CHAPTER

6 Forensic Archaeology and Scene Processing Methods

6.1 Principles of forensic archaeology

Forensic archaeology is the application of archaeological theory and methods to the resolution of medicolegal and humanitarian issues (Scientific Working Group for Forensic Anthropology [SWGANTH], 2013). It may include methods involved in searching for, locating, surveying, sampling, recording, and interpreting evidence, as well as the recovery and documentation of human remains and associated evidence (SWGANTH, 2013). Forensic anthropologists and archaeologists are therefore often requested to assist investigators and law enforcement in assessing the applicability of remote sensing techniques, developing recovery strategies, mapping recovery scenes, dating evidence, and reconstructing events. Proper implementation of forensic archaeological techniques provides a scientific basis for interpreting the context in which remains and associated evidence are found.

The origins of forensic archaeology lie in the fact that traditional crime scene processing methods were often abandoned when scenes occurred outdoors. It was long believed that outdoor contexts too quickly degraded evidence, and were not easily sketched or mapped because there were often no good points of reference. Instead, any obvious evidence was quickly photographed and collected for lab processing. It has recently become more standard practice to use forensic anthropologists with archaeological training to assist in crime scene recovery and evidence collection.

In the United States, archaeology and physical anthropology are considered subfields of anthropology. Thus, forensic anthropologists are typically educated and trained in both skeletal analysis and archaeological methods as part of their advanced studies. In other areas of the world, however, such as the United Kingdom, forensic archaeology is considered a separate discipline from forensic anthropology.

It is recognized that traditional archaeological methods can be very tedious and time-consuming, and that not all forensic archaeological investigations can be carried out in exactly the same fashion. Unlike many archaeological field projects, time is often more limited in forensic contexts because investigators may be trying to develop leads quickly, collect evidence before it is lost or destroyed, or identify a suspect. There may also be additional safety concerns for forensic searches in conflict situations, in remote locations, or under hazardous conditions. It is therefore important to maintain good communication with the investigating agency, and to balance

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factors such as safety, scene security, resources (including personnel and equipment), evidence quality, and time.

The purpose of forensic archaeology is to properly investigate a recovery scene from the beginning of a search to the removal and transport of the evidence from the scene, and to maintain context and the chain of custody for all evidentiary materials recovered (Morse et al., 1983; Cox et al., 2008). Specific goals and objectives of forensic archaeological operations are summarized in Table 6.1. The rest of this chapter will provide an overview of the principles, recommended approaches, and challenges of forensic archaeological methods in locating and recovering human remains.

6.2 Recovery scenes

Human remains can be discovered in and recovered from a wide variety of scene types, including indoor and outdoor, confined, or dispersed. The location where human remains are found is often called a **scene** or **recovery scene** (the term *crime scene*, though often applied to recovery scenes, may not always be appropriate). Outdoor scenes may involve remains that are on the surface, buried, submerged, or involved in fires (which are technically specialized surface scenes, having factors that make recovery approaches somewhat more challenging). Large scale mass disasters typically involve more complex scene processing methods and multiple investigating agencies, and are addressed in more detail in Chapter 15.

Surface scenes occur when remains are deposited on the surface of the ground (i.e., are not deliberately buried or submerged). Sometimes the remains will be in a very similar location and position to that where they were deposited. More often, however, especially for remains that have decomposed to the point of skeletonization,

Table 6.1 Objectives of a forensic archaeological operation

1. To select a detection or recovery strategy that maximizes data recorded and physical evidence recovered from a scene while minimizing scene and evidence alteration.
2. To establish and fully document the context in which all evidence is found. The recording of all spatial and contextual associations should be such that any subsequent identification process will not be hindered or compromised.
3. To recover all evidence that may be relevant to identifying the remains, determining the cause and manner of death, reconstructing the scene, determining how the remains were deposited, estimating time since deposition, and identifying post depositional taphonomic processes should be recorded.
4. To ensure safe and secure collection, storage, and transportation of human remains and associated materials from the point of recovery to accession by the appropriate agency.
5. To maintain a chain of custody through documentary and photographic records that link the recovered evidence to the scene.
6. To ensure safe and secure transport of evidence to the responsible agency.

(From Scientific Working Group for Forensic Anthropology [SWGANTH], 2013)

scavenging and other natural and physical forces (e.g., water, wind, gravity) contribute to the scattering of remains from their initial deposition site. Remains that have been redistributed in this manner are referred to as a **surface scatter**.

Burial scenes involve remains that are **interred**, or deliberately buried underground in a grave. Because these remains are not usually visible on the surface, burial scenes are often more difficult to locate, sometimes requiring specialized search techniques and technologies. While in many cases, remains are intentionally buried by a perpetrator in a clandestine grave, remains may also become buried naturally by movement of water, soil, or debris, or transported underground into burrows by animals. Some burial scenes may also involve remains that were interred in cemeteries as part of funerary practices.

Submerged scenes are those involving remains that are in aquatic environments. These may be large bodies of water such as oceans, lakes, and large rivers, but may also be swamps, small or shallow ponds, or streams. Remains in these cases may be floating on the surface of the water, resting on the substrate at the bottom, or possibly suspended in between.

Fire scenes are those involving thermally altered remains, which are often intermixed with other burned debris such as building materials or plant debris (e.g., trees and leaves). While such remains may be found in buried or submerged scenes, they are most commonly surface scenes. Fire scenes are often very complex, requiring different methods of documentation and collection because they are often associated with a high degree of fragmentation as well as other scene considerations such as access and safety hazards.

6.3 Archaeological methods and theory

Forensic archaeological methods are typically applied to the outdoor location and recovery of remains including surface remains and burials, usually when substantial decomposition or fragmentation has occurred (Cox et al., 2008). Forensic archaeological principles, however, can also be applied to indoor scenes as well as underwater and fire scenes. One important feature of archaeological methods is that the processes are inherently and unavoidably destructive. When remains and evidence are collected and removed from the scene, the context is permanently altered and the actual spatial relationships are lost. Thorough documentation and careful preservation of the material and contextual information are therefore very important.

Archaeological methods have a long history of testing and application in a wide variety of complex environments. Given the success of these approaches in investigating and interpreting past events from the archaeological record, it makes sense that they can also be successfully applied to forensic casework, particularly for locating and processing scenes. In fact, most modern crime scene processing approaches (for both indoor and outdoor scenes) are now based largely on principles developed in the field of archaeology (Hunter and Cox, 2005). The main principles of archaeology are the understanding of temporal and spatial relationships which are exemplified in **Steno's Laws**, and which form the basis of the interpretation of context though the understanding of **stratigraphy** and relative positioning (Box 6.1).

BOX 6.1 NICOLAS STENO (1638–1686) AND STENO'S LAWS

Nicolas Steno was a Danish anatomist who spent much of his professional time working for the Medici family in Florence, Italy (Cutler, 2004). During his time in Florence, Steno dissected the head of a large shark caught by local fishermen and noted that the teeth of the shark were very similar to certain stones found throughout the countryside referred to as *glossoperae* ("stone tongues"). In reality these *glossoperae* were fossilized shark teeth, but fossils were not well understood at this time and most scholars believed that fossil shells and other forms naturally grew in the stone in which they were found. Based on his comparison of the shark teeth to the *glossoperae*, Steno began to look more closely at the geologic formations and processes around him. These observations culminated in the publication of his *dissertationis prodromus:* "*Prodromus to a dissertation on solids naturally enclosed in solids*" in 1669 (Steno, 1916). In this work, Steno defined the science of stratigraphy and developed Steno's four laws (below). Steno's laws form the basis of the interpretation of context though the understanding of relative positioning as well as **relative dating**, which is a system for sequencing artifacts or other materials and is commonly performed in archaeological investigations. Because stratigraphy relates specifically to geologic sedimentary layers, the term **soil horizon** is typically used in archaeology. The difference is that soil horizons (layers) may be formed from other natural processes than geologic phenomena; one may have multiple soil horizons in a single **stratum** (Holliday, 2004).

1. *Law of Superimposition*: Lower strata must have formed before upper strata
2. *Law of Original Horizontality:* Strata which are not horizontal formed horizontally and were later shifted out of their original position
3. *Law of Cross-Cutting*: If a burial pit is found in strata, the strata must have formed prior to the burial disturbance.
4. *Law of Lateral Continuity*: The size and shape of each stratum is determined by the natural boundaries it formed in.

There are four generally recognized phases of archaeological investigation, which can also be applied to forensic contexts (Dirkmaat and Adovasio, 1997).

Phase I – Systematic search: The search phase involves locating areas that may warrant further investigation. In archaeological investigations, this phase primarily involves surface survey, often by walking transects and noting archaeological features; remote survey using maps and aerial photography is also common. In a forensic context, Phase I involves a search for human remains, usually a burial feature or surface remains.

Phase II – Evaluation of an area for significance: Once a potential area of interest is located or identified, the area is evaluated to determine whether additional investigation is required. In archaeological investigations, this phase involves subsurface survey in order to determine site boundaries and focal areas. In certain applications of archaeology, particularly **Cultural Resource Management** (or CRM), Phase II is performed in order to evaluate whether an area of interest warrants full scale excavation, such as if a construction project during which ancient human remains were uncovered needs to be halted to permit a large scale archaeological excavation. The evaluation phase is typically brief and straightforward in forensic scenarios such as an isolated burial or surface scatter because the area of interest is rather small and can be investigated relatively quickly without significantly disturbing the scene. Phase

II evaluations may be more involved in large scale scenes such as a plane crash or conflict region, because these scenes can be quite large and often require complex investigative work prior to a full excavation.

Phase III – Recovery: Phase III encompasses the systematic recovery and preservation of the material of interest from the scene. In an archaeological context, this phase involves the excavation of an archaeological site, feature, or structure and collection of associated artifacts and ecofacts in order to gain information about a culture through the materials they left behind. In a forensic context, this phase involves the recovery and preservation of context and evidentiary materials in order to reconstruct the death event, deposition of the body, and taphonomic modifications that have occurred since deposition.

Phase IV – Interpretation and reporting: Phase IV involves the generation of a report and interpretations based on the activities and products of the previous three phases. Phase IV reporting should be accompanied by a map of the project area as well as interpretations and conclusions. In an archaeological context where sites may be investigated slowly over the course of many years, Phase IV reports are often completed annually, providing a summary of past work, detailing the current progress, discussing all findings to date, and making justifications and recommendations for the next year's work. In a forensic context, this report is submitted to the investigating agency, and provides a summary of the approaches used and the interpretation of the evidence that was located and collected. Even if a search did not result in the location of remains, the report should document the procedures used as well as the area that was searched. These details may help the investigating agency determine the next step of the investigation.

6.4 Detection methods

The detection of a scene involves the search for and location of remains. The selection of the methods used in the detection or identification of a recovery scene and its boundaries is dependent on the type and scale of the case as well as aspects of the terrain itself. Methods differ, for example, when searching for surface remains versus buried or submerged remains, and different approaches may be required in steep, dense terrain versus an open field. In many cases, the type of scene may not yet be known when the search begins, and detection methods may need to be modified depending on initial findings.

The most common search technique for outdoor scenes of virtually any type is the pedestrian survey or **line search** (see Figure 6.1). A line search is performed by having a number of search personnel form a straight line at one end of the search area. This often includes a forensic anthropologist or archaeologist as well as a team of law enforcement personnel and other specialists at the scene (e.g., search and rescue, cadaver dogs, forensic geologists). Each member of the line search stands approximately an arm's length apart so that their fields of vision overlap. Each person should also carry pin flags to mark areas of interest (including potential evidence such as

FIGURE 6.1 Standing line search

FIGURE 6.2 Hands and knees line search

(Image courtesy of Dennis Dirkmaat)

bones or other features that may indicate a burial or other activity) as they are encountered in the search. The line search then progresses by walking on foot and closely observing the ground and surroundings at a slow, steady pace marking evidence as it is encountered (depending on the size of the area). Additional searches are often conducted after the first search; for example, a walking line search may be conducted to locate the remains, followed by a similar search on hands and knees in order to allow the searchers a better view of small details on the ground (Figure 6.2). If the area to be

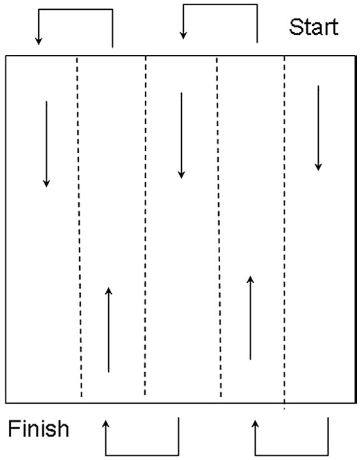


FIGURE 6.3 Back-and-forth line search

covered exceeds the length of the personnel on the line search, a back-and-forth pattern approach can be used (Figure 6.3).

Care should be taken to avoid disturbing any possible evidence during the search. A line search should have a "line leader" who keeps the pace and direction of the line as it progresses through an area of interest, ensuring that the search occurs systematically. Often, the forensic anthropologist will follow behind the search, evaluating flagged items for forensic significance (e.g., whether flagged items are human bones or possible indicators of a burial). When remains are initially discovered, knowledge of potential scavengers in a particular geographic area as well as their feeding behavior may assist in further search strategies. In addition to the remains themselves, other relevant evidence may also be discovered that is associated with the scene, such as animal dragging trails or maggot trails, rodent burrows/nests, and artifacts such as clothing or jewelry. It is also important to visually scan the rest of the search area above ground, including up in trees. Birds will often take hair from remains to be incorporated into their nests.

Burial scenes can also be discovered by examining the surface in a line search. Buried bodies will often be associated with a soil depression, differential vegetation growth due to the disturbance of living plants when digging or changing of the soil from body decomposition, or abnormal accumulation of tree branches or other forest debris from perpetrators attempting to cover the disturbed area. Other soil disturbances associated with burials may include variation in soil color, cracks, soil mixing, and leftover dirt (**back-dirt**) (Figure 6.4). When a grave is dug, the horizons are disturbed, and the soils from the different horizons are mixed together. The new soil mixture that is placed back into the grave (called **infill**) will typically differ in color and quality from the individual undisturbed soil horizons, which may appear visibly different on the surface. Once a body is placed into the grave, all of the soil will not

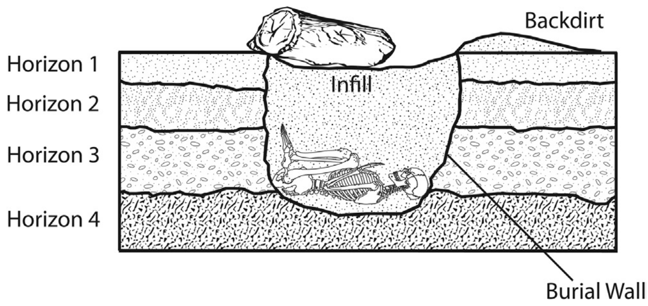


FIGURE 6.4 Features of burial site

fit back into the hole. This will result in left over dirt that can usually be found in a mound over the grave, or as a back-dirt pile near the grave. As the body decomposes and the infill settles and becomes more compact, a depression will usually form over the grave site. This settling may also result in cracks in the surface of the infill. Aerial surveys (photographs taken from airplanes) of the search area taken at different times can also be compared to look for possible surface disturbances.

Another method of burial scene detection is **subsurface probing**, which is useful for locating burial features or other soil disturbances. The utility of probing is based on the principle of relative soil compaction. The disturbed infill that is placed back into the grave will be less compact than the surrounding undisturbed soil. The probe will therefore insert more easily and to a greater depth in areas where the soil is disturbed (i.e., less compact). Soil probes are typically made of fiberglass or metal and are pushed into the ground surface at regular intervals (Figure 6.5). Subsurface probing should be performed in a systematic (usually linear) fashion, probing every 6–12 inches throughout an area of interest. Although the ends of probes are typically blunt, care should be taken to avoid potential damage to skeletal remains with the probe. Similar to subsurface probing, soil cores or small test pits can assist in the determination of whether the natural soil horizons have been disturbed.

Other methods of searching for buried remains involve the use of geophysical or remote sensing devices which detect anomalies in subsurface soil. Approaches include resistivity techniques which detect disturbances using electrical current and measuring resistance, ground penetrating radar (GPR) which detects soil disturbances using electromagnetic pulses, and magnetometry which detects minor magnetic changes in disturbed soil. These approaches are typically best in very specific terrains and soil types, and often require specialized training to operate and interpret. They are not considered standard forensic archaeological approaches, and are associated with a high degree of error (both false positives and false negatives). When geophysical and remote sensing approaches yield negative results, it should not be considered an indication that remains are not present.

Cadaver dogs can assist in locating decomposing human remains using their well-developed sense of smell which can detect the odor emitted by decomposing

FIGURE 6.5 Subsurface probing

tissue. Cadaver dogs are trained to systematically progress though a search area, honing in on the source of the odor, and to then alert (usually by sitting or barking) at the odor's strongest location. Cadaver dogs are typically only able to locate more recent remains which emit a stronger odor, and most are less successful in cases involving skeletonized or buried remains. In cases of buried bodies, probing the soil may release the odors of decomposition to the surface and allow the cadaver dog to detect the odor more easily. Various factors can affect the reliability and effectiveness of cadaver dogs in remains searches. For example, weather conditions may affect the ability of a cadaver dog to locate the source of the odor, or a large number of people at a scene may distract the animal. Moreover, cadaver dogs are frequently the pets of their handlers which can create emotional bonds that could affect performance. The effectiveness of cadaver dogs, as with other forensic tools, also relies heavily on the quality and integrity of the user (see Box 6.2).

Although minimally destructive search techniques using small or remote tools is the ideal approach, in certain circumstances, such as when a very large or deep area needs to be searched, it may be necessary to employ more extensive (and potentially destructive) methods to locate a burial site. These methods often involve the use of heavy construction equipment to remove large volumes of soil in a relatively

BOX 6.2 SANDRA ANDERSON

Sandra Anderson was once considered one of the best cadaver dog trainers and handlers in the United States. She claimed to have conducted ~200 cadaver dog searches per year for 17 years. In 2002, while working with her dog Eagle, the FBI discovered Anderson planting evidence (including bone fragments and carpet fibers) around a tree stump. Numerous other cases were later confirmed in which Anderson had planted evidence. In one case, Eagle alerted to a human toe found in a search area, but the missing man's body was later found with his boots on and his feet intact. In other searches in Michigan and Ohio, Anderson is said to have planted human bones in search areas and even used her own blood to stain a saw blade, coins, and a piece of cloth. Anderson was eventually convicted, sentenced to 21 months of jail time, and ordered to pay more than $14,500 in restitution for falsifying a material fact, making false representations, one count of obstruction of justice, and two counts of making false statements and representations.

short period of time. A backhoe is often the machine of choice because it can remove soil with its blade without having to drive over the search area, but bulldozers can also be utilized in a minimally invasive way (Christensen et al., 2009). Such machines should only be used as a last resort due to their potential to damage remains as well as destroy contextual information, and a smooth-edged bucket is preferred over a toothed bucket. If heavy equipment is employed, it should only be used until remains are discovered, and it is highly advisable that an anthropologist be present to assist in searching the excavated soil for skeletal remains. Once the scene is located, the excavation should proceed by more careful archaeological methods.

Detection methods for submerged remains usually involve specialists such as public safety divers or forensic divers who may perform an underwater dive search. They may also use sonar, remotely operated vehicles (ROVs), or other remote sensing techniques to potentially detect anomalies that may be human remains prior to entering the water. Underwater, divers use many of the same approaches as on land to locate evidence including the use of systematic linear searches and devices such as screens, metal detectors, and specialized light sources (Christensen et al., 2014). Ideally, a forensic anthropologist should be present during the search, and evaluate any potential human remains that are collected and brought to the surface to help determine whether a scene has been located.

6.5 Recovery methods

In any search that is successful, the medicolegal authority must be contacted immediately and prior to recovery. This is typically the responsibility of the investigating agency (such as a police department), but anthropologists involved in the recovery of remains should ensure that proper notifications and approvals have taken place prior to disturbing or removing any human remains from the scene. Recovery methods are aimed at removing the evidence from the scene in a systematic manner while maintaining context, which will allow reconstruction of the events that resulted in the creation of the recovery scene (Dirkmaat and Adovasio, 1997). Recovery operations should therefore include detailed field notes taken during the recovery which document scene processing procedures. These notes should eventually be accompanied by a scaled map documenting the locations of all evidentiary materials and other landmarks significant to maintaining context.

The first step in the recovery process is **denuding** the scene, or carefully clearing the **overburden** so that all evidentiary material is exposed but not disturbed. This allows for the general distribution of evidence as well as the scene perimeter to be visualized, photographed, and mapped. After the scene has been cleared, a **datum** should be established. The datum is the primary reference point used for mapping and should be placed in a location from which the evidence can be accurately mapped. In cases where there may be multiple layers of evidentiary material (e.g., a fire scene), the datum may need to be established prior to denuding so that evidence can be mapped, recorded, and moved to access the next layer beneath.

The recovery of surface remains is usually as simple as retrieving the items identified and flagged during the search process. Any overburden such as leaf litter or loose topsoil should be screened for small bones or other evidence items that may not have been detected in the initial search. Screens are typically constructed of wire mesh (commonly ¼ inch, but smaller sizes may be needed) attached to a wooden or metal frame, and often suspended by moveable legs so that the screen can be shaken (Figure 6.6). This configuration facilitates the movement of material through the screen, so that skeletal elements or evidence items can be located and removed. Depending on factors such as soil quality and available resources, material may be screened dry or wet screened.

With submerged remains, collection receptacles or lift bags may be used to remove the remains from water. Very few anthropologists are trained divers with

FIGURE 6.6 Screening

experience in underwater recovery procedures. There is a specialized area known as **underwater archaeology**, which employs all of the same principles and approaches as terrestrial archaeology, but is performed underwater. While the physical collection of submerged remains should be left to these trained specialists, an anthropologist should at least be on scene to address any questions of forensic significance and evidence handling.

The recovery of buried remains typically involves **excavation**, or the exposure and recovery of the remains through a slow and careful digging process. This usually involves small hand tools including trowels and brushes (Figure 6.7). When recovering buried remains, it is important to not only excavate and recover details of the

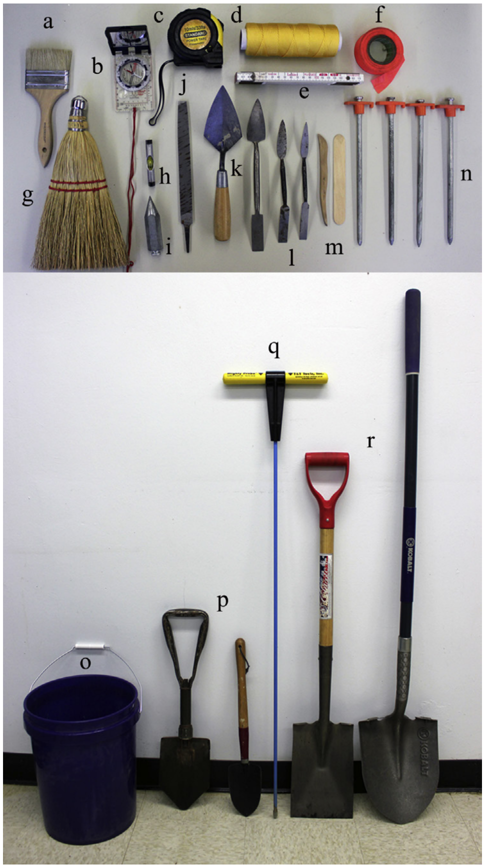


FIGURE 6.7 Archaeological tools

(a) Small brush, (b) sighting compass, (c) metric tape measure, (d) string, (e) folding tape measure, (f) flagging tape, (g) whisk broom, (h) line-level, (i) plumb-bob, (j) file (for trowel sharpening), (k) trowel, (l) small leaf trowels, (m) wooden carving tool, (n) stakes, (o) bucket, (p) small shovels, (q) probe, and (r) large shovels remains themselves, but also those of the burial feature in which they are interred. The burial feature may contain evidence such as tool marks from the burial implement (such as a shovel) which may be present along the walls of the pit, shoe prints which may be found in the back-dirtpile or in the bottom of the burial, or disturbed vegetation may be mixed with the infill which could be examined by a forensic botanist to determine when the pit was dug.

Once the outline of the burial feature has been identified and defined, string held by stakes or chaining pins can be used to bisect the feature. Excavation of the infill of one half of the burial feature should then proceed slowly from the bisection line toward the grave wall using hand trowels. This approach allows for the preservation of possible tool marks in the walls of the burial. Exposing half of the remains also allows for documentation of the position of the body and the body's relationship to evidentiary material encountered and the burial feature itself. The interpretation of soil horizons and stratigraphy is also important in an excavation, because it can help to differentiate between undisturbed (sterile) soil and disturbed soil. After excavating one half of the grave feature, the exposed wall should be mapped, and the other half of the burial can then be excavated. In archaeology, it is common to **pedestal** artifacts and remains encountered during excavation. When potential evidence is encountered during a forensic excavation, it should be carefully exposed, photographed, mapped, and then removed. This will prevent it from becoming accidently disturbed and losing its context before it can be recorded, and will preserve the grave cut.

The excavation of a burial feature should result in an open grave resembling the feature as it was originally dug. Once the remains have been removed from the grave, a metal detector should be used on the grave floor to search for additional evidence such as bullets, coins, or jewelry still obscured by soil (Figure 6.8). Careful excavation of the bottom of a grave may also reveal shoe or tool impressions (Figure 6.9).

During excavation, all osseous and other evidentiary materials should ideally be recovered ***in situ***. In some cases, however, bone fragments or other pieces of evidence (e.g., clothing items, bullets) may be small or difficult to see due to their small size or adhering soil, and may accidentally be excavated along with the soil and removed from the grave. Excavated soil should therefore always be screened

FIGURE 6.8 Metal detector used on the bottom of a burial

FIGURE 6.9 Tool impressions in a grave wall

for small bones and teeth or other associated evidence. If something of evidentiary value is recovered in a screen, it is helpful to document where in the feature or scene the soil came from (such as a grid quadrant) in order to maintain as much context as possible.

Fire scenes with burned remains are often complex recoveries because the remains may be very fragile and obscured by other burned materials. The removal of fallen burned debris covering human remains should be conducted carefully and systematically, layer by layer, and be accompanied by comprehensive documentation of the process. This allows investigators to observe, identify, and uncover patterns based on the relationships between the items recovered (Dirkmaat, 2002; King and King, 1989). In fatal fire scenes, documentation of the position of the body and its relationship to other features is important in the interpretation of the thermal alteration pattern of the remains during later lab analysis. In any of the scene types, after collection of the visible remains, the recovery area should be excavated somewhat below the surface (usually at least 10 cm) to look for remains or other evidence that may have settled into the soil or foundation material.

6.6 Scene documentation

Scene documentation should include detailed written notes, and ample photographs of the overall scene, midrange views, and close-ups of the material recovered. Videography or laser scanning (e.g., Lidar) may also provide good overviews of the scene and the approaches used. It is most important to document the context and provenience of the evidentiary material recovered for later interpretation. The best way to accomplish this is by generating a map, which should document the spatial distribution of all remains and associated materials recovered. Mapping is best conducted after performing a thorough search, denuding the area, and exposing the remains and any associated evidence. Different types of recovery scenes are better documented using certain methods, and several approaches are discussed below.

Maps can be created in two or three dimensions depending on type and scale of the scene, and may range from hand-drawn sketches (for example, see case study and Figure 6.20) to electronic maps generated by mapping instruments (for example, see Figure 6.17). Maps should be as accurate as possible and at a minimum should include a north (N) arrow, indicate scale (or "not to scale"), and include the author's name, date, and the location of the datum. Mapping a scene can be accomplished using various methods including triangulation, trilateration, baseline, azimuth, or grid methods. The selection of the mapping approach to be used depends on the extent and terrain of the scene, as well as the proficiencies or preferences of the recovery personnel. Surface remains, for example, are typically better mapped using a baseline or trilateration, while burials are usually better mapped using a grid.

For any of these approaches it is important to keep the measurement tapes level to avoid adding measurement error. It is also strongly recommended to use a **plumb-bob** to keep vertical measurements straight (Figure 6.10). As a rule, measurements should be taken using metric units, which can later be converted to other units if necessary.

Triangulation is the process of determining the location of a point (here, the piece of evidence such as a bone) by measuring the angles to that point from a line between two known points (Figure 6.11). A similar process, **trilateration**, involves determining the location of a point by measuring the distance to that point from two known points (Figure 6.12). In either case, the approach essentially

FIGURE 6.10 Plumb-bob used to take a vertical measurement

(Image courtesy of Dennis Dirkmaat)

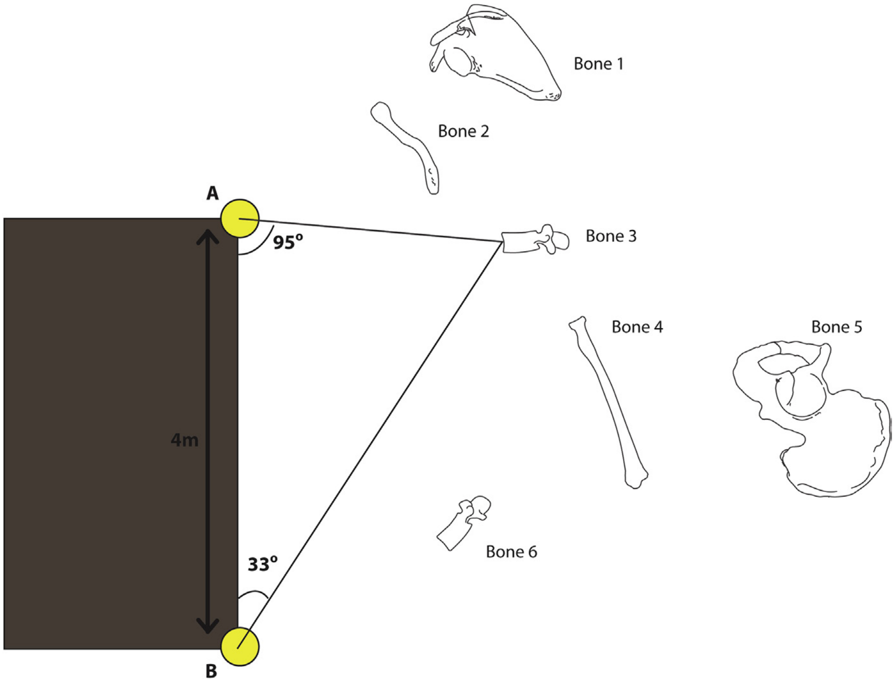


FIGURE 6.11 Triangulation mapping

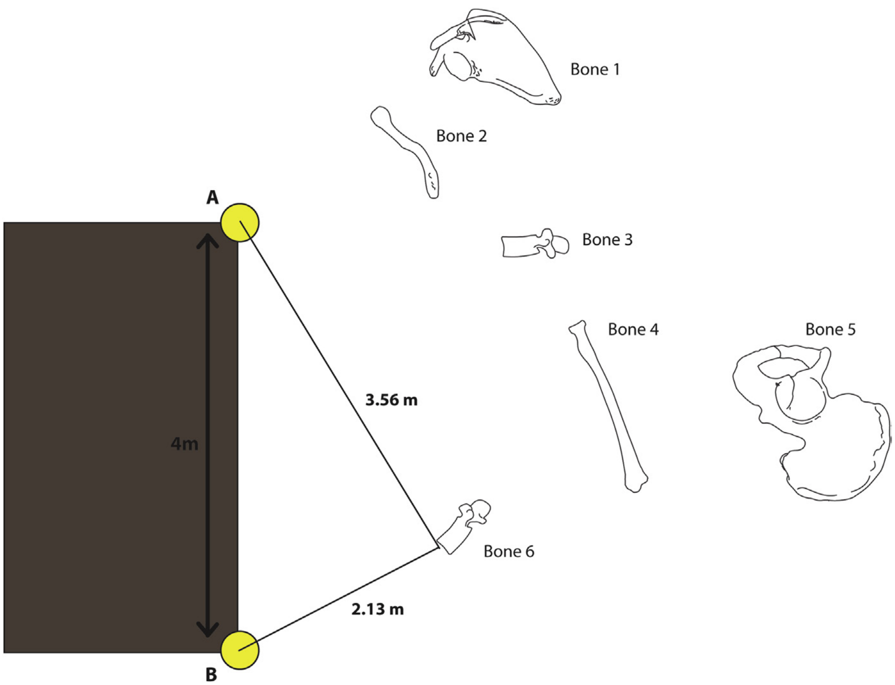


FIGURE 6.12 Trilateration mapping

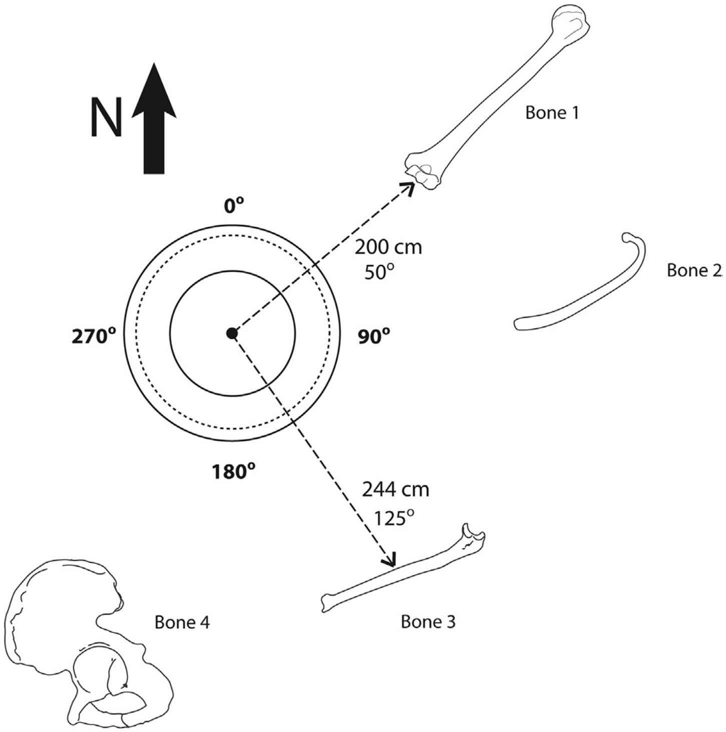


FIGURE 6.13 Azimuth mapping

involves forming a triangle where the locations of two of the points are known, and the third can then be derived from those two known points. The known points in these methods are typically fixed objects that can be easily located such as two corners of a building, one of which is usually the datum. The data collected in the field can be easily documented in a table that records the angles or distances between the points. It is important to also record the distance between the two known points.

Another approach is the use of an **azimuth**. This mapping technique involves the measurement of the distance and angle (from north) of an evidence item from a single, fixed point using an *azimuth board* (or *azimuth wheel*). The azimuth board is placed at a point of origin (typically the datum), aligned with 0/360 to north, and anchored. The zero end of the tape is also anchored at the center of the azimuth board, and evidence items are mapped using the distance along the tape and the angle of the azimuth (Figure 6.13). This method allows for very rapid measurements, and can be especially useful in scenes that are widely dispersed or involve uneven terrain.

A common mapping approach is the use of a **baseline**, which is a line that cuts through the scene transversely, from which the evidence items are measured. For

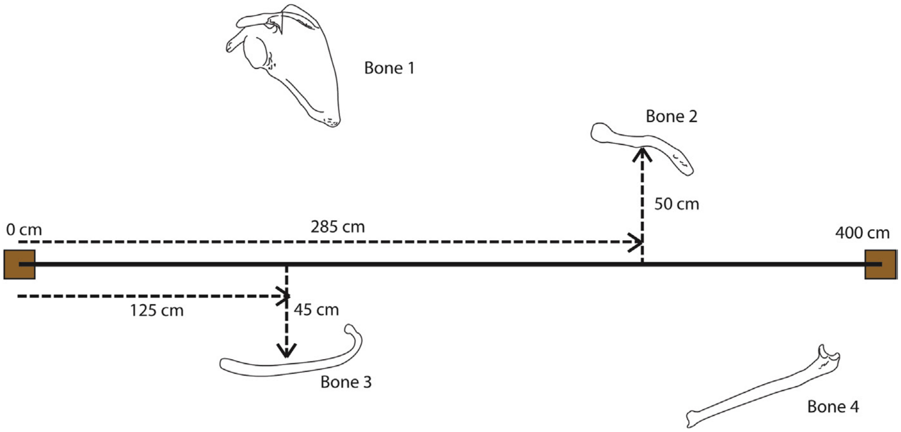


FIGURE 6.14 Baseline mapping

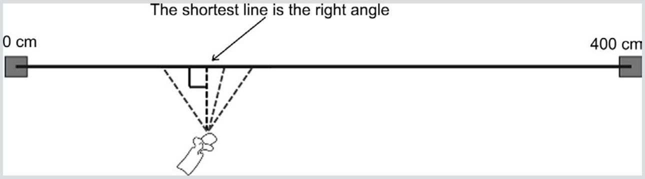
the baseline method, a tape measure is placed in a straight line between two points (one of which is often the datum), roughly bisecting the main concentration of evidence. A string tied between two stakes along with a line-level can help keep the tape measure level. Next, the distance of the evidence items are measured at right angles to the baseline, noting the distance on the tape from one of the ends of the baseline (Figure 6.14 and Box 6.3). It is also important to note from which side of the baseline the measurement was taken, which can be accomplished using positive and negative measurements (positive for one side of the baseline and negative for the other). Baseline mapping allows for quick measurements to be taken with little measurement error because of the relatively small distance from the baseline measuring tape and most of the evidence. While baseline approaches are most commonly used for horizontally mapping items resting on the ground surface, they can also be used to plot vertical distances by measuring above or below the baseline.

Another mapping approach is the use of a **grid** which uses quadrants based on two fixed axes. While grid systems can also be used to map surface remains, they are most commonly used to map burial scenes (Figure 6.15). Grid mapping allows for good control of small spaces and makes subsurface measurements somewhat easier and with less measurement error compared to other hand mapping methods. To set up a grid, the x- and y-axes are first established, usually using the datum as the point of origin (Figure 6.16a). The axes must meet at right angles (Box 6.4). Along the axes, stakes can be placed at intervals depending on the size of the area to be mapped, often at 1 m apart, with the total number of stakes depending on how many units or quadrants the excavation requires. Stakes can then be placed within the grid, making sure that the grids are accurate squares (Figure 6.16b and c). The rest of the grid stakes can then be placed as necessary (Figure 6.16d).

BOX 6.3 FINDING A RIGHT ANGLE FROM A BASELINE

When measuring evidence from a baseline, it is important that the measurement is taken at a right angle from the baseline. This can be accomplished in several ways. A *square*, which is a triangular-shaped tool used to measure right angles (commonly used in construction) can be used to ensure that the tapes are placed at right angles. Another approach that is useful in the field can be applied quickly and accurately to find a right angle to the baseline:

Place the end (the "zero") of the tape measure at the evidence item. Next, move/swing the free end of the tape along the baseline. Wherever the free end of the tape makes the *shortest* distance to the baseline is a right angle.



A number of more advanced technological mapping tools are also available. With proper training and use, these tools can facilitate very rapid and accurate scene documentation. A **total station** is a digital laser **theodolite** (or *transit*) used for three dimensional mapping (Figure 6.17). Total stations are commonly used in archaeology, surveying, and crime scene reconstruction. The benefits of using a total station include the rapid collection of three dimensional points over large areas, the instant creation of simple digital maps, and the ability to process the data later using computer software to make complex maps and analyze spatial patterns. Total stations, however, can be rather expensive and require specialized training, both in operating the total station itself and also in using the associated computer software.

Global Positioning Systems (GPS) measure the time it takes radio signals from GPS satellites to reach a GPS receiver from different angles to determine their position (Figure 6.18). The accuracy of a GPS location is determined by the number of satellites available, the number of points taken at one location, multipath interference, and atmospheric conditions. It is recommended that at least one GPS location is documented at every recovery scene; this will allow investigators to return to the exact area later if necessary. GPS data are especially useful for documenting the position of the site datum, the corners of a grid, and other landmarks at the scene. If a GPS is used, documentation of the data should include the number of satellites, the accuracy (e.g., ± 3 meters), the GPS grid system (e.g., MGRS), and the GPS datum (e.g., WGS-84). Most GPS receivers are fairly inexpensive and simple to use. The primary drawback of GPS is that it is not typically accurate enough to piece-plot multiple items at the scene. Most smart phones, for example, have GPS capabilities, but they also have very large associated error. GPS locations are typically only recorded on a limited number of features while still relying on detailed maps made using hand measuring tapes or total stations.

FIGURE 6.15 Grave with grid

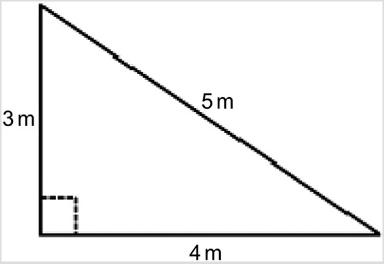
(Image courtesy of Dennis Dirkmaat)

BOX 6.4 FINDING A RIGHT ANGLE FOR A GRID

When establishing a grid, there are a several approaches that can be used to determine a right angle for the axes and the smaller grids within them. One way is to use a construction square. If not readily available, however, other field methods can be used to quickly and accurately find a right angle. These approaches use the **Pythagorean Theorem** which describes the relationship between the lengths of the sides of any right-angled triangle. For lengths a, b, and c, the theorem states that: $a^2 + b^2 = c^2$ where c is the hypotenuse, and a and b are the other two sides.

One approach is to make a 3-4-5 triangle (see below). For a triangle that has sides of length 3, 4, and 5 in any units (or multiples of 3, 4, and 5 such as 6, 8, and 10), the angle between the 3- and 4-unit sides will form a right angle ($3^2 + 4^2 = 5^2$). From the datum point, simply measure 3 and 4 units away at approximate right angles using two tape measures. Using a third tape measure (which forms the hypotenuse), bring the two ends of the 3 and 4 unit tapes together until they measure 5 units apart. This approach can be used to establish the right angle, regardless of the units that will be used to map the site.

Another approach is to use standard unit sizes with known hypotenuse values (see below), and using these measures to find a right angle in the same manner as the 3-4-5 triangle. Finally, another approach is to calculate what the hypotenuse should be based on the lengths of the two sides of the grid using the derivative of the Pythagorean Theorem: $c = \sqrt{(a^2 + b^2)}$.



Unit size (m)	Hypotenuse (cm)
1 × 1	141
1 × 2	223
2 × 2	283
4 × 2	447
4 × 4	566
5 × 5	707
10 × 10	1414

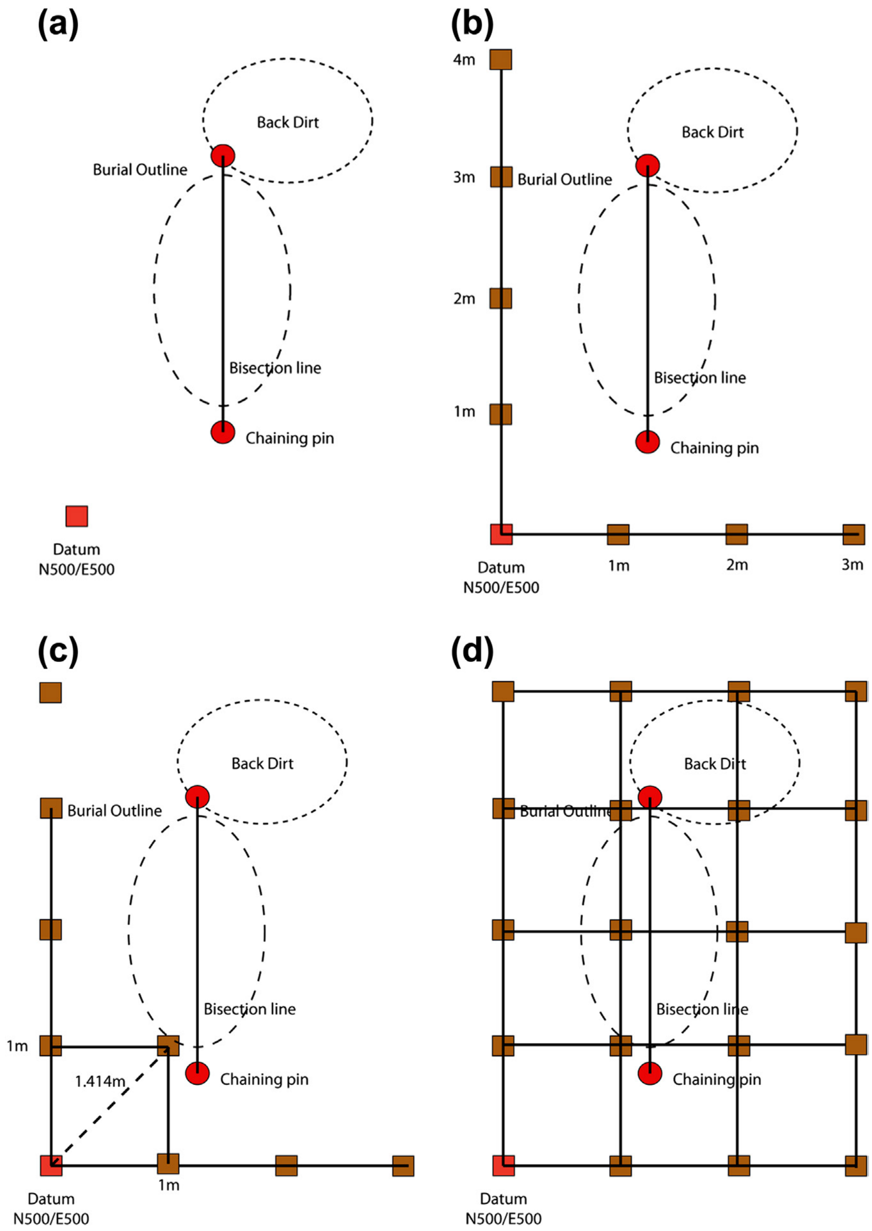


FIGURE 6.16 Grid mapping

Steps to setting up a burial feature excavation: (a) Establish datum and bisection line of the burial feature; (b) set up major grid axes; (c) triangulate hypotenuse to make sure grid stakes are placed correctly; (d) emplace additional grid stakes as needed

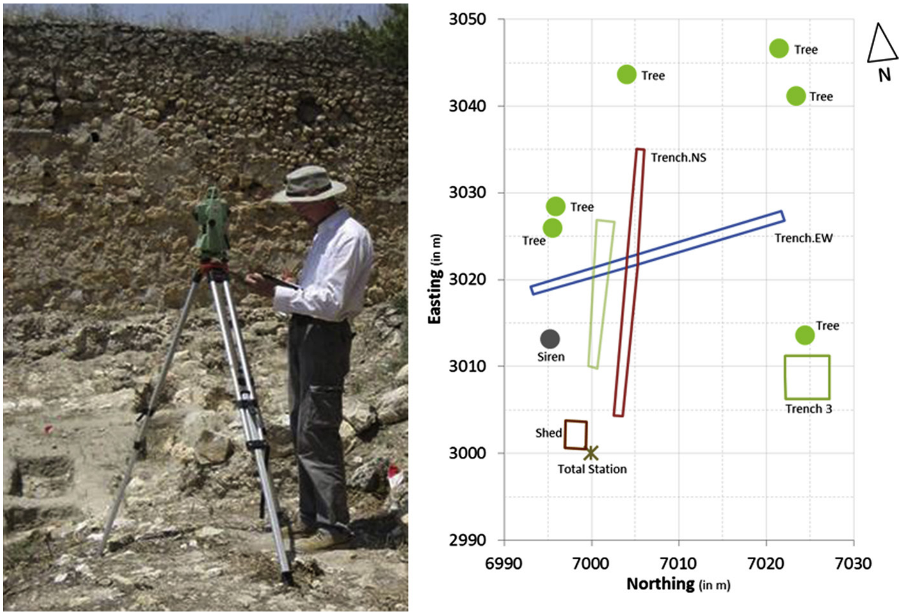


FIGURE 6.17 Total station (left) and map generated by total station (right)

(Images courtesy of Roland Wessling)

FIGURE 6.18 Global positioning system (GPS) device

6.7 Evidence collection and packaging

After the scene has been processed, human remains and associated evidence should be collected and packaged in a manner that preserves the integrity of the evidence and as much pertinent contextual information as possible. An inventory should be maintained of all items collected. Skeletal remains should generally be packaged in paper bags or other breathable material. This will prevent the growth of mold, which can occur if damp skeletal remains are packaged in materials such as sealed plastic bags. Mold on skeletal remains can obscure and stain surface features used in anthropological analyses, and can also complicate DNA analyses. If bones are wet, they should be allowed to dry prior to packaging. Plastic or other non-permeable packaging may be appropriate for skeletal material with a significant amount of adhering soft tissue, but they should be unpackaged and processed once they arrive at the medicolegal authority's office or forensic laboratory. Paper packaging will also offer some protection to the skeletal material during transport, preventing breakage or fracture from bones contacting one another.

Additional packaging and protection measures may need to be considered in certain circumstances, such as if the materials will be transported a long distance or mailed, or if the remains are thermally altered. Burned bones are often very fragile and the slightest movement may cause additional fragmentation. One approach is to carefully wrap foil around individual bones which can keep any subsequently formed bone fragments in relative anatomical position. Cotton, gauze, or other soft packaging may also help prevent further damage.

The packaging should be marked with the date and location of the recovery (including the name of site, grid position, etc.), the person who packaged or recovered the evidence, and a case identification number. In many instances, law enforcement officials and/or medical examiner personnel will be on the scene and take custody of the remains and associated evidence as it is collected. If skeletal remains are to be examined in a forensic anthropology laboratory, custody may be transferred to the anthropologist while still on scene, or the remains may be delivered to the laboratory at a later time (e.g., after autopsy).

6.8 Case study – burial recovery

In 2008, a sheriff-coroner's office in Northern California requested the services of a forensic anthropology team to aid in the excavation of a clandestine grave. Acting on information from an associate of an already convicted suspect, the sheriff's office identified what they believed to be a grave site. Each forensic anthropology team member was assigned a specific role, such as photography, excavating, mapping, screening, documentation, evidence collection, and metal detection. The suspect had already been convicted and sentenced for homicide in the absence of the victim's body, but the case was under appeal and it became essential to locate the victim's remains and reconstruct the circumstances surrounding death.

The grave outline was located by using trowels to scrape the surface and identify differences in soil color and texture. The excavation proceeded by excavating in approximately 5 cm levels using small hand tools such as trowels and small brushes. A datum was established near the southeast corner of the grave with a metal stake, and a baseline was established to map evidence and the position of the body within the grave. All soil removed from the gravesite was screened using 1/8 inch mesh. A metal detector was used over the grave multiple times during the course of the excavation, and indicated the presence of metallic objects near or within the skull. The decedent was discovered in a supine position within the grave, along with clothing and other material (Figure 6.19). The skeleton and associated evidence items were photographed, mapped (Figure 6.20), and placed into paper evidence bags. The remaining fill was carefully removed from below and near the body to completely empty the grave (Figure 6.21). Probable shovel tool marks were identified within the grave walls, but no tool marks or footprints were identified within the grave itself. A final metal detector search of the grave floor failed to locate any additional metallic objects. The laboratory analysis revealed evidence of multiple gunshot wounds to the skull, and the bullet remnants were linked to a firearm that had been in the possession of the suspect following the homicide. The evidence collected from the scene and in the subsequent analysis was instrumental in resolving the case.

FIGURE 6.19 Remains and other evidence within grave

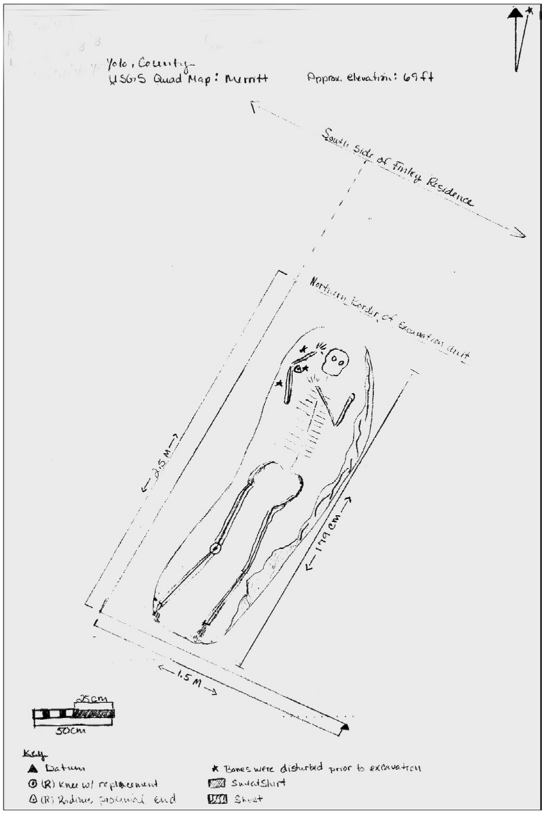


FIGURE 6.20 Sketched map of recovery scene

FIGURE 6.21 Grave after remains and evidence have been removed

6.9 Case study – fatal fire scene

In September of 2010, a natural gas pipeline exploded in a residential neighborhood of the San Francisco Bay Area. The explosion resulted in a massive crater that was 40 feet deep, 167 feet long, and 26 feet wide, and nearly 40 homes were destroyed. Fire suppression efforts continued into the following day, and law enforcement and search and rescue began an initial recovery effort for fire victims. Three days following the explosion, forensic anthropologists were requested at the scene to search for additional human remains at one of the residences affected by the explosion and resulting fire.

After conducting an initial site and risk assessment of the scene, the team consisting of 19 anthropologists began a systematic recovery operation (Figure 6.22). Each room in the residence was hand excavated, and debris was placed into buckets to be screened in an area outside the foundation of the residence (Figure 6.23). Using this approach, specific rooms could be excluded as containing human remains. One location eventually yielded the remains of multiple fire victims. Careful assessment, excavation, and screening were conducted at this location to maximize the recovery of highly fragmented, calcined remains. The team successfully recovered the remains of three fire victims, which was consistent with the number of individuals believed to be in the residence at the time of the explosion. In total, there were eight fatal fire victims within the vicinity of the explosion. Neighborhood-scale disasters such as this one often exceed a local jurisdiction's capabilities, and the coordination of multiple agencies in the recovery effort usually leads to a more successful outcome.

FIGURE 6.22 Fire scene recovery

FIGURE 6.23 Screening debris from fire scene

6.10 Summary

- Forensic archaeology is the application of archaeological theory and methods to medicolegal cases, including searching for, locating, surveying, sampling, recording, and interpreting evidence, as well as the recovery and documentation of human remains and associated evidence.
- A location where remains are found is called a scene or recovery scene. Common scene types include surface, burial, submerged, fire, and mass fatality.
- Similarly to excavating an archaeological site, processing a scene is inherently destructive, permanently altering the context. Documentation and preservation of contextual information is therefore critically important.
- Methods of locating a scene may include line searches, subsurface probing, thermal imaging, geophysical techniques, or cadaver dogs. Each has limitations, and certain approaches may only be appropriate in certain situations.
- The recovery process typically involves denuding the scene, establishing a datum, screening, excavation, and collection.
- Scenes can be mapped using a variety of approaches including triangulation, trilateration, azimuth, baseline, and grid. Specialized mapping approaches such as a total station and GPS may also be employed.
- After collection, remains should be packaged in a way that preserves the quality of the evidence. Skeletal remains should generally be packaged in paper bags or other breathable material that is marked with the date and location of the recovery, the person who packaged or recovered the evidence, and a case identification number.

6.11 Test yourself

- What are the goals of forensic archaeology? How can the methods used in the detection and recovery of human remains affect laboratory analyses?
- In addition to the scene types mentioned here (surface, burial, submerged, fire), can you think of any other scenes that might be encountered by a forensic anthropologist? What methods of detection, recovery, and documentation would you use and why?
- Forensic divers are utilizing sonar equipment to look for anomalies that may be consistent with a drowning victim in a lake. Which of the four phases of an investigation would you consider this?
- You are excavating a shallow burial feature, and within the soil horizon directly below the body is a coin dated to 2010. Based on principles of relative positioning, how would you interpret this?
- Identify some of the issues you should consider when attempting a search for remains that are suspected to be buried. What search techniques might you use? How would you document the remains?
- You have determined that a baseline will be the most appropriate method to document a surface scatter, but you have forgotten your construction square back at the office. Describe how you would determine whether you are measuring the evidence at a right angle from the baseline.
- Describe some of the complexities of recovery in a fire scene. Why might some of the methods described in this chapter be inappropriate for a fire scene?

Definitions

Azimuth A mapping approach that involves documenting the location of a point by measuring the distance to that point from a single known point, and the angle of the item from north using an azimuth wheel

Back-dirt Leftover soil that does not fit back into a grave after it is removed

Baseline A mapping approach that involves the use of a line that roughly bisects the scene transversely, from which the evidence items are measured at right angles

Cultural Resource Management (CRM) The process of protecting and managing cultural heritage as dictated by legislation

Datum A reference point at a scene from which measurements are taken

Denude To strip something of its covering

Excavation The exposure and recovery of material (including remains) through a slow and careful digging process

Forensic archaeology The application of archaeological theory and methods to the resolution of medicolegal and humanitarian issues

Grid A mapping approach involving the use of quadrants based on two fixed axes

In situ In its original position or place

Infill Soil used to fill in a hole or other feature such as a grave

Inter To bury a body in a grave

Line search A method of scene detection where pedestrians systematically walk over an area looking for and flagging possible evidence and other potentially significant items or features

Overburden The material that is covering an area or item of interest

Pedestal An excavation technique in which items are left *in situ* on columns of soil until the entire unit/feature is excavated

Plumb-bob A weight suspended from a string that is used to form a vertical reference line

Pythagorean Theorem The geometric relationship between the sides of any right-angled triangle; for a triangle with sides of lengths a, b, and c, the theorem states that $a^2 + b^2 = c^2$ where c is the hypotenuse, and a and b are the other two sides

Relative dating Determination of the relative order of past events (as opposed to *absolute dating* such as radiocarbon dating, which determines a numerical date and range)

Scene A location from which evidence is recovered; in forensic archaeological contexts, typically human remains and associated evidence; may be surface, burial, or submerged; also called a *recovery scene*

Soil horizon A layer in a soil profile that has different characteristics (mainly color and texture) than the surrounding layers

Steno's Laws Four laws developed by Nicolaus Steno which deal with properties of stratigraphic layers and their relative associations to other features and objects

Stratigraphy The study of the geological layers (strata) of the earth

Stratum One layer in a stratigraphic sequence (plural, *strata*)

Subsurface probing The technique of systematically inserting a thin blunt probe into the ground to assess relative soil compaction which can be an indicator of disturbed soil and a possible grave; also called probing

Surface scatter Scene type in which surface remains have been redistributed from the initial deposition site

Theodolite An instrument that is used for measuring horizontal and vertical angles and distances (also called a *transit*)

Total station A digital laser theodolite

Triangulation A mapping approach that involves documenting the location of a point by measuring the angles to that point from a line between two known points

Trilateration A mapping approach that involves documenting the location of a point by measuring the distance to that point from two known points

Underwater archaeology Archaeology performed underwater

References

Christensen, A.M., Horn, K.J., Smith, V.A., 2014. The use of an alternate light source for detecting bones underwater. J. Forensic Sci. In press.

Christensen, A.M., Lowe, W.M., Reinecke, G.W., 2009. The forensic bulldozer as a clandestine grave search tool. Forensic Sci. Commun. 11 (4).

Cox, M., Flavel, A., Hanson, I., Laver, J., Wessling, R., 2008. The Scientific Investigation of Mass Graves: Towards Protocols and Standard Operating Procedures. Cambridge University Press, Cambridge.

Cutler, A., 2004. The seashell on the mountaintop: How Nicolaus Steno solved an ancient mystery and created a science of the earth. Plume, New York.

Dirkmaat, D.C., 2002. Recovery and interpretation of the fatal fire victim: The role of forensic anthropology. In: Sorg, M.H., Haglund, W.D. (Eds.), Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives. CRC Press, Boca Raton, pp. 451–472.

Dirkmaat, D.C., Adovasio, J.M., 1997. The role of archaeology in the recovery and interpretation of human remains from an outdoor forensic setting. In: Haglund, W.D., Sorg, M.H. (Eds.), Forensic Taphonomy: The Postmortem Fate of Human Remains. CRC Press, Boca Raton, pp. 39–64.

Holliday, V.T., 2004. Soils in Archaeological Research. Oxford University Press, Oxford.

Hunter, J., Cox, M., 2005. Forensic Archaeology: Advances in Theory and Practice. Routledge, London and New York.

King, C.G., King, S., 1989. The archaeology of fire investigation. Fire Eng. 142 (6), 70–74.

Morse, D., Duncan, J., Stoutamire, J., 1983. Handbook of Forensic Archaeology and Anthropology. Rose Printing Co., Tallahassee.

Scientific Working Group for Forensic Anthropology, 2013. Scene Detection and Processing Revision 0.

Steno, N., 1916 (Original work published in 1669). The prodromus of Nicolaus Steno's dissertation concerning a solid body enclosed by process of nature within a solid (J. G. Winter, Trans). Macmillan Company, New York.