, and emergency medical responders should be directed into and out of the scene so as to minimize their impact. If there is a body at the scene, once death has been established, it should remain untouched until the arrival of the coroner or medical examiner. The original positions of anything that the medical team moves, such as furniture, need to be recorded. Otherwise, nothing at the scene should be moved unless absolutely necessary and the telephones at the scene should not be used.

Once the scene is under control, witnesses and possible suspects should be located and separated as soon as possible. Everyone needs to be kept from discussing what they have seen and thereby inadvertently, or intentionally, tampering with each other's memories. Interestingly, the tendency to tidy up can be a stress reaction, unrelated to guilt or innocence, and any witnesses at the scene must be kept from indulging in any housekeeping, such as sweeping up the dirt on the kitchen floor or wiping up spilled liquids.

One of the next people to arrive at the scene would typically be the lead investigator(s), the person(s) who would be ultimately responsible for oversight of the entire case. It is usually the lead investigator's job to determine what other personnel are needed at the scene and to perform tasks such as securing search warrants, if necessary. It would usually be the lead investigator's decision to call in others, such as crime scene technicians, to assist with the investigation.

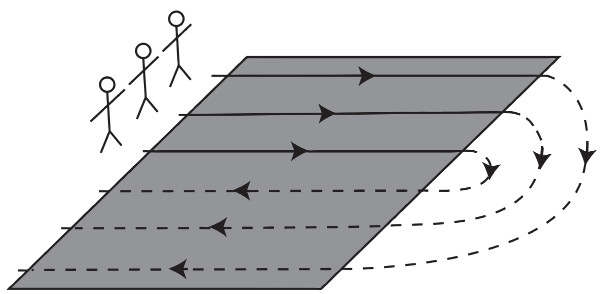
Processing the Crime Scene

Processing the crime scene is a lengthy, exacting process that involves detailed documentation of the conditions at the scene and collection of all pertinent physical evidence. In larger cities, a team of investigators who specialize in the identification, collection, and preservation of physical evidence would process the crime scene. Many different names are used for these teams, such as crime scene team (CST), crime scene investigators (CSI), or evidence technicians. In areas with smaller forces, specially trained police officers might collect the evidence. In whichever case, the lead investigator would not be the person doing this work. Nor would the CST be involved in the interrogation of suspects or interviewing witnesses. Furthermore, the people who collect the evidence very rarely are the same people to perform any analysis.

The CST would usually be called in after the scene has been secured. This team could consist of just one or two crime scene technicians or it could be a whole group of people with a range of different types of expertise. If it has not already been done, the first thing the CST would do is to set up a command post outside of the crime scene with a sign-in sheet for everyone entering and leaving the scene. This sign-in also serves as part of the chain of custody for any items or samples collected.

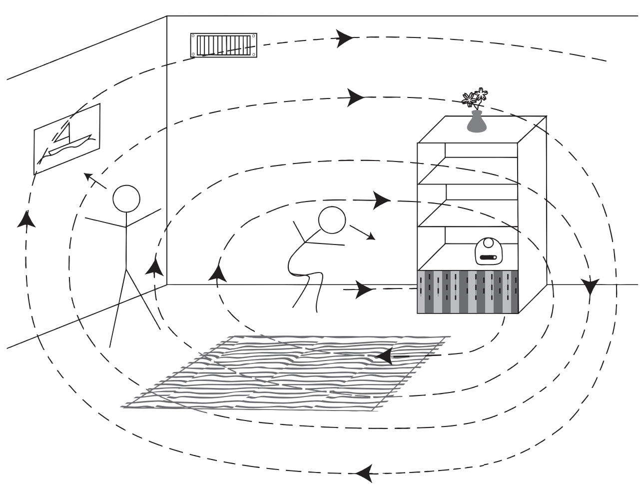
Next, the CST would conduct a survey, or preliminary walk-through, to make observations and create plans for processing the scene. Nothing would be touched yet; everyone at this point is conducting a visual examination. The goal here is to take note of as much as possible about the scene and gather information about such things as points of entry and exit, items out of place, and items that are missing. Anything could potentially be evidence. The only exception to the "no touching" rule is with transient evidence, evidence that by its very nature, or due to the conditions at the scene, will disappear or lose its evidentiary value if not preserved or protected. Evidence such as wet shoe prints, bloodstains in the rain or small quantities of spilled liquid must be processed as quickly as practicable. In this case, the crime scene technicians have to work swiftly to preserve and record what they can.

Following the walk-through, the CST will come up with a search plan. Since each scene is different, the resulting plans will be based on the situation at hand. In all cases, searches must be performed systematically and thoroughly. Members of the CST work their way methodically through the area following a specific pattern, for example working an outdoor scene using a line search pattern (Figure 1.8a) or spiraling around inside a room working from bottom to top (Figure 1.8b). Each item of evidence would be tagged with a numbered freestanding marker or a flag, again without touching anything. In complex crime scenes, once an investigator



(a)

Figure 1.8a Example of an outdoor line search.
Source: With thanks to Darrel Kassahn



(b)

Figure 1.8b Example of an interior spiral search.
Source: With thanks to Darrel Kassahn

finishes searching an area, they often trade places with someone else who would then search the same area over again, often using a reverse pattern, i.e. working from top to bottom rather than bottom to top, to recheck the area for anything that was missed the first time.

Still without moving anything, the scene would be photographed, sketched, measured, and possibly videotaped. As one crime scene analyst from Virginia put it, "Shoot your way in, and shoot your way out." Everything should be photographed, from far away and from close-up. The CST photographer would start by taking pictures of the overall crime scene from a variety of angles and vantage points. Each item of evidence would be photographed several times, initially from a distance to orient the evidence within the overall scene, then from close-up. All close-up photographs should include a scale, a direction up indicator (if not horizontal) and be taken at a 90° angle. Film is cheap, as is media for digital storage of myriad image files, so everything should be well photographed, even if its relevance is not immediately apparent. A photograph of dusty cobwebs on a staircase could turn out to be important if a suspect claims that the victim rolled down the stairs. There is no harm in having extra photographs, while it can be potentially be devastating to miss a critical image.

In addition to the photographs, an investigator would also sketch the scene to record the exact locations of each item of evidence (Figure 1.9). The sketch map

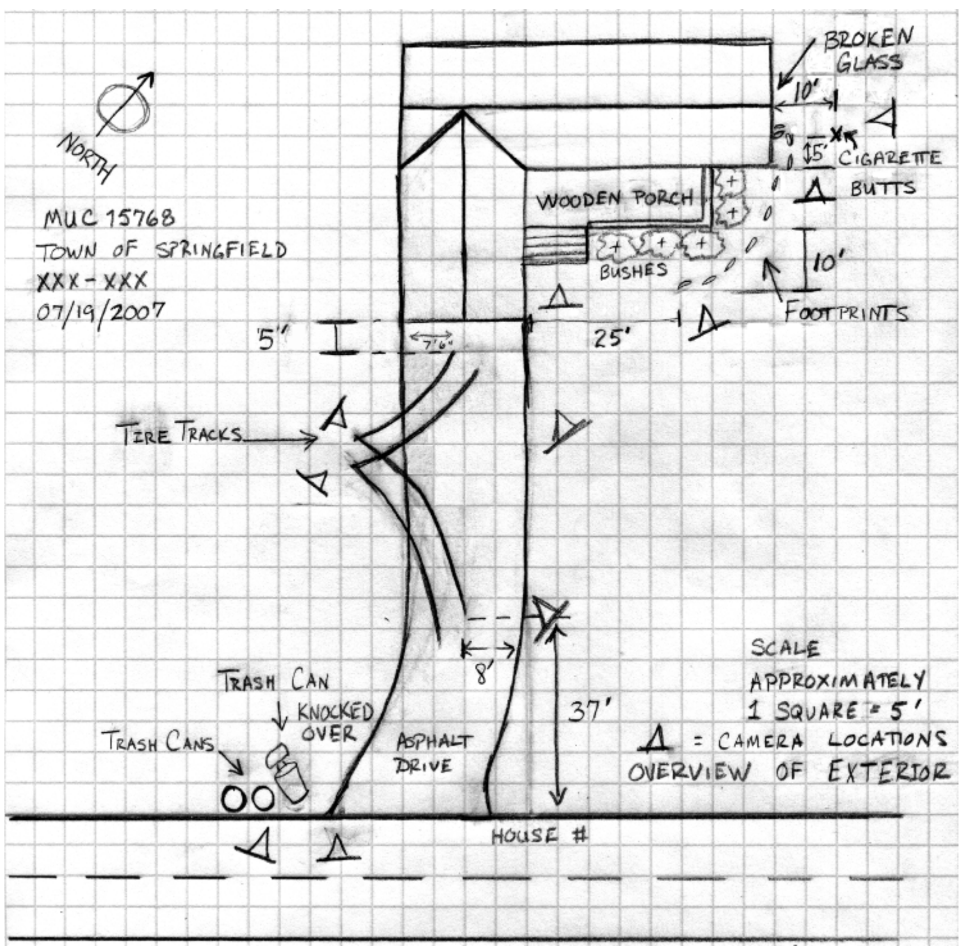


Figure 1.9 Example of a crime scene sketch with north arrow indication and notations showing the location of each camera.

needs to indicate north, which should be determined at the scene using a compass. Investigators must then make careful location measurements for each item of evidence from at least two fixed reference points using tape measures or measuring wheels. In large outdoor scenes, a global positioning system can be used to determine locations. There needs to be a scale on every sketch as well. It is useful to make sketches showing the locations from which photographs of the scene have been taken.

Once the scene has been sketched and photographed, and the locations of all of the marked pieces of evidence have been thoroughly documented, investigators can begin to invasively search the scene. At this point investigators can start to disturb the scene somewhat in order to locate hidden evidence. Close-up photographs must be taken of anything discovered during this phase of the search.

Only after the scene has been thoroughly documented can the collection of evidence begin. The order in which evidence is collected is prioritized: fragile materials are collected first, then moving from the most accessible items to the least accessible ones. Processing of the scene would also progress from less invasive techniques to more invasive techniques. Invasive techniques include using powder to look for latent fingerprints, or using chemical indicators to search for blood or drugs. If possible, trace evidence should be collected prior to the use of fingerprint powder or chemicals since it might inadvertently be moved or contaminated by the technician performing such activities. The goal here is to ensure that no evidence is compromised by premature removal or treatment.

Once an investigator is ready to collect an item, they must start a *chain-of-custody* form or tag that gives a complete description of the item, the time, date and location of recovery, who collected it, a case number and the tag number associated with the item in the photographs (Figure 1.10). If the item is large enough, the investigator will also mark it for identification. The chain-of-custody form started here must accompany the evidence from the point of collection, to the laboratory or storage locker, all the way to the courtroom and must list every person who ever had possession. For anything collected at the crime scene to be admissible as evidence, it must have been legally obtained, its origins identifiable by a crime scene technician and there must be an intact chain of custody.

Different types of evidence have different handling and storage requirements. For example, liquid bloodstains should not be stored in plastic, since they would immediately start to grow mold and decompose. Sand and soil samples should not be stored in glass. Many of the mineral components of such a sample are harder than glass and could break loose minute pieces of the sample bottle. This might make it difficult or impossible to separate any glass native to the sample from the glass introduced from the sample bottle. Items must be packaged securely and individually in order to prevent cross-contamination. If items of clothing are being collected, each item should be packaged separately, including the shoes (i.e. left shoe packed separately from right shoe). All evidence containers must be sealed at the scene. Once an item has been picked up, the spot where it was located should once again be photographed.

Once evidence collection is complete, items will be arranged for transport to the appropriate laboratory for analysis or to a police storage locker. The lead investigator would usually be responsible for authorizing the removal of evidence from the scene. The sign-in sheet forms another part of the chain of custody because the identity of every person transporting evidence is recorded as they sign out.

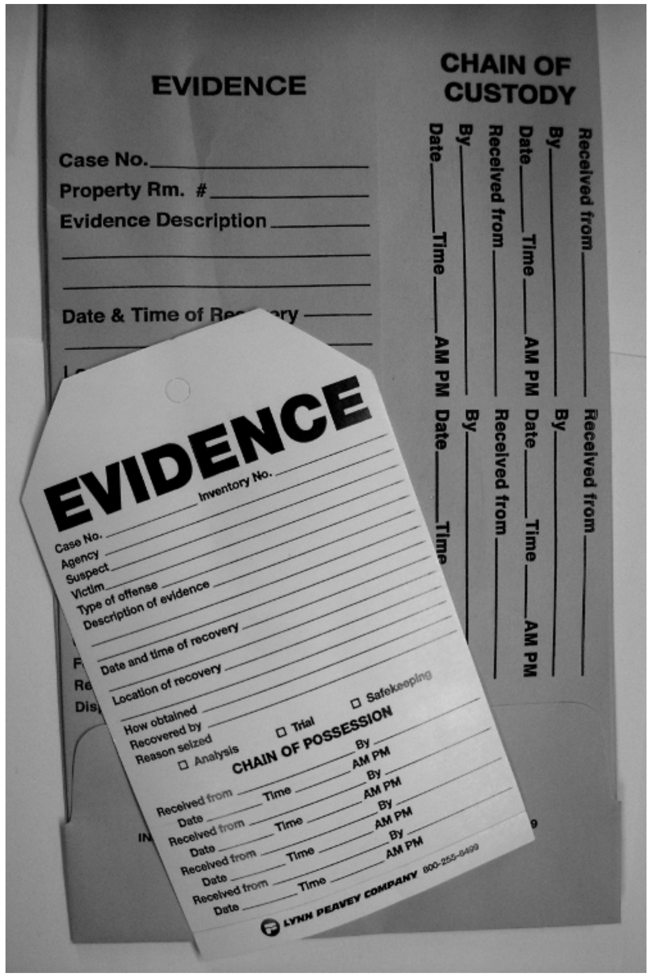


Figure 1.10 Evidence bag and tag with chain-of-custody forms.

It is important to collect all pertinent evidence prior to the release of the scene. Once the lead investigator releases the scene, it would most likely take a search warrant to return, and any evidence collected later could be viewed with suspicion. For a much more authoritative introduction to this topic, see Barry Fisher's (2005) *Techniques of Crime Scene Investigation* or a similar text.

Types of Evidence

Pretty much anything can be evidence. Common types of physical evidence include fingerprints, glass, documents, and fibers, plus biological and geological materials. The items of evidence collected for a case and submitted for analysis are often referred to as *questioned samples*. The first stage of analysis for most trace evidence is *identification*. If the evidence provided is a white powder, what is it? Is it heroin, ground aspirin, or talcum powder? In some cases, for example in a drugs bust, all that might be necessary is an identification. There are also times where an identification is all that is possible.

The next step after identification is *comparison*: a determination of whether two (or more) samples could have a common origin, like with DNA. For geological materials, it is usually much more fruitful to approach this step by applying the principle of *exclusion*; working through a series of steps to see if you can demonstrate that two (or more) samples could or could not have the same point of origin. For example, if you have soil samples taken from a crime scene and from a suspect's boots, it is usually not possible to prove that they are from the same source (you would need some significantly atypical properties for that). Instead, you determine whether they are *excluded* from potentially having the same source (i.e. could not have) or are *not excluded* from having the same source (i.e. could have come from the same place). This might seem like a strange semantic quibble, but it is actually a vital step in understanding the appropriate mindset for analysis.

In this example, the soil samples collected from the crime scene would be called *control samples*, or samples of known origin. The samples taken from the boots would be the questioned samples. In addition, for this type of investigation, *alibi samples* might be collected from alternative locations a suspect reports visiting. This way the analyst can determine whether the soil on the suspect's boots has more in common with the soil from a public park the suspect said they visited than with the soil from the crime scene.

Forensic comparison sometimes starts with comparing the questioned, control, and alibi samples with *reference samples* of known origin that have been extensively examined and are well documented. This type of evaluation is used to determine the key characteristics of each evidentiary sample. The next step is to see how many key characteristics each of the evidentiary samples share in order to determine which of them, if any, are related and to what degree. *Substrate samples* (background blanks) are also sometimes needed to determine what might be unique about questioned samples or if there are components of the sample that might somehow interfere with the analysis technique. For example, in an arson case or when investigating a suspected toxic chemical dump, it is important to distinguish what is in the background from what might have been added in the questioned samples.

There are two basic levels of comparison. The first is *class comparison*, or determining that the samples being compared come from the same group. For example, if you determine that a bloodstain is of type A blood, then you know that it comes from someone in the class of people who have type A blood, which encompasses around 26% of the population. This result also excludes anyone who does not have type A blood, or the remaining 74% of the population. Most of the time, this level of comparison is the best one can do with geological materials. This means that you can identify a soil as a silty clay loam, but you cannot tell exactly which silty clay loam. For geologic evidence, you would typically report that a sample was either *excluded from* or *not excluded from* belonging to a particular source/class.

The second level of comparison is *individualization*, where it is possible to determine to a high degree of probability that the two samples being compared have the same origin or source. This is how DNA examination works, but is rarely possible with geological materials. For DNA, we have a finite set of possible sources (the total population of humans), a finite number of characteristics to compare, and an ever-growing database of samples, making it possible to statistically calculate the probability that two samples came from the same person. There are no such known parameters for geological materials (i.e. exactly how many different types and combinations of geological materials exist and where exactly they all are), nor is there a forensic database for comparison, which makes it impossible to statistically calculate the probability of a common source.

However, you do sometimes run into mixtures of minerals that are very rare, have unusual elemental signatures or materials that might have some characteristics formed under very specific weathering conditions, which make those samples distinct from more common geological materials. When you have a distinctive sample, you can look at the ranges of common materials in the same general area, and if there are no other comparable materials, you can consider your sample to be normatively individualized.

Most often, trace evidence units handle geological materials. In practice, this includes not only obviously geological materials, such as rocks, fossils, and soil, but also building materials, glass, potting soils, kitty litter, and the mineral components of pigments, inks, cosmetics, and other household products. According to a contact in the FBI Mineralogy Division Trace Evidence Unit, the work performed there is: identification ~12% of the time; class characteristics ~81% of the time; *provenance* (determining the source or origin of something) ~5% of the time; *fractography* (studying patterns of breakage, usually to match them) ~2% of the time; and body recovery ~0.1% of the time. The real point here is that forensic geologists have to be very flexible and able to deal with a wide range of materials.

Further Reading

This was just a brief introduction to the history of forensic science, specifically to the application of geology in law enforcement, and to crime scene investigation. It must be emphasized that crime scene investigation is a very complex and specialized topic, and the information here is by no means authoritative. Every police agency and forensic laboratory has their own set of standard operating procedures (SOPs) and quality assurance/quality control (QA/QC) programs. For an introduction on how to create and maintain an appropriate forensic laboratory notebook, please go to the companion website (www.wiley.com/go/bergslien/forensicgeoscience). Parties interested in more background on forensic geology are also directed to:

Murray, R. C. (2004) *Evidence from the Earth*. Mountain Press Publishing Co., Missoula, MA. [A nice overview of the topic.]

Murray, R. C. and Tedrow, J. C. F. (1992) *Forensic Geology*, 2nd edn. Prentice Hall Inc., Englewood Cliffs, NJ.

Ruffell, A. and McKinley, J. (2008) *Geoforensics*. John Wiley & Sons Ltd, Chichester, UK. [A more advanced book, very informative.]

Wilson, C. and Wilson, D. (2003) *Written in Blood: A history of forensic detection*. Carroll and Graf Publishers, New York.

For more information on crime scene processing, the following books give a good introduction to the topic (there are lots of other well-written books out there).

Federal Bureau of Investigation (2008) *FBI Handbook of Crime Scene Forensics*. Skyhorse Publishing, Inc., New York. [Inexpensive and useful.]

Gardner, R. M. (2005) *Practical Crime Scene Processing and Investigation*. CRC Press, Boca Raton, FL. [A concise "how to" approach.]

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