Forensic Archaeology and Forensic Taphonomy: Basic Considerations on How to Properly Process and Interpret the Outdoor Forensic Scene

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ABSTRACT

Medicolegal death investigation requires a multidisciplinary approach to the collection of data from the crime scene to the autopsy table. Law enforcement processing of the indoor crime scene works extremely well for documenting evidence and producing reconstructions of past events. However, outdoor crime scenes require a new set of scene processing protocols — a need primarily derived from the wider array of natural agents, such as plants, animals, soil chemicals, or environmental conditions that will affect the evidence after burial or deposition outdoors. Forensic archaeology provides the principles, practices, and protocols for documenting and analyzing this type of evidence at a variety of outdoor and other complex crime scenes, including large-scale scene searches, surface-scattered remains, buried body features, fatal fires, and mass disaster scenes. Scene recovery protocols require 1) documentation of the context of the scene, including specific location, local flora and fauna, and geological, geographic, and environmental factors and conditions and 2) detailed notation of the spatial distribution of the evidence in order to establish association of evidence to other evidence and to a particular incident. The discipline of forensic taphonomy provides the techniques and conceptual framework to combine these scene-derived data with laboratory analysis of the biological tissues in order to build and test scientific hypotheses regarding the events surrounding death and deposition. The primary assessments resulting from a forensic taphonomic interpretation include scientific estimates of postmortem interval; whether and how remains have been moved, removed, or altered; and ultimately, whether there is an indication of human intervention. *Acad Forensic Pathol.* 2016 6(3): 439-454

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INTRODUCTION

Medicolegal death investigation is a complex multidisciplinary endeavor involving law enforcement, coroners and medical examiners, and a variety of forensic scientists including, but not limited to forensic pathologists. The information required to clarify the death event is obtained from a wide array of evidentiary materials and contextual observations gathered from the body, crime scene, and police inquiries on the circumstances surrounding victims, witnesses and suspects. Similarly, the analyses and inferences of each forensic expert taking part in the investigation are informed not only by the isolated evidence or pieces of information derived from their own work and type of evidence, but also require the collection and transfer of other types of information from the remaining experts.

DISCUSSION

The Outdoor Scene

Medicolegal death investigation of the indoor scene is generally conducted with detailed protocols based on

clear standards and objectives proven to render best results in determining forensic significance, establishing chain of custody, and collecting all necessary information at and about the scene. However, if the body is discovered at an outdoor setting, the classic protocols and procedures for the collection of evidence from outdoor scenes are often neither comparably robust nor often as comprehensive (1-3). Further, these scenes may be associated with lower expectations of significant outcomes, compared to what is expected from indoor scenes (**Image 1**). This raises several concerns. Are the standard questions asked at the indoor scene still relevant at the outdoor crime scene? Is there still information to be gathered? What new/different factors affect the evidence that has been exposed to the elements? How do we gather/preserve outdoor information and evidence?

Upon reflection, the primary questions asked at the outdoor scene are nearly the same as those that are asked at the indoor scene. Who is the individual? How did he/she get here? How long has he/she been here? What are the specifics of the events surrounding the death (and in particular, the role that other humans

Image 1: A) General view of outdoor forensic scene following denuding. The image illustrates the complex nature of the outdoor scene in which forensic significance needs to be determined, careful mapping procedures are required, and random and nonsystematic collection of evidence would not provide useful information. **B)** Close-up of scene showing mixture of garbage and forensically significant human remains.

may have played in the victim's demise and placement at that location)? Other than determining identity, however, how these questions are addressed and what evidence is used in the formulation of answers must necessarily be a bit different.

The primary difference between indoor and outdoor scenes is indeed that evidence at an outdoor scene has been potentially disturbed/modified by more agents and processes that are not commonly encountered at indoor scenes: plants, animals, insects, environment, water, gravity, and a whole range of environmental, climatic, and biotic factors. However, that does not mean that all evidence has been destroyed and the amount of information decreased; but rather, it suggests that the quantity and array of information will be different, and in many cases, actually greater, resulting in a scene more complex than the indoor scene. This added information requires a different approach and different datasets for the reconstruction of past events (1, 4). Since so many natural factors impact the evidence after the death event, reconstructing events that have transpired at the outdoor scene also requires a wider array of factors and variables to be considered and recorded (e.g., temperature, humidity, plants, animals, insects, sunlight, snow, rain, water, soil), placing a much more intense focus on post-depositional/postmortem alteration than at typical indoor scenes.

The approach to processing outdoor scenes, therefore, must address a new set of questions. Have the remains been moved, removed or altered from their original depositional positions? If so, what are the agents responsible for those alterations (e.g., plants, animals, water, gravity, humans)? How long ago have the remains been deposited at this location, taking into account the combined effects of those natural factors?

Forensic Taphonomy

The answer to many of the questions asked of the outdoor scene, lies in the discipline and approach of forensic taphonomy. Forensic taphonomy has been defined simply as the study of what happens to a human body after death (5, 6). Since most of what happens to the body (and evidence) at an outdoor setting is the result

of alteration or modification by natural agents such as plants, animals, soils, environment, gravity, and many others, the recognition and documentation of the specific role played by each of these natural agents is critical to understanding and explaining why evidence ends up where it ends up, or why it looks as it looks at present. This allows us to focus on unusual patterns of dispersal or removal of evidence and remains that can provide indications of human intervention (e.g., moving/removing remains to hide evidence). Providing hypotheses of the role that humans play in altering a scene or evidence after the death event therefore represents one of two major assessments provided by a forensic taphonomic investigation. The other primary assessment is that of postmortem interval (PMI), and how long the body has been at the location.

Even though the scene, body, and evidence have been disturbed to some degree at all outdoor scenes, it must be emphasized that much information remains and we will be able to present a evidence-based scenario of what transpired at the scene based on proper documentation and collection of that information. The forensic taphonomic approach to the processing and understanding of the outdoor scene thus represents an important paradigm shift from the old-school thinking that the outdoor scene is almost totally devoid of usable forensic information (especially with respect to reconstructing past events) to the active scientific pursuit of uncovering the fine details of past events hidden in the seemingly complex outdoor scene (4, 7).

As mentioned above, the pieces of information required for these reconstructions of outdoor scenes include new types of evidence (e.g., details of decomposition of biological tissues, or of marks on tissues resulting from animal, plant, and insect interactions) and new factors to consider (no walls to the scene and no easily definable boundaries). Therefore, new documentation and recovery protocols are required as compared to what is employed at the indoor scene. Forensic taphonomy focuses on the identification, documentation and interpretation of a wide variety of potential taphonomomic agents, including how and to what extent they have altered the remains and evidence at the outdoor scene. It includes large amounts

of information drawn from both the scene and laboratory examinations. As with indoor scenes, it is vital to place the focus firmly on maximizing evidence location and collection, including comprehensive documentation of context and association of scene and evidence. Indoor scene processing protocols do not cover all natural taphonomic agents and are generally ineffective and incomplete for dealing with the outdoor scene. Thus, we must turn to other disciplines, and in fact one is ready-made: forensic archaeology, by which standard archaeological principles, practices and methods (with some minor modifications, see below), is employed to systematically and comprehensively locate, document and interpret evidence at the outdoor forensic scene (8).

General Considerations of Forensic Taphonomy and Forensic Archaeology

The discipline of forensic archaeology arose in the 1980s just after the debut of forensic anthropology in the 1970s. It was quickly realized by all parties in the forensic investigation that scene processing protocols for outdoor scenes may not have been as rigorous as those employed at indoor scenes, and the quality and density of informations gathered diminished. Possibly, this can be attributed to common mistaken assumptions that since the scene and associated evidence was exposed to the elements and animals, it likely was lost entirely or altered to such a degree that it was no longer of much value. Common questions asked of the indoor scene could thus not be addressed at the outdoor scene, as the evidence for the construction of the scientific hypotheses had not been collected. The most effective tool for evidence collection of the outdoor scene was clearly archaeology (1, 4, 7-9). This was evident simply by comparing the coincidental primary goals of both disciplines: reconstruction of the past based on evidence found in highly altered contexts. In the 1970s and 1980s, discussion of the role of archaeology in forensics focused on the recovery of clandestine graves (10, 11). Since that time, common archaeological methods and practices began to be employed on other forensic scenes, including searches, burials, surface scatters, and eventually, fatal fire and mass disaster scenes. These methods and practices, modified

to meet forensic standards, were incorporated into a new discipline appropriately named forensic archaeology (8).

With the consideration that the discipline of archaeology provided the appropriate methods, principles and practices to uncover, document, and collect evidence, as well as to understand patterns of evidence distribution through consideration of stratigraphy, context, and association at the outdoor scene, came the realization that a more general framework was required in order to put together the additional field and laboratory information considered in forensic contexts as compared to archaeological sites and in a manner that permitted the interpretation of outdoor crime scenes much in the same way that indoor scenes were analyzed and interpreted. The discipline of taphonomy, originally defined by Ivan Efremov (1940), and considered as a branch of paleontology, would come to bridge this gap (12). Taphonomy studies all the modifications and alterations that a biological organism suffers since its death to the moment we recover its fossil remains and study them. This includes how the animal (or plant) died (necrology), how it ended up in its current location (biostратinomy), and how it was altered after burial by different physical and biological agents and processes (diagenesis and bone modification), including by the manner in which its remains were located, excavated and handled. It is immediately clear that there are distinct parallels between these goals and those of a forensic investigation, with the advantage that taphonomists had already been studying these issues for half a century. They have constructed the best methods for determining issues such as whether a particular fracture occurred antemortem or could instead be better attributed to natural postmortem damage or decay; whether the remains had been originally deposited at that location, or had been transported there after death by different physical and biological processes; or how and how fast they had been interred. With the introduction and quick adoption of taphonomy into anthropology and archaeology in the 1970s and 1980s (13-15), taphonomic methods and inference came to incorporate past human behavior, including how to distinguish alterations caused by

humans from similar ones caused by natural agents, if a deposit could represent an intentional burial or natural interment post deposition, or how to identify the tool or process that fossil humans employed to break or cut a bone. These are almost exactly the same questions posed by forensic scientists regarding forensic significance or manner of death, considering exactly the same natural processes playing a role at outdoor crime scenes and addressed by many of the same types of materials (human and animal remains).

Producing Testable Hypotheses

Perhaps it is best to consider that forensic taphonomy focuses on the creation of testable hypotheses that attempt to provide key answers related to the death event, including 1) the condition, location, position and orientation of the body when deposited at the scene originally; 2) what has happened to the body between the time of deposition and the time of recovery and how long it took (PMI), and importantly, whether humans were involved; and 3) whether we can provide information of events leading up to the body getting to the site. Important answers that can now be provided scientifically include how the individual got to the site, whether they were alone, whether they were alive when they arrived at the scene, how long ago the event transpired, the taphonomic agents responsible for moving and removing remains out of anatomical position, whether animals scavenged or altered the remains and when this occurred, whether humans came back to the scene and attempted to hide evidence, and the assessment of broken and damaged bones.

How are These Questions Addressed at the Outdoor Scene?

The answers to these questions always begin with the proper location, documentation, and collection of evidence at the scene. Similar to the indoor scene, the processing protocols focus on noting context and association attributes of the evidence. Following scene processing, the detailed analysis of the biological tissues (e.g., soft tissue decomposition characteristics, bone surface modification, skeletal trauma analysis) in the laboratory permits better assessment of a wide

variety of forensic taphonomic interpretations: PMI (16-18), effects of various taphonomic agents (19), the identification of perimortem vs. postmortem trauma (20), and scientific reconstructions of past events.

Forensic Archaeology Practices at the Outdoor Scene

The following is a general schematic of how an outdoor scene is approached and processed utilizing forensic archaeological principles, methods, and practices. One significant difference from an indoor scene is that a search of a large outdoor area may be required in order just to find the outdoor site. When a forensic scene is located, similar to an indoor scene, the processing requires the detailed notation of context and association. This information in turn is linked with the results of the analysis of materials in the lab so that an evidence-based scenario of what happened in the past can be presented.

Forensic Searches for Unlocated Scenes

Unlocated remains or scenes will require a systematic search of the suspected area or areas. To be both efficient and effective, search protocols require: 1) a visual assessment of 100% of the surface within the target search area and 2) a detailed notation of the specific area that has been covered at each step by exacting search methods (preferably on maps or aerial photographs). Drawing from both forensic research and what has been learned in regular archaeology, the most effective search methodology is based on straight-line pedestrian searches, with searchers lining up shoulder-to-shoulder and scanning the surface thoroughly and rapidly (8). Properly trained cadaver dogs are often useful in the early stages of the search for relatively fresh (i.e., actively decomposing) remains and can expedite the finding of the body (21). If the remains are lying on the surface anywhere within the searched area, these methods produce nearly 100% success rates in locating the body. However, the probability of locating the body drops dramatically if the remains have been buried. Specialized equipment able to detect subaerial anomalies potentially indicative of a burial, such as ground penetrating radar or fluxgate

magnetometers, can be helpful in searches under the appropriate conditions such as open fields, relatively small search areas, and areas with certain soils or soil conditions, although their efficacy may decrease at less ideal scenarios such as extensive searches in forested areas (22).

Associated with all searches is the necessity that determinations must be made whether a particular item of evidence is forensically significant or not. Ultimately this determination depends on whether it relates to the forensic incident and will be based on whether there is an indication that an item was generated, moved, or altered during the event (and in what state and where it was before the incident). Everything may be potentially altered, and the nature of that alteration must therefore be documented and incorporated into the reconstruction of the death event. If the alteration is determined to have occurred during the death event, it would immediately become 1) forensically significant, 2) evidence, and 3) associated with that particular event. Thus, the documentation and eventual analysis of the *in situ* position, location, and orientation of the evidence is vitally important and plays the most significant role in the death event reconstruction. Importantly, this documentation process also establishes the first link of the chain of custody (2).

Thus, it is particularly important to have a trained individual available during the search who can quickly and accurately assess forensic significance of found remains, especially suspected osteological materials. These professionals can make real-time evaluations of human vs. animal, even in cases in which the remains are isolated, fragmented, or heavily modified rather significantly by animal gnawing or burning (23). With smart cell phones available to law enforcement, evaluations of forensic significance can be conducted through email or text messaging exchanges in near real time.

Processing of Outdoor Scene Through Forensic Archaeological Methods

After evidence is located and potential significance has been established, the processing of the scene involves

properly documenting context and association of that evidence. In the field of archaeology, hypotheses of association are used to indicate that artifacts found in proximity actually entered the scene at the same time and are related to a particular depositional event (9, 24, 25). This depositional event could be hours, days, weeks, or even months in duration. In forensics, the depositional event is usually of very short duration (on the scale of minutes or hours). It must be kept in mind that although pieces of evidence may be found in the same place/same room, they may not have been deposited at the same time. The focus of the recovery is on the acquisition of locational information and will include 1) general and specific descriptions of the scene, including geographical location (geographical coordinates, street address) and 2) the notation of the precise location, position, and orientation of the unaltered, as-found evidence within the scene (defined, in archaeological parlance, as its *provenience*) (24). This documentation of the spatial distribution of evidence leads to hypotheses regarding the association of evidence to a particular depositional event (thus establishing association).

The best way to properly collect all these data is through forensic archaeological principles, methods, and protocols, which share the same basic goals as indoor forensic protocols but with an added component largely derived from classic archaeology. However, due to a few major differences in perspective, requirements, and in general, the types of information and evidence targeted at outdoor scenes, forensic archaeological protocols incorporate new, additional techniques, data types, and objectives not considered at either indoor scenes or archaeological sites (1, 8, 9).

The primary difference between indoor and outdoor scene protocols is that the latter must focus on the post-depositional factors affecting the remains, requiring a complete inventory of the taphonomic agents moving, removing, and altering the evidence and remains. As important as listing these factors is assessing the degree and scale of their impact (e.g., rodent chewing on the ends of a few bones, as compared to a black bear scattering remains 30 meters from the main concentration of the body). As always, the pri-

mary goal of this taphonomic agent inventory and impact documentation is sorting out natural factors from forensically significant human activity.

The types of evidence encountered, considered, and documented in the reconstruction of events at the outdoor scene are quite different from those at the indoor scene, and nearly always related to potential taphonomic agents interacting with the evidence (8). They will include environmental evidence, including trees, grass cover, and leaf litter; soil chemistry; animal interactions (e.g., scavenging, bone gnawing activities); insect interactions (especially anthropophagic insects); past weather and temperature conditions; humidity and flowing water factors; and gravity effects on remains located on sloping terrain, among many others.

Thus, it must be kept always in mind that the goal of the recovery of the outdoor scene is not just making sure that all remains are found and recovered, but recording and understanding the variety of taphonomic agents that affected the remains, as well as how they did so. We seek explanations of why things are moved or removed, determination of where the body was originally located, and even suggestions for the original position and orientation of the body since the time of deposition on the scene.

In the following section, we describe general forensic archaeological recovery procedures employed during the processing of the outdoor forensic scene.

Step 1: Careful Documentation of the Condition/Context of the Scene at the Time of Discovery

Descriptions of the forensic scene begin with the notation of location. Identifying the location of the outdoor scene requires more precision than the street address commonly available for the indoor scene. Currently, global positioning system (GPS) coordinates obtained through the use of higher quality GPS units work best, especially considering that this information is critical for eventual incorporation into geographic information systems (GIS) analysis.

The immediate vicinity of the scene is described thoroughly via written notes and photography. Notation will include descriptions of factors such as tree and ground cover, slope, general soil types, proximity to water, roads and trails, and a myriad of other scene attributes that may be of potential relevance to reconstructing past events (e.g., how the individual got to the scene, impact on decompositional sequence and rates, the particular scavenging animals residing in the area). Photographic documentation begins from afar, capturing the general setting of the scene and then progresses inward toward the scene.

Step 2: Clearing Debris From Atop the Evidence

Following initial documentation of the scene, efforts to expose the remains from beneath vegetative covering can be started without disturbing or altering the position and location of the remains themselves. This denuding effort progresses from outside to inside the scene and serves to locate and expose the evidence as well as the underlying microtopography of the ground surface or substrate that the remains are resting upon, which permits further understanding of effects of taphonomic influences such as slope wash and gravity (**Image 2**). However, it should be noted that the process of searching and clearing the scene must not be conducted hastily and indiscriminately to serve the sole purpose of locating the underlying evidence. The presence and condition of biotic evidence and other evidence beyond the body might be key to addressing issues of missing or out-of-place remains or PMI estimation. For example, in the northeastern U.S., the stratification of deciduous leaf litter relative to the human remains provides a useful indicator of depositional timing of the body on the scene.

During this stage of scene processing, the ability to evaluate forensic significance of biological tissues (i.e., bone from non-bone, human vs. animal, fragment and altered bones) remains a crucial skill. If the scene is recent, it is important to search for recently overturned dirt, footwear impressions, and damaged vegetation indicative of recent human activity. In addition, evaluation of forensic significance extends to determining whether other natural items found at the

scene may be directly associated with the death event. Has the log, or branches, or leaf litter been moved over the remains or the burial in order to conceal them? If they have, they provide a piece of the forensic taphonomic interpretation of past events and must be noted as evidence.

Step 3: Notation of the Spatial Distribution of the Evidence

Following removal and notation of the overlying vegetation, the next step in scene processing requires the careful notation of the precise location, position, and orientation of all the evidence via cartographic means. This could involve hand-drawn maps created through rather standard coordinate system mapping procedures as well as through electronic total stations, survey-grade GPS, or even three-dimensional (3D) scanners. The best practice combines multiple mapping procedures through several of these methods. A map of the immediate scene, including all the evidence associated with the death, body, or deposition event will allow the analysis of the spatial distribution of evidence as well as the assessment of forensic taphonomic factors (e.g., remains scattered in a pattern common to coyote or bear activity and behaviors).

The map should include indications of scene contour (slope) and microtopography. This is best acquired through electronic total station mapping procedures. Notation of GPS points provides the location of the site at the global scale and permits incorporation into already existing maps and geographical resources and subsequent analysis in GIS software.

Extensive photographic and written notation of the evidence continues. This is particularly important not only for chain of custody purposes, but also for the analysis and interpretation of human skeletal trauma patterns. Detailed notation of the condition of the bones at the scene will provide evidence related to the relative timing of the trauma to bone, primarily, but not limited to, the distinction between perimortem trauma (at and around the time of death) and potential trauma induced during collection, transport, or laboratory examination.

Step 4: Collection and Transport

After completing all mapping procedures, proper collection and removal procedures can be started. Prior to placement in appropriate collection receptacles, each item of evidence receives a unique label matching that

Image 2: A) General view of human remains partially covered by leaf litter, obscuring appendages and other evidence. **B)** Plan-view hand-drawn map of remains following denuding with all associated evidence visible.

in the plan-view and topographic maps, which is of prime benefit to subsequent analysis of the spatial distribution of the evidence and to retain chain of custody. The collection and transport process is then completed with protocols aimed at preventing any further alteration of the evidence from the time of recovery to the time of analysis in the laboratory or of postmortem examination.

Step 5: Laboratory Analysis

Either at the autopsy or at the forensic anthropological laboratory, key assessments are made of the condition of the biological tissues, especially relative to the state of decomposition, location, condition of the clothing and apparel on the body, and any other information that could potentially have an impact on forensic taphonomic interpretations. Next, soft tissues are removed from the bones in order that all surfaces of the bones can be examined. In addition to standard assessments of biological profile (chronological age, sex, stature, and ancestry), evidence is sought to explain unusual stains on the bones (20), fracture and traumatic impact patterns (26), and other bone modification patterns, such as animal gnathic marks, or burning and heat alteration of the bones (20). Analysis of other evidence found at the scene, including soil chemistry, weapons analysis, clothing specifics, potential fingerprints, and many others, can be completed by forensic specialists.

Step 6: Forensic Taphonomic Interpretation

The final step in the interpretation of the outdoor forensic scene is to put together the multidisciplinary recovery and analytical efforts into a coherent, scientifically defensible hypothesis of past events that have occurred at the forensic scene under investigation. This requires that the outdoor forensic scene must be processed with the idea that much critical information still resides there and exacting, well-thought out recovery procedures can retrieve it. It is no longer acceptable to use random, rapid, non-systematic collection procedures to find and recover evidence and remains at the outdoor scene. Taking a few pictures of the outdoor scene, randomly searching and collecting what can be seen without clearing the scene, and plac-

ing the body into body bags for rapid transport to the morgue or lab will always result in losses of evidence, context, and association information, and ultimately will prevent scientific reconstructions of key events transpiring at the scene. Just as this would not be acceptable at an indoor scene, this haphazard approach and destruction of evidence is not tolerable at the outdoor scene.

The common goal when processing all of these outdoor scenes is collecting the appropriate information to produce and test hypotheses regarding what happened there. The key first step requires the employment of the now common forensic archaeological methods and protocols described above, which have been shown to provide optimal results at outdoor forensic scenes time and again (9). These approach and protocols maximize the detection of evidence while minimizing the potential disturbance and loss of relevant forensic information and evidence.

Large-scale searches for unlocated scenes and remains that employ proper search protocols result in efficient and effective searches of large areas. These approaches maximize the finding of evidence while minimizing the potential disturbance and loss of information.

The recovery of surface-scattered remains focuses on the notation of the spatial distribution of the evidence through precise mapping procedures in order to understand how the remains were scattered and which taphonomic agents (e.g., gravity, slope wash, animals, humans) were most responsible for the moving, removing, and alteration of the evidence (1). By combining all the information recorded at the scene related to environmental factors and conditions, physical processes and indications of activity of potential natural agents that could have altered the remains, with laboratory analysis of the observed bone modifications (20), it will be possible to identify the specific agents most likely responsible for post-depositional modification. The analysis of this scene information takes into considerations factors such as animal behavior, botanical influences, and decompositional sequences and patterns, as well as considering the effects of environmental parameters affecting all the above, such

as humidity, temperature, and water transport. Once these natural agents are identified, the focus turns to determining unusual or suspicious patterns that might not be explained by them and thus could provide evidence of human intervention. Attempts will be made at every scene to determine the location of the body when originally deposited at the scene, based on factors such as where are most of the remains congregated, location and spatial distribution of articulated remains or body decomposition fluids, as well as attempts to determine the position and orientation of the body at the time of deposition (e.g., face up or face down, feet upslope, head downslope). The forensic case example below provides a case study that will serve to better illustrate these points.

The recovery procedures for buried bodies in clandestine graves (27) will draw upon methods and practices of regular archaeology for the excavation of bodies and evidence in a burial feature, although with a few differences: 1) unlike the excavation of a prehistoric burial, much attention will be focused on the evidence of digging activities outside of the burial pit (e.g., footwear impressions, trampled vegetation, moved branches and logs); 2) the back-dirt pile will be carefully documented and excavated; 3) the configuration of the grave feature (e.g., size, shape, depth, presence of vertical walls) will be used to indicate haste or preplanning; 4) tool mark impressions on the edges of the grave will prove important as an indicator on the digging instrument employed, and may even point out a specific tool (27); 5) the position and orientation of the body in the feature will be compared to witness descriptions of the burial event; and 6) evidence may be found within the grave that might provide useful PMI estimates, such as the state of decomposition of plant material inadvertently added to the grave (1, 4, 8).

Fatal Fire Victim Scenes

Fatal fire scenes also benefit from a forensic archaeological approach to the collection of evidence. Scene processing at most fatal fire scenes traditionally involved little more than photographing the scene and the victims as found—a practice that, unfortunately,

is still common today. Typically, no search for evidence is conducted through the fire-altered rubble. Following cursory notations, the body is then placed in a soft-sided body bag and taken back to the morgue for identification. A first problem with this approach is that following exposure to heat and fire all materials within a fire scene take on a similar appearance, making it difficult to detect and distinguish severely altered biological tissues from their surroundings, which may result in remains being left behind (28-30). A second problem is that skeletal tissues, following exposure to fire, become brittle, shrink, warp, and tend to fracture easily due to the losses in moisture and organic (collagen) components (31) and tend to break easily during recovery. Placing the remains in a soft-sided body bag exposes them to adverse conditions during transport, such that when the remains arrive on the morgue table they are commingled and significantly altered. Forensic archaeological protocols once again address and correct all these issues (28, 29). The context of the body relative to the scene is addressed diligently and with attention to detail, such as noting in which room of the house and on what floor the individual was located (based on the stratigraphy of debris covering and beneath the body) at the time of the fire, and whether there is evidence (e.g., guns, shell cases, knives) associated with the body. The documentation and recovery of the fatal fire scene calls for 1) a detailed search conducted at a distance from the body in order to locate associated evidence *in situ*; 2) careful hand-screening of burned debris in the vicinity of the body; 3) careful documentation of body position, location, and orientation via written, photographic and cartographic notation; and 4) detailed examination and documentation of the condition of the unmoved body *in situ*, specifically focused on initial descriptions of trauma, including specific location of defects (e.g., tool or cut marks).

Heat/fire alteration of bodies often leads to disassociation of parts such as distal appendages, cranial fragments, and dental remains. Careful recovery methods and attempts to associate all elements to a particular individual while excavating, even in commingled scenarios, lead to fewer disassociated remains to be sorted in the morgue and through DNA analysis.

Processing at Mass Disaster Scenes

The crash of a plane, especially a large commercial airliner, results in a large, typically widely scattered scene in which large numbers of fragments of the crashed vehicle, human remains, and personal effects are commingled and altered, often including burning. Efficient and effective search, documentation and recovery methods to deal with the huge volume of material in a large area are even more crucial at these scenes. Forensic archaeology fits the bill best at these scenes, because of well-conceived search methods and the application of technology to the documentation process, including the inclusion of electronic total stations and survey-grade GPS units, bar-code scanning technology, high-quality digital photography, and even 3D scanning. Recently, research conducted on mock scenes have validated high throughput protocols for processing disaster scenes, and have resulted in national standards in the form of the Weldon Spring Protocols (32, 33) applicable to widely dispersed scenes, such as those encountered during the recovery of USAir Flight 427 (Pittsburgh, in 1994) and United Flight 93 (Shanksville, PA, in 2001), and the Clarence Center Protocols (34) for processing more condensed scenes, such as that found at the crash of Colgan Air 3407 (Buffalo, NY, in 2009).

Forensic Case Example: Surface-Scattered Remains in Deep Woods

A couple taking an early September walk on a wooded trail in central Pennsylvania discovered what looked to be a human skull (**Image 3A**). They decided the best course of action was to not disturb the skull and instead call the local authorities, the Pennsylvania State Police (PSP). A text message exchange between the county coroner and the first author confirmed the humanity of the specimen. The county coroner and PSP requested assistance from Mercyhurst University's Forensic Scene Recovery Team (M-FSRT) to process the scene. The next day, a preliminary review of the scene (following a search by the PSP the previous day) revealed the presence of many other human remains scattered a distance away and upslope from the skull (**Image 3B**). Prior to proceeding directly into

scene processing activities, consideration was given to addressing the standard questions asked of these outdoor scenes from a forensic taphonomic standpoint. It was suggested to the recovery crew that during the processing effort they were to think about how to answer and address each of the following questions (in essence, creating and then testing forensic taphonomic hypotheses, in real time at the scene). What evidence can be used to assess PMI? Why are the remains scattered? What taphonomic agents played an active role in moving/removing the remains? Is there evidence that humans interacted with the remains after initial deposition? What was the original location and position of the remains prior to dispersal? Each member of the recovery team was to be involved in hypothesis building and testing, such that they would have to make a case for a particular hypothesis and provide the evidence to back it up. They would be attempting to analyze the patterns of evidence distribution, and trying to explain unusual patterns. In this way, discussion on-site would attempt to answer many of the questions prior to the team departing the scene.

The first step of the recovery required a systematic search of the scene and vicinity for the purpose of attempting to find all of the remains of the victim, as well as any associated physical evidence. A straight-line pedestrian search ensued (**Image 3C**) and it was noted early on that the remains were situated stratigraphically on top of the leaf litter from the previous fall (**Image 3D**). This fact made the search more successful and less time consuming since a hands-and-knees search was not required to search beneath the leaf litter, especially given that the remains were widely scattered (approximately in a 30 m x 20 m dispersal area). This observation also provided evidence of one important aspect of the PMI hypothesis: the individual was deposited on the site sometime between the date of recovery (early September), and mid to late fall (October-November) of the previous year (Hypothesis 1).

After multiple pedestrian search transects were completed and the found evidence (human bones, clothing, belt, and watch) flagged, one area on the site exhibited a concentration of remains that included a collection of ribs and vertebrae, most still articulated, as well as

a still-articulated right leg, including the pelvis and foot in boot (**Image 3E**). This pattern of a large portion of the skeleton in a concentrated area, with many elements still-articulated, suggested that the body was originally placed (deposited) in this particular location of the scene (Hypothesis 2).

A more detailed hands-and-knees search and vegetation denuding of the main concentration of human remains was then conducted, based primarily on expectations of locating a higher density of evidence in this area. The search revealed a number of smaller skeletal elements and associated evidence and provided fur-

Image 3: **A)** General view of human skull on surface of wooded area, prior to scene processing. **B)** General view of scene showing the scattering of remains (marked with red flags) prior to scene processing. **C)** General view of straight-line pedestrian search. **D)** Close-up of human remains lying on top of previous Fall's leaf litter level, indicating deposition of remains after September or October of the previous year. **E)** General view of main concentration of remains showing articulated pelvis, left leg, left boot and pants.

ther support to Hypothesis 2. In addition, the leaf litter and soils beneath the remains (especially beneath the ribs and vertebrae) exhibited dark staining indicative of decomposition fluid presence (**Image 4A**), thus providing further indication that the remains were originally located above this layer (Hypothesis 1) and in this position (Hypothesis 2), with most of the decomposition process occurring at this spot.

A hand-drawn map of the main concentration of remains was completed (**Image 4B**). In addition, an electronic total station was used to map the scattered remains and evidence located away from the main concentration (**Image 4C**). The 3D notation of the provenience (exact location) of the evidence was used to create scene topographic contours, showing that the scene was situated on a slope. This provided evi-

dence of a potential taphonomonic agent (i.e., gravity) during the attempt to answer questions related to why the remains were scattered as they were.

The isolated skeletal elements were individually numbered (Field Specimen Number) on the map, and collected in individual bags which were labeled with the appropriate field specimen numbers. Congregated, commingled, and/or articulated elements were documented and collected as a unit and individually numbered on the map and on the collection bag. The numbering system extended to the permanent labeling of the bones in the laboratory, which in turn facilitated the analysis of the spatial distribution of the remains, again, in attempts to attribute a reason for the scattering (e.g., scavenging animals, slopewash, gravity).

Image 4: A) Close-up of concentration of thoracic elements, also showing dark staining of soil and leaf litter suggesting in-place decomposition. B) Close-up hand-drawn plan-view map of main concentration of remains. C) Total station-generated map of the scene showing the distribution of evidence. Contour intervals obtained through GIS after collection of GPS points via Trimble R8. Boxes show individual relevant evidence.

After scene documentation and collection of evidence, and prior to leaving the scene, reflection by the M-FSRT on all aspects of the recovery process and discussion of questions that needed to be addressed in the forensic taphonomic assessment indicated that two rather unusual observations regarding the condition and distribution of the evidence needed to be addressed. One related to the PMI estimates: the leaf litter to human remains stratigraphic profile indicated a PMI of 3-11 months, although the limited amount of soft tissue found on the skeletal remains was usually indicative of a PMI interval of 12-24 months (35). A closer examination of the human bones revealed that much of the articular cartilage remained on many of the long bones (**Image 5**), which corroborated the more recent depositional timeframe.

In addition, the significantly disarticulated and widely scattered pattern of the skeletal elements did not fit the normal pattern of canid scavenging typically found in forensic cases in most parts of Pennsylvania. Reference to another forensic case completed by M-FSRT a few years earlier led to the hypothesis that the body had been deposited in colder conditions and remained relatively fresh until the Spring, when hibernating black bears emerged, hungry, from their dens. Their scavenging behavior of removing most of the soft tissue without total destruction of the long bones, though some tooth marks are noted at the ends of the bones (documented in the laboratory) and scattering the bones widely, fit the pattern well. In addition, bear scat was found within the immediate scene.

In the laboratory, all of the soft tissue associated with the skeletal remains were carefully noted prior to removal. A partially decomposed foot was found still in the boot, further corroborating a PMI of less than 11-12 months. The search and inventory of all bone surfaces noted both definitive animal gnawing activity and somewhat equivocal fractured and fragmented bones. The laboratory analysis then focused on trauma patterns and distinguishing between perimortem (human-induced) from postmortem (animal-induced) damage. After comprehensive examination of the bones both macroscopically and microscopically, the trauma patterns noted in the cranium (**Image 6**)

were confirmed to coincide with perimortem blunt force trauma to the face (anteriorly to posteriorly directed) and to the underside of the mandible (inferiorly to superiorly directed) with a heavy instrument that resulted in fracturing of the mandible, much of the maxilla, and many of the teeth. Evidence of sharp force trauma, in the form of a knife defect, was found in the back of the skull behind the ear. Indications of initial impact into the bone were noted, as well two subsequent episodes of altering the path of the blade in order to extract the blade from the bone.

In the final analysis, the forensic taphonomic hypotheses of PMI, perimortem events, original location of the victim, and postmortem events were eventually proven accurate by witness testimony and trial deliberations: murder of the victim in January (four-month PMI, after the previous Fall), deposition during a significant snow storm, use of a shovel handle to inflict blunt force trauma, no subsequent human attempt to alter the evidence, and bears in the area.

CONCLUSION

After proper collection and documentation of the scene, laboratory analysis of human tissue, clothing, decomposition patterns, bone surface modification patterns, analysis of the spatial distribution of the ev-

Image 5: Superior view of femur showing significant amounts of articular cartilage indicating relatively short postmortem interval.

idence is then matched and analyzed with the scene information detailing context and association of the evidence. This matching process permits testing of a variety of forensic taphonomic hypotheses that relate to PMI, the original position and orientation of the body on the scene, and the role played by humans in the subsequent redistribution of body and the evidence. We can now properly address the following questions scientifically: 1) how long has the body has been on the scene (PMI); 2) whether it was moved from elsewhere; 3) why some bones are out of place (anatomically and originally) or even missing; 4) whether the body was originally located at the time of death; 5) whether we can determine how the body was situated in terms of position and orientation at the time of death; and 6) whether the victim was dead or alive at the time of entering the scene?

We can see that, as is certainly true of the indoor forensic scene, the thorough understanding of the con-

text of an outdoor forensic crime scene, derived from exacting and comprehensive documentation and recovery methods, is critical to the successful resolution of the medicolegal death investigation. The multidisciplinary approach to the collection of evidence and information results in defensible reconstructions of what happened in the past at the crime (death) scene. It is clear that with regard to law enforcement methods, practices and principles employed during the processing of the indoor scene are well-defined and extremely effective (3, 36-38). It is also just as clear that law enforcement may not have equally appropriate methods to deal with the outdoor scene. This is where the employment of forensic archaeological methods, principles, and practices can provide the most thorough and comprehensive data collection standards, which in turn provide the best available information for the construction of forensic taphonomic hypotheses of what happened in the past at the scene.

Image 6: A) Inferior view of cranium with close-up of blunt force trauma damage on inferior surface of mandible. B) Frontal view of cranium with close-up of fractured alveolar bone. C) Right lateral view of cranium with close-up of sharp force trauma defect. D) Occlusal view of right portion of mandible showing enamel fracturing of many of the teeth.

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