Recovery, Analysis, and Identification of Commingled Human Remains

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Preface

Public fascination with the rapid developments of forensic science in recent years has led to greater expectations of success in the field of human identification. This relates to field recovery, laboratory analysis, and analytical findings. Mass fatality events can result in the intermixing, or commingling, of human remains from numerous individuals. As the number of individuals increases, so does the complexity of the forensic investigation and the skills needed for case resolution. Body fragmentation adds an even further level of difficulty since each separate fragment initially has to be treated independently until it can be proven to link to another. With forensic investigations, commingling must be resolved to the greatest extent possible since it impairs personal identification of the decedents and prevents the return of remains to next of kin. Even in the archaeological context when personal identification is not an issue, accurate sorting and reliable estimates of the number of individuals are critical to an understanding of the population demographics and cultural practices.

The treatment of these complex scenarios and the science of identification have benefited tremendously from advancements in basic research, improvements in crime scene procedures, development of reference databases, improvements in computer technology, the addition of molecular biology, and more. *Recovery, Analysis, and Identification of Commingled Human Remains* is a collection of chapters dedicated to the description of many of these tools, as well as more general discussions of ethics, policy, logistics, documentation, and other more administrative issues that relate to the challenges associated with the recovery, analysis, and identification of commingled human remains.

In Chapter 1, Ubelaker provides an historical overview of the anthropological attention given to commingled human remains. As he points out, the issue of commingling has only been glossed over in forensic anthropology textbooks until recently. Greater attention to this topic has been recognized as the discipline experiences an increasing emphasis on mass fatality events such as aircraft crashes, terrorist attacks, natural disasters, human rights violations, and other contexts where human remains are apt to be commingled. This chapter also sets the stage for the diverse topics covered throughout the rest of this volume.

The next chapters (2 and 3) discuss field recovery techniques and present case examples involving commingled remains. Although field context has always played an informal role in the process of sorting remains, Tuller et al. (Chapter 2) and

Reineke and Hochrein (Chapter 3) provide convincing arguments that field context is a significant line of evidence that must be captured by appropriate field recovery procedures. Proper training and experience with archaeological techniques are essential for personnel tasked with the recovery of commingled human remains. Field data and spatial relationships can potentially indicate associations of fragmentary remains with each other, as well as other evidence critical to case resolution. Failure to adequately document field context can jeopardize all phases of the investigation. In Chapter 2, Tuller et al. present an example from a human rights investigation of a mass grave in Serbia, while in Chapter 3, Reineke and Hochrein use case examples to outline the protocols employed by the Federal Bureau of Investigation's Evidence Response Teams.

Chapters 4 through 6 present diverse case examples involving commingled human remains. The state of the art for resolving commingling incorporates a mix of traditional methods (e.g., gross techniques) and cutting-edge technology (e.g., DNA testing). In Chapter 4, Egaña and colleagues present several challenging cases associated with international human rights investigations in El Salvador, Zimbabwe, and Argentina. These examples by the Equipo Argentino de Antropología Forense (EAAF) describe not only difficulties in the field, but also obstacles with identification. It is through research, controlled field recovery, and laboratory analysis that many of these cases can be resolved. In Chapter 5, Steadman et al. present a look into one of the most bizarre forensic situations to occur in the United States, the Tri-State Crematorium in Noble, Georgia. In this case, hundreds of bodies intended for commercial cremation were discarded by an unethical crematorium owner on his wooded grounds. As a result, bodies and body parts in varying states of decomposition were dispersed across many acres. Members of the Disaster Mortuary Operational Response Team (DMORT) worked with the Georgia Bureau of Investigation to deal with the unique recovery and identification challenges. Not surprisingly, questions were also raised by families that had received cremated remains processed at the Tri-State Crematorium, and a subsequent analysis of numerous urn contents was undertaken. Chapter 6 by Ubelaker and Rife presents an archaeological perspective of the recovery and analysis of commingled human remains from Greek tombs. While decedent identification is not an issue, these findings are important for paleodemographic reconstructions and an understanding of mortuary behavior. As the authors demonstrate, many of the challenges related to recovery and analysis faced in this context are the same as those encountered in modern forensic contexts.

Chapters 7 though 13 deal mainly with laboratory and morgue analysis of commingled remains. Chapter 7 by Mundorff highlights the role of anthropologists in mass fatality events, specifically the triage of remains at the morgue. It is during the initial triage that commingling problems are likely to be recognized, and the skills of an anthropologist are well suited for this task. Three distinct incidents that occurred in New York City are discussed (the 9/11 attacks on the World Trade Center, the crash of Flight 587, and the crash of the Staten Island Ferry). The similarities and differences between them are highlighted, and the role of the anthropologist in morgue triage is discussed for each of these very different disasters. In Chapter 8, Viner provides an overview of the role of radiology in mass fatality events and the various technological options currently available. Radiology plays an important role from triage through the final stages of identification. Radiology is one of the best means of recognizing the presence of commingling, especially in cases of extreme fragmentation, when body parts of different people may become embedded within each other. It is also a critical component in the identification process. Case examples, including the London bombings of July 7, 2005, and human rights investigations by the International Criminal Tribunal for the Former Yugoslavia (ICTY), show the role of radiology in the analysis of mass fatalities.

Chapter 9 by Warren outlines laboratory procedures for assessing commercially cremated remains for the presence of commingling. Due to the extreme fragmentation associated with commercial cremation, this can be very challenging. Often times these types of cases involve litigation when families suspect the mishandling of bodies by funeral homes. Due to the nature of commercial cremation, some degree of commingling is inevitable in every case. A jury will make a determination as to whether or not there was negligence in the cremation practice largely based on the anthropological findings. Chapter 10 by Byrd explores laboratory methods for sorting remains; in essence, “rebuilding” individuals. This chapter extends the method of osteometric sorting to paired elements and adjoining bones that articulate. New statistical models are provided for application to forensic cases. In Chapter 11, Schaefer provides yet another technique for recognizing commingling and for sorting remains. In this case, stages of epiphyseal fusion are used to identify relationships that are incongruous and indicative of commingling. Typical fusion patterns are identified and methods are presented to statistically evaluate fusion stages between various elements.

Chapter 12 by Adams and Konigsberg describes the best methods for estimation of the number of individuals (i.e., the death population) represented by skeletal remains. This issue can be of great importance when there are a large number of individuals represented and an accurate estimate of the dead is needed. An archaeological example is presented, but these techniques are amenable to both modern and prehistoric contexts. While the techniques for quantification outlined in Chapter 12 are mainly for well-preserved bones, a quantification technique suitable for fragmentary remains is presented by Herrmann and Devlin in Chapter 13. This innovative method uses geographic information systems and treats individual bone specimens as though they were geographic regions. Application of the method permits one to systematically evaluate which bone portions are duplicated in a large assemblage and derive a count of the minimum number of individuals represented.

The introduction of DNA technology into forensic science has revolutionized the process of identification. It has also proven essential to the process of sorting commingled remains, especially those that are too fragmentary to be suitable for gross techniques. However, excitement over the boost we have enjoyed as a result of the introduction of DNA testing can promote naïveté on the part of administrators and the general public as to the reality of these capabilities. It is easy to presume that use of DNA testing renders other methods superfluous. Chapters 14 through 16 reveal that DNA testing is most powerful when utilized in the context of all the evidence and in conjunction with other methods. In Chapter 14, Yazedjian and Kešetović describe the successful DNA-led program of identification at the International Commission on Missing Persons (ICMP) in Bosnia-Herzegovina. It is estimated that as many as 40,000 people went missing as a result of conflicts in the former Yugoslavia. Many of the missing individuals highlighted in this chapter are young men, and there is a lack of reliable antemortem data. The similarity of the biological profile and the lack of antemortem records severely limit the role of anthropology in the identification effort, but its overall importance is not diminished. This chapter details the importance of DNA in the identification effort and the collaborative role played by anthropology in ensuring quality control measures and validation of the DNA results. In Chapter 15, Mundorff et al. discuss identification efforts at the New York City Medical Examiner's Office with more than 20,000 human remains from the World Trade Center attacks of September 11, 2001. Similar to the previous chapter, the WTC examples show the complementary relationship between anthropology and DNA analysis in the quality control of the identification effort. This chapter highlights the advantages and caveats of the heavy reliance on DNA testing for the resolution of commingling. Case examples are presented that show how mistakes were made and how these problems were subsequently recognized and resolved. The lessons learned in the efforts of the New York City Medical Examiner's Office are certain to benefit other forensic organizations for years to come. In Chapter 16, Damann and Edson showcase the benefits of collaboration among various specialists, including anthropologists, odontologists, pathologists, and molecular biologists. They describe the process employed by the most successful sustained program of identification utilizing DNA testing, that of the U.S. Department of Defense. The experiences of the Joint POW/MIA Accounting Command's Central Identification Laboratory and the Armed Forces DNA Identification Laboratory have led to the development of a model program of DNA sampling and processing.

The final two chapters cover more general issues, including the nexus between policy and method and between condition of remains and administrative procedures. In Chapter 17, Kontanis and Sledzik discuss the special problems encountered when mass fatality incidents result in commingled remains. Of particular interest are the severity of body fragmentation and the overall effect on incident resolution (e.g., time involved in decedent identification). They present data from several disasters ("open" and "closed" populations) and discuss the numerous challenges associated with each one. In any of these scenarios, it is critical that goals and guidelines must be established at the onset. These protocols relate to the identification of bodies and body parts, as well as policies regarding "common tissue." To help in these assessments, Kontanis and Sledzik propose a "probative index" that is applied to individual bodies or body portions to prioritize analytical work for each specimen. In Chapter 18, Hennessey treats a topic seldom discussed in the literature: commingling of data. The forensic identification process is data-intensive, particularly when confronted with mass fatalities. Information from a plethora of analyses crossing disciplinary boundaries must be collated and stored in searchable databases. Antemortem information for the missing is often collected in an *ad hoc* manner, including inputs from doctors, dentists, family members, and friends. This information comes in a variety of formats, ranging from antemortem radiographs and dental charts to descriptions of tattoos. Analysts can be easily overwhelmed by the volume, variety, and inconsistencies of data. Standardization and quality control of the data are critical. Hennessey shares his considerable experience in coping with the inevitable errors and provides guidance as to how they can be minimized in future operations.

The chapters in *Recovery, Analysis, and Identification of Commingled Human Remains* reveal that the public's heightened expectations for quality in forensic recovery and identification of the dead have a legitimate basis. Novel methods and increased rigor in analysis and data management have led to significant gains in our ability to deal with commingled remains. We are confident that the reader will find many new tools to add to his or her analytical toolkit in the pages that follow.

Bradley J. Adams and John E. Byrd

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Chapter 1
Methodology in Commingling Analysis: An Historical Overview

Douglas H. Ubelaker

In 1962, Wilton Krogman published the first major text focusing specifically on forensic anthropology. Although his *The Human Skeleton in Forensic Medicine* is widely recognized as a classic historical text, it presents little discussion of issues of commingling in the analysis of human remains. The more focused 1979 follow-up text by T. Dale Stewart devoted only 2 of its 300 pages to commingling topics despite existing publications that focused on bone weight analysis (Baker and Newman 1957), ultraviolet fluorescence (Eyman 1965; McKern 1958), forensic neutron activation (Guinn 1970), statistical approaches to commingling issues (Snow and Folk 1965), and other considerations (Kerley 1972). Stewart noted (1979: 38) that most remains studied by forensic anthropologists at that time had been found as primary skeletons. For such cases, context and field documentation indicated that commingling likely was not a major issue.

In 2005, many skeletons studied by forensic anthropologists also were found as primary interments. Increasingly, however, cases are presented involving commingling issues. Mass disasters (Stewart 1970), cremation litigation (Murray and Rose 1993), human rights investigations, separation of recent from ancient remains, and many other types of modern cases raise questions such as, "How many individuals are represented in a group of remains?" and "How can remains of single individuals be identified within collections of remains from multiple individuals?" Cases and questions involving commingling issues are highly variable and problem-specific in modern forensic anthropology (Ubelaker 2002).

The methodology employed in answering these questions also can be highly variable (Rösing and Pischtschan 1995). As with most analysis in forensic anthropology, there is no "cookbook" approach to commingling issues. Practitioners must be aware of the myriad of techniques available and craft a case-specific protocol to address the specific problems at hand.

The chapters assembled in this volume represent a testimony to the growing need for commingling analysis within forensic anthropology and to the vast array of approaches available now to meet that need. Although basic inventory and documentation techniques are desirable in all cases, specific problems call for the selection of particular methods. This volume provides the reader with an overview of both the problems and the solutions.

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Separation of Bone and Tooth from Other Materials

Some problem applications call for identification of bone and tooth materials and their separation from other, similarly appearing items. These issues emerge particularly in small particle analysis of fragmentary and/or burned materials. Since DNA analysis can be employed even with small, fragmentary evidence to contribute to identification, many submitted cases involve such evidence. Particles of drywall, plastic, geological materials, and many other items can resemble bone and tooth, especially after exposure to intense heat or other taphonomic factors. Likewise, bone and tooth can be difficult to recognize as such after taphonomic alteration.

When gross morphology is inadequate to distinguish materials in such cases, microscopy can be useful. A high-quality dissecting microscope may allow detection of structure unique to bone and tooth (Ubelaker 1998). However, lack of such detail may be problematic since some bone and tooth fragments can be altered to the extent that surface diagnostic features may be lacking. Thin sections may be useful in such cases, but preparation techniques are destructive and may preclude molecular analysis with very small fragments.

Scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) provides a useful new tool in separating nonbone and tooth material (Ubelaker et al. 2002). Analysis presents not only a highly magnified surface image, which may in itself be useful, but compositional spectra that can be identified as elements. The presence and relative proportions of the constituent elements can be useful to distinguish bone and tooth from other materials. A comparative database of analyses of many known materials, including bones and teeth representing a variety of conditions, is now available to provide the probabilities of association. This system is especially useful to exclude materials from being bone or tooth but also can be helpful in the diagnosis of their presence (Ubelaker et al. 2002).

Recognition of Nonhuman Animal

In some commingling cases it may be necessary to document the presence of nonhuman animals or even determine species. Again, morphological assessment is the initial method of choice if the materials present diagnostic information. If bone and tooth fragments lack the necessary morphological features due to fragmentation or taphonomic alteration (Haglund and Sorg 1997), then microscopy may prove helpful. If sufficient material is present to support preparation of ground thin sections, the occurrence of plexiform bone or a characteristic osteon banding pattern may rule out a human origin (Mulhern and Ubelaker 2001). However, the presence of a typical human microscopic pattern is not necessarily diagnostic for human origin since that general pattern can be shared with some other animals (Mulhern and Ubelaker 2003).

In such cases, the technique of choice likely would be protein radioimmunoassay (pRIA). Very small samples (200 mg or less) can be utilized not only to conclusively and quantitatively separate human from nonhuman but also to identify nonhuman species (usually at the family level) if necessary (Ubelaker et al. 2004). The technique involves protein extraction followed by a solid-phase double-antibody radio-immunossay utilizing controls of antisera (raised in rabbits) and radioactive (iodine-125) marked antibody of rabbit gamma globulin developed in donkeys.

Separation of Ancient and Modern Remains

Case analysis may call for the separation of remains of recently deceased individuals from those who died long ago. Scenarios calling for such analysis might include a collection of remains found in the possession of an individual suspected of both grave-robbing and homicide, remains of a potential homicide victim found in an old cemetery with evidence of looting, or a mass disaster with modern victims at the site of a cemetery, or another such collection of older remains.

Presented with such problems, authorities might consider radiocarbon dating, focusing particularly on artificial radiocarbon. Atmospheric testing of thermonuclear devices beginning in the early 1950s produced abnormally high levels of artificial radiocarbon that, through the food chain, were incorporated into the tissues of all living things, including humans (Taylor 1987).

Levels increased steadily until about 1963 when international test ban agreements ceased the practice. Atmospheric levels of artificial radiocarbon have subsequently declined but still remain above pre-1950 levels. If analysis detects elevated levels of radiocarbon, the investigator knows that the individual was alive after 1950. Analysis of different tissues and consideration of the age at death of the individual may help pinpoint the birth dates and the death dates of the individual within the bomb-curve period (Ubelaker 2001; Ubelaker and Houck 2002).

Sorting Procedures

Once nonhuman materials have been separated out, analysis of the human remains usually begins with careful inventory (Buikstra and Ubelaker 1994). The extent and nature of the inventory typically are problem-driven but should document in appropriate detail what bones or parts of bone are present, approximate ages at death, and bone side (left or right). Other observations that may prove relevant include bone morphology, bone size, and articulation patterns (Buikstra and Gordon 1980; Buikstra et al. 1984; Kerley 1972; London and Curran 1986; London and Hunt 1998). Inventory and morphological assessment may be supplemented with such techniques as ultraviolet fluorescence (Eyman 1965; McKern 1958), radiography, serological testing, neutron activation, trace element analysis (Finnegan 1988; Finnegan and Chaudhuri 1990; Fulton et al. 1986; Guinn 1970), and bone weight (Baker and Newman 1957) and density studies (Galloway et al. 1997; Lyman 1993; Willey et al. 1997).

Modern DNA techniques increasingly are employed in commingling cases, especially to identify fragmentary evidence and assemble separated remains of single individuals following mass disasters. As noted in this volume, DNA technology and other complex approaches are best used in consideration of context and the prudent use of resources. Selection of remains to be analyzed for DNA should be driven by context, morphological analysis, and available resources. It would not be logical to obtain DNA profiles from more than one bone in an assemblage if they all were found in articulation. Similarly, it would not be necessary to have DNA data from more than one bone fragment of several found in separate locations if morphological study found that they fit together and originated from a single bone.

Approaches to documenting the minimum number of individuals present (MNI) have evolved beyond simple counts of elements present and their duplication (Allen and Guy 1984; Casteel 1972, 1977; Chase and Hagaman 1987; Steele and Parama 1981; Wild and Nichol 1983). Methodological and statistical approaches available include computer procedures for matching bones by size (Gilbert et al. 1981), a modified mark-capture procedure (LeCren 1965), the Lincoln Index based on matching pairs of bones (Winder 1992), and the more complex Lincoln/Peterson Index (Adams 1996; Adams and Konigsberg 2004). These approaches not only refine the estimation of the MNI but also seek to establish the MLNI (most likely number of individuals present).

The chapters in this volume explore the issues discussed above in great depth. They present the range of problems encountered in modern forensic anthropology that call for commingling analysis. They also present the growing methodology to address these problems. Anthropologists continue to study remains in their laboratories brought to them by law enforcement officials, similar to the way it was done when Wilton Krogman and T. Dale Stewart were publishing their volumes over two decades ago. However, today anthropologists deal with commingling issues at crash sites, makeshift morgues, and medical examiner's offices, frequently working alongside other professionals as part of analysis teams. The nature of the cases and the format and methodology for their analysis continue to evolve. This volume documents important aspects of that evolution and provides the reader with the information needed for successful resolution of commingling issues.

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Chapter 2
Spatial Analysis of Mass Grave Mapping Data to Assist in the Reassociation of Disarticulated and Commingled Human Remains

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Introduction

When considering possible solutions to the problem of sorting commingled human remains from a mass grave context, one is inclined to think of methods conducted within a laboratory setting (Dirkmaat et al. 2005), such as physical pair-matching of skeletal elements, evaluating articulation of elements, statistical analysis of measurements taken from the elements, or other such techniques that use data generated during mortuary analysis (Buikstra et al. 1984; Byrd and Adams 2003); in short, techniques that focus on the remains well after they have been recovered from the grave. Data generated during the excavation of a mass grave unfortunately are not often consulted when attempting to tackle problems of commingling. Nevertheless, observations and recordings taken during proper excavation can directly assist in the reassociation of disarticulated and commingled remains. In particular, mapping data and grave depositional event recording can be valuable information for use in the reassociation of disarticulated body parts to their corresponding bodies.

The potential of disarticulation and commingling of bodies and body parts is an issue in every mass grave. Not only are bodies initially commingled as they are deposited in the grave, but the condition of the bodies prior to burial, decomposition processes, taphonomic conditions within the grave, and the intentional destruction and/or tampering with the bodies by those who buried them contribute to the eventual disarticulation and mixing of elements, more so when an initial (primary) mass grave is disturbed and bodies are moved to a secondary mass grave(s). Care in exposing and removal of remains from a grave by an observant excavator, knowledgeable in human skeletal anatomy, is the single most important step limiting (and hopefully eliminating) further disarticulation during the recovery. Without a controlled excavation, disarticulation will be compounded, further adding to the already confused mix within the grave. Yet careful exposure and removal of remains does not have to be the only contribution a proper excavation makes. A well-documented, archaeologically led excavation generates data that may be used not only for prevention of further commingling, but also for resolving commingled remains.

Recognition of archaeological techniques and observations as potential key elements in assisting forensic case work has been acknowledged in the past (Dirkmaat

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and Adovasio 1997; Morse et al. 1976; Owsley 2001; Skinner 1987). Nevertheless, no suggestion has been proposed as to how archaeological observations can be logically and consistently utilized within mortuaries, especially those processing hundreds of remains from mass graves. Unfortunately, mass grave investigation is often sharply divided between two activities, recovery operations (grave excavation) and mortuary examination (autopsy), with neither activity having much contact with the other. While the forensic anthropologist or pathologist in charge of the mortuary may fully respect the contributions archaeology makes during the recovery operations, he may be unaware of the potential role archaeology can play in sorting commingled remains *after* the excavation. Archaeology, for the most part, is still very much viewed by mission planners as an outdoor (or at least out-of-mortuary) activity with no further connection to the mortuary other than delivering remains and associated evidence as intact as possible. Only under unusual circumstances does archaeology seem to be consulted during mortuary examination.

For example, Haglund (2001) describes a circumstance where excavation maps displaying the position of remains within a mass grave were used to help sort out fragmented crania superimposed upon each other. While Haglund uses this example as one of several positive contributions archaeology can bring to the investigation of mass graves, he unfortunately does not detail how the maps were used. It is assumed that the physical maps, not the recorded spatial data used to create the maps, were consulted to help rectify the commingling issue. Furthermore, it seems that this use of excavation maps may have been an isolated example; that the maps were consulted only after the commingling issue with this particular case was recognized in the mortuary, and the use of maps was not a standard aspect of their mortuary operation. No further reference to map use within their mortuary was mentioned.

In our study, a computer program is used to analyze spatial relationships between disarticulated and commingled remains within a mass grave. Similar to Haglund's example using maps to assist in sorting commingled crania to adjacent bodies, the computer program examines the spatial data generated during the electronic survey of body and body parts within a grave and comparing the locations of disarticulated elements to all possible matching points. The hypothesis is that a disarticulated body part closest to the point on the body missing that part is the most likely correct match out of all other possible matching body parts within the grave. Such a program can be run prior to or during mortuary examination, providing mortuary personnel with immediate suggestions as to which disarticulated body part(s) may belong to a particular body. When confronted with hundreds of bodies and body parts from a mass grave to sort through, prior knowledge of potential matching elements can be an effective starting point for rectifying commingling issues. Although not a definitive method or technique for reassociation, spatial analysis provides an objective and systematic approach based on the nature of the grave that may aid in reassociations.

In addition to generating data that can be analyzed spatially, an archaeological approach to mass grave excavation can identify events in the creation of the grave, which, in turn, has the potential to assist in resolving commingling issues. Specifically, the identification of depositional events of human remains within a grave, when combined with spatial analysis, can narrow the search parameters of possible matching disarticulated body parts within a group of recovered remains.

Materials and Methods

The focus of this study is on the largest of a series of mass graves excavated during 2002 on the Special Police Training Grounds in Batajnica, a suburb of Belgrade, in Serbia. Victims in the grave have thus far proved to be Kosovar Albanians killed in the spring of 1999 and transported to Belgrade for disposal. As of this writing, the majority of the remains have been identified. While overall control of the site and the associated evidence belonged to the Belgrade District Court, the actual excavation of the grave was conducted by forensic archaeologists from the International Commission for Missing Persons (ICMP) assisted by a crew of archaeologists from the University of Belgrade. All authors were employed by ICMP at the time of this excavation.

The grave in discussion, designated BA05 (Batajnica 05), was approximately 25 meters long, 3 meters wide, and 2 meters deep. We can deduce from the archaeological findings that a front-end loader-type construction machine dug the grave, creating a ramp down into the earth at one end as it removed soil (Fig. 2.1). BA05 was a complex mass grave in that it consisted of elements of both primary and secondary depositions as well as having areas within the grave where attempts were made at cremating the grave contents. Furthermore, we can infer that while many of the bodies transported to Belgrade from areas in Kosovo were gathered off the surface of the ground and loaded onto trucks; some were even wrapped in blankets or plastic sheeting, others were dug up from graves where they were originally buried. A situation occurred where, on one extreme, a number of trucks likely carried neatly packaged bodies, while others contained jumbled mixes of soil, bodies, and even some pieces of coffin. Before the trucks deposited their loads into the grave, the base of the grave was lined with old vehicle tires and pieces of lumber. The first trucks appear to have backed into the grave, where they dumped their loads. Later trucks dumped their contents on the surface of the ground next to the grave, where the remains either were directly pushed into the grave from the side or were first set afire and allowed to burn for a time before being pushed in. As remains and backfill were deposited into the grave, gasoline and additional tires were added to the mix in an apparent attempt to keep the fires going.

The perpetrators, however, were not as methodological in the destruction of the bodies as they had planned. Perhaps because of fear of ongoing NATO bombing strikes in the area at the time, or simply because those carrying out the orders to make the graves were not enthusiastic about their assigned task, the bodies appear to have been buried shortly after they were deposited in the grave, putting many of the fires out almost as quickly as they were started. As bodies mounded up over the edge of the grave, a construction machine repeatedly drove over the top of remains, crushing them down into the grave as it deposited more soil. The combined activities

Fig. 2.1 Completed excavation of the BA05 mass grave. The ramp into the grave begins near the bottom of the photograph. Note vehicle tires on the base of the grave

of different body collection strategies in Kosovo, the act of transporting them to Belgrade by truck, attempts at destroying them by fire, and machine activities made the excavation, recording, and recovery of the human remains within this grave extremely challenging.

In order to accurately map spatial relations within and around the grave, the ICMP archaeologists employed an electronic Sokkia set 600 total station equipped with a Sokkia SDR 31 data logger. Total stations, which are being used increasingly at archaeological sites and outdoor crime scenes, are becoming familiar equipment at mass grave excavation sites. Capable of recording position points in three dimensions in a fraction of the time traditional tape measure and transits take, a total station's data can be downloaded by computer programs and rendered into three-dimensional maps illustrating the exposed human remains, artifacts, and grave features, in any imaginable combination (Wright et al. 2005). What would have taken days to map by hand can now be accomplished in a few hours.

While a single point recorded from a complete body or disarticulated body part in a grave can be used to represent those remains on a map, excavators of mass graves using total stations typically record a series of points to represent a set of remains. This series of points can then be connected in stick-figure manner in a geographic information systems (GIS) program, to represent a body for map purposes. Points recorded on a complete body are typically the head of the body and all major limb joints. During the excavation of mass grave BA05, a total of 15 points for a complete body was recorded. In addition to the head and joint points mentioned, a central pelvis, central body mass, and, when found in isolation, the mandible had points taken on them. While the amount of points recorded may seem excessive, we have found that it takes only 3–4 minutes to survey a complete body and does not interfere with the flow of work. Indeed, by recording the series of points, it forces the person recovering the body to check that all the major elements are present, helps to eliminate possible commingling mistakes during the recovery, and ensures an accurate field inventory of the remains.

Many current total stations and/or related data loggers have limited capacity for recording text to describe the points recorded. The Sokkia data loggers used by ICMP could only accommodate up to 16 characters and spaces in their description field. Although this limits the amount of text that may be attached to a particular record, one would not necessarily want to be slowed down inputting long, descriptive text during the excavation. It may be possible to preprogram an alternative data logger such as a tablet PC or laptop with these codes to operate in a quicker usable format, but standard data loggers are currently incapable of doing this alone.

To bypass the lack of available space and ensure speedy input of text, short descriptive codes, adopted from the International Criminal Tribunal for the former Yugoslavia's mass grave survey procedures (Hanson et al. 2000), were used to identify the points taken. Points recorded on a body received a four-letter code beginning with the side from where the point is being taken, followed by the first three letters of the body element. A left shoulder would be recorded as LSHO. Elements such as the cranium (CRAN) that does not have a side used the first four letters of the name of element. Table 2.1 lists the codes and elements they represent used during the excavation of BA05.

Table 2.1 Body Points Recorded and Their Associated Total Station Codes

Code Entry	Description
CRAN	Cranium
RSHO	Right shoulder
RELB	Right elbow
RWRI	Right wrist
LSHO	Left shoulder
LELB	Left elbow
LWRI	Left wrist
CPEL	Central pelvis point
RPEL	Right pelvis point
LPEL	Left pelvis point
RKNE	Right knee
RANK	Right ankle
LKNE	Left knee
LANK	Left ankle
CPOI	Central point—body
MAND	Mandible (if disarticulated)

A total station records the location of a given point in X, Y, and Z (e.g., north, east, and elevation) coordinate format. Each body or body part uncovered in the grave received a unique evidence number. This evidence number was added to the mass grave identifier (BA05) along with the four-letter body location code. A string of recorded total station code for a single point taken on a body may read BA05 123B RELB followed by the X, Y, and Z numerical coordinates. In this example, BA05 represents the grave number at Batajnica, 123B is the individual body evidence number (B = body), and RELB indicates the point recorded was the right elbow. A complete body would be represented by 15 sets of these codes, while an individual body part (BP = body part), for example, an unassociated disarticulated left arm, would have only three points recorded: the shoulder (LSHO), elbow (LELB), and wrist (LWRI). Figure 2.2 is an example of what a complete body may look like after exposure in a grave and then rendered in a map as a stick figure, each position point taken labeled with the appropriate code. It should be noted here that while 15 points were taken on a complete body, the central point (CPOI) taken on a body was not used in our spatial analysis for reasons explained in the Discussion section.

A word regarding body (B) vs. body parts (BP) classifications. There is currently no standard used in the international community of mass grave investigators regarding the definition of what constitutes a body or body part. Indeed, this is a constant source of debate among practitioners—debates that unfortunately often take place at the graveside as the first disarticulated remains are about to be removed. While it may seem obvious that a complete articulated body can be defined as a body (B), it becomes less clear how to classify a body in progressively disarticulated condition. At what point does a body become categorized as a body part? It is easy to imagine that an unassociated disarticulated limb or skull will be categorized as a body part (BP), but should remains consisting of a torso missing its head and a leg be considered a body part or a body? What if it is also missing the other leg

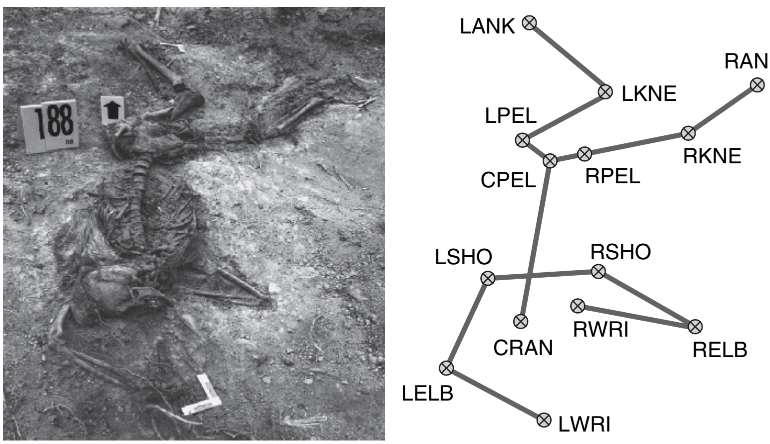

Fig. 2.2 Body 188B *in situ* and represented in map form

and an arm? Or if, as regularly happens, the remains become disarticulated at the lumbar vertebrae and the upper half is missing a limb or two? Proposals such as "If 75% of the remains are present it can be categorized as a B and less than 75% a BP" promote disagreements in the grave between recovery team members over how much of the body is present. Currently, the categorization of remains is usually left up to the lead recovery leader or individual team member removing the remains from the grave. This is often without thought regarding how the categorization may affect mortuary operations. There is a need to standardize these categorizations in a comprehensive manner that assists mortuary analysis.

In mass grave BA05, as with most excavated graves, the categorization occurred in an ad hoc fashion. While most of the remains were intact enough to be classified as Bs, on occasion it was unclear and the lead archaeologist made the call. In general, if 50% or more of a body was present, then it was classified as a B. Fortunately, most BPs tended to be disarticulated limbs consisting of at least two articulating bones. Single disarticulated bones without association were categorized as "general bones" (GB) and were not recorded by the total station (as a result of this study, we now advocate the recording of all long bones as well as a carefully planned classification system for potential spatial analysis). Only complete hands and feet were recorded as body parts; two or more of these "minor" bones recovered in articulation were categorized as GBs. It should be recognized that while it is desirable to reassociate as many disarticulated elements back to their bodies, a number of elements such as unassociated ribs and the bones of the hands and feet are often beyond the capacity of anthropology to reassociate given the number of remains within large mass graves. Until DNA technology becomes easier and less expensive, the possibility of reassociating such elements with limited funding and time constraints is economically out of reach. Numerous GBs as well as hands, feet, and sections of torso will not be reassociated because of these reasons, and so mission planners, with relevant governmental bodies and family associations, will have to decide what to do with these "extra" elements.

In addition to recording points on a body/body part for spatial analysis, surveying the remains also renders a basic skeletal inventory of that case. At the completion of an excavation, the total station data can act as a backup to any evidence/photographic log or other documentation source. In addition, all the individual body or body part points can be downloaded to provide an instant inventory for mortuary use. A quick glance at a case's code will indicate not only if it is a body (B) or body part (BP), but what elements that case consists of. Elements absent from the inventory represent disarticulated elements—an important heads-up for an anthropologist or pathologist getting ready to begin an autopsy.

Within the BA05 mass grave, according to records, 378 cases comprising 289 Bs and 89 BPs, and 594 single disarticulated bones and bone fragments (GBs), were recovered from 12 separate deposits of human remains. Each deposit, identified through archaeological techniques, represents a truck load dumped into the grave, or a collection of bodies dumped on the surface beside the grave and then pushed into the grave by a construction machine. The excavation team recorded location points on all body and body parts, as described. In addition, the individual deposit within the grave from which the remains were recovered was noted. As mentioned, the single disarticulated bone and bone fragments (GBs) were not recorded by the total station, but instead were gathered in separate bags according to the deposit from which they were recovered. As no points were recorded from these elements, they are not included in this study. Again, as a result of this analysis we would suggest that single disarticulated long bones receive the same attention as Bs and BPs if spatial analysis is to be conducted.

All Bs, BPs, and artifacts were assigned an individual, sequentially assigned evidence number. The remains and artifacts were placed in separate body bags or plastic bags depending upon their size. The evidence number was recorded in an evidence log book and written on the outside of the body/evidence bag. A separate slip of paper with the evidence number was sealed in a Ziploc-type bag and placed inside the body bag with the remains. The remains were then transferred to a storage area to await autopsy. The mortuary/evidence personnel were provided a copy of the evidence log.

Autopsies were conducted on site while the excavation of the Batajnica mass graves was ongoing. This manner of operation precluded most reassociation efforts. Reassociation can only be attempted after a grave is completely excavated and a remains inventory established, or you risk the chance of missing a matching element still buried within the grave. Due to both legal and political considerations between the Belgrade authorities and ICMP, DNA took the lead in identification and reassociation of recovered remains. During autopsy, hard-tissue samples were taken from all bodies and body parts and later processed through ICMP DNA laboratories. It was through DNA results that reassociations were eventually established. Not only did positive results assist in identification, but identical sequences between disarticulated body parts and bodies allowed for reassociation of 41 disarticulated elements from the BA05 mass grave.

As there was little opportunity for reassociation methodologies to be applied at Batajnica, analysis of the spatial relationship of remains within BA05 presented here was done at a much later time and was not part of the original mortuary effort. The spatial analysis was performed without prior knowledge of ICMP DNA reassociation results, which serve as a control.

A spatial analysis program, derived from Microsoft Access, was used on the BA05 survey data to calculate the distance between bodies missing elements and potential matching body parts in the mass grave. The formula used for this analysis calculates the distance between two points in three-dimensional space and then produces a list of potential matches in order from nearest to furthest. It is important to use three-dimensional distances and not, as is sometimes done, two-dimensional maps, which distort the real relationships between elements. The idea of using mass grave mapping data to search for nearest probable matches has most likely occurred to many people in the past. However, few seem to have actually gone as far as to develop the idea. One person who has attempted to use mass grave mapping data in this manner is Richard Wright.

Wright kindly provided ICMP with a program for spatial analysis (Wright 2003), which he adapted from his earlier cranial morphometric research (Wright 1992). However, Wright's spatial analysis program lacked the option to narrow the search to only those elements that could potentially match the remains being examined. Instead it computes the distance from the point you wish to search from, say a RELB for a missing lower right arm, to *all* other points recorded within the grave regardless of whether or not those points are lower right arm points. What you want is a list of potential disarticulated right lower arms. However, you end up with a list, organized by distance, of crania, shoulders, knees, wrists, and all the other points recorded within the grave, as well as the potential matching lower right arms. Although Wright's program allows the number of points displayed to be limited, this does not diminish the fact that numerous points with no relationship to the remains being examined must be filtered through to reveal those that do represent potential matches.

The spatial analysis program designed for this study is based on a number of SQL Queries in Microsoft Access and allows data gathered from the total station or GIS software to be imported in various formats. Unlike Wright's program, only potential matches are listed in the results of a query. All other points are ignored, and thus filtering is automatic.

We currently do not offer our spatial program for public use. However, it must be emphasized that a number of commercially available database programs are able to perform spatial analysis. As mentioned, we used Microsoft Access, already available on most PCs. Anyone experienced in creating SQL Queries in Microsoft Access or a similar program should be able to make a program capable of spatially analyzing total station data given the parameters described below. This study's aim is to inform the reader of the potential of spatial analysis of mapping data, not to provide step-by-step guidance on how to create their own Microsoft Access (or other program) database. Such guidance could not keep up with computer program technology, and it is certain that anyone wishing to use such a program would want to tailor it to his specific needs. If no current member on your team is experienced in database management, we suggest an Information Technology (IT) specialist be employed to create your queries and train your staff on the program's operation. Database managing is one of many aspects of mass grave investigation that must be planned for in advance. A spatial analysis program to be used in the mortuary can be created at the same time and incorporated into your overall operating procedures.

For this study, the steps for running searches in our spatial analysis program are as follows:

From a given case, the code of the specific point where disarticulation occurs is entered. For a body (e.g., case 030B) missing a right lower leg, this would be "030B RKNE." Next, possible codes of matching elements are entered. In this case of mass grave BA05, it would have been another "RKNE." As a result of this study, the point codes have been modified to perform more detailed queries as later detailed in the Discussion section. In addition to searching for elements with matching code, a wildcard can be used in the search, e.g., to find both left and right lower legs, in case they have been sided wrongly during excavation. If desired, the search may further be limited to a certain deposit of human remains within the grave, thus narrowing the possibilities even more. Tables 2.2 and 2.3 display results of a spatial analysis query for the example case.

The result of this query is a list of potential matching elements, ranked by three-dimensional distance from nearest to furthest (Table 2.2). Displayed in the table is the target point (the right knee of case 030B, in this example), the deposit from which the remains were recovered (if applicable), the case number of the possible matching body part, the distance in meters between the targeted point, the element of the body part queried for (right knee in this example), and the ranking of the possible matching body part. The ranks are according to distance; rank 1 being the closest, rank 2 the second closest, and so on.

It is also possible to include the inventory on all the points surveyed on each body or body part, so as to give an idea of which elements are present in each case. In this manner, when the potential matching part inventory shows the body part to have repeated elements with the case body, the potential matching part may be removed from initial consideration. This could eliminate the need to physically retrieve the possible matching body part from the collective remains in storage (no small task when you have hundreds of remains to sort through) while those body parts that better match with the body are examined.

For example, in Table 2.3 the first (and thus closest) body part to the targeted 030B RKNE is case number 058BP at just under 0.25 meter's distance. Examination of all the points recorded on 058BP reveals that it consists of both left and right lower legs. Both knee and ankle points are present (RKNE, LKNE, RANK, and LANK) but no pelvic points, which would indicate if the presence of a femur was recorded. If case 030B has a left lower leg, 058BP can be excluded as a potential match. On the other hand, if the body is missing both lower legs, 058BP should be considered as the best possible match according to distance.

For the 378 cases (289 Bs and 89BPs) recovered from BA05 mass grave at the time of the study, 46 reassociations had been completed on the basis of matching DNA. Out of these, five were excluded from this study because the matching DNA samples had been taken from the same cases and thus only corroborated original association. Nine more matches were excluded because of lack of sufficient data for the queries. The lacking data were in part information on what body elements

Table 2.2 Example Results of Spatial Query Showing Possible Matches, Listed in Order of Distance from the Targeted Point (030B RKNE), When Searching for a Right Lower Leg

Body Survey Code	Deposit Number	Case Number	Distance in Meters	Element	Rank
030B RKNE	1	058BP	0.24866	RKNE	1
	1	067BP	0.89834	RKNE	2
	8	225BP	3.62864	RKNE	3
	9	300BP	5.525004	RKNE	4
	9	425BP	5.646783	RKNE	5
	11	347BP	10.35154	RKNE	6

Table 2.3 Detailed Query Result Showing Four Possible Lower Leg Matches, by Distance, to case 030B with All Recorded Points Displayed

Case Number	Distance in Meters	Deposit Number	Recorded Code Present
058BP	0.24866	1	058BP RKNE 058BP LKNE 058BP RANK 058BP LANK
067BP	0.89834	1	067BP RKNE 067BP LKNE 067BP RANK 067BP LANK
225BP	3.62864	8	225BP RKNE 225BP RANK
300BP	5.525004	9	300BP RKNE 300BP LKNE 300BP RANK 300BP LANK

the matching parts consist of (due to unclarity in the field and the inaccessibility of certain anthropological data at the time of this study) and in part missing spatial data (coordinates). For each of the remaining 32 cases, a query was run, producing a list of possible matches. As stated before, these lists display the possible matching cases in an order from closest to furthest, thus ranking them according to distance. From this list of possible matches, the true matches, as corroborated by the DNA analysis, were marked. On each list, the ranks were numbered and the match that was actually corroborated by DNA was marked.

Again, the hypothesis is that the nearest-ordered disarticulated body part is more likely to be the matching element than all other possible matching body parts within the grave. This hypothesis should certainly be expected to be valid in a simple primary mass grave. On the other hand, it is likely that the stronger the commingling, as we find in complex secondary mass graves or cases of intentional commingling of remains, the less likely the hypothesis is to be true. However, running the analysis against disarticulated remains from the *same deposit* should help alleviate this problem, even in a secondary mass grave, especially if it consists of clearly defined deposits from different primary sites.

As explained, spatial analysis will produce a list, ordered by distance, of every possible match within grave. Yet, as noted, many mass graves are made of separate deposits of bodies, often gathered from different geographic locations. Remains recovered from BA05, for example, came primarily from three different municipalities in Kosovo. Analysis of the spatial relationships between all remains within BA05 would produce a list that contains possible matches of body parts originating from different municipalities. By narrowing the search to the separate deposits within the grave, particularly complex graves such as secondary burials, the accuracy of the list produced by the spatial analysis program should increase.