Chapter 13
Assessment of Commingled Human Remains Using a GIS-Based Approach

Nicholas P. Herrmann and Joanne Bennett Devlin

Introduction

The quantification of fragmentary human remains offers a challenge for physical and forensic anthropologists. Physical anthropologists frequently borrow methods and quantification techniques developed by zooarchaeologists to assess such collections. Traditionally, zooarchaeological examinations deal with highly fragmentary, commingled samples from numerous contexts. As such, the archaeofaunal literature is rich with analytical approaches to assess these complex assemblages. However, the appropriate application of zooarchaeological approaches to human bone assemblages is uncertain.

The present study examines the commingled burned human remains from the Walker-Noe site (15Gd56) in Garrard County, Kentucky. The site is a small, early Middle Woodland Adena crematory located on the southern periphery of the Bluegrass physiographic region of the state of Kentucky. Extreme fragmentation of the remains precludes the use of a simple elemental coding system to generate a skeletal inventory. This chapter details the application of a geographic information systems (GIS)-based approach developed by zooarchaeological researchers (Marean et al. 2001) to provide both a minimum number of elements (MNE) and minimum number of individuals (MNI) estimate. The methods presented in this study have applications for both bioarchaeology and forensic anthropology. The physical anthropologist needs tools to accurately quantify the number of elements and individuals recovered from a commingled context, whether prehistoric, historic, forensic, or part of a human rights investigation.

Issues of Fragmentary and Commingled Human Remains

Though several measures exist for quantifying individuals represented in an assemblage, most frequently, biological anthropologists seek to estimate the minimum number of individuals (MNI). Simply, the MNI is generated by sorting elements to side of the body and recognizing the highest value as an indicator of the number of individuals present (Grayson 1984). This generates an approximation of the minimal number of individuals represented in the assemblage but cannot be

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considered as a reflection of the size of the population that produced the recovered assemblage. Estimations of the original population size are possible (see Adams and Konigsberg 2004); however, extreme bone fragmentation limits the accuracy of such approaches and renders pair-matching impossible. For most examinations of extremely fragmentary remains, the estimation of the MNI is an appropriate approach.

At the core of MNI assessments must lay an accurate determination of the minimum number of skeletal elements (MNE) present in a collection. Seemingly straightforward, the relationship between the MNE and MNI is, in practice, a complex one. The MNE is defined as a derived quantitative measure (Lyman 1994) and, as such, requires explicit definition as to its calculation. Lyman presents multiple examples of MNE definitions that would result in several different estimates. Similarly, MNI calculations based on elemental coding systems are susceptible to the same problems of over- or underestimation as the MNE. Given the basic practice of sorting and coding elements by context to side of body and recognizing the highest count as indicative of the MNI, it is apparent how such values can underrepresent or potentially inflate the MNI. Recently, Adams and Konigsberg (2004) proposed a technique for estimating the most likely number of individuals (MLNI) as a variation of the Lincoln Index (LI). However, these techniques, predominantly based upon pair-matching, are poorly suited to extremely fragmented and cremated assemblages, as noted by Adams and Konigsberg (2004). Further, in an overview of methods for interpreting cremated remains, Mayne Correia and Beattie (2002) illustrate the lack of a cohesive analytical approach to estimating the MNI from cremated remains.

Osteological data collection manuals are lacking in coding systems for highly fragmented and taphonomically modified deposits. Buikstra and Ubelaker's (1994) osteological standards manual does provide for analysis of commingled remains, but the system is primarily useful when dealing with large fragments. Elements are to be coded according to the presence of specific percentages for the diaphysis (in thirds) and articular ends for long bones. Whole cranial elements and specific axial elements or groups of midline bones are to be recorded as such. The database recording structure presented in the standards manual (Buikstra and Ubelaker 1994) does allow for bone identification, element completeness, MNI count (based on identifiable elements), and demographic parameters. While providing a good structure for complete or near-complete skeletal recording, the methods presented in the standards manual (Buikstra and Ubelaker 1994) do not provide enough detail for highly fragmentary remains, cremations, or large commingled samples.

Church and Burgett (1996) and Burgett (1990) adapted a zooarchaeological coding system in an attempt to capture the variation in extremely fragmentary human remains. Burgett (1990) initially developed this information recording and retrieval system to document *in situ* commingled and fragmentary faunal remains. Church and Burgett (1996) describe the coding system as an alphanumeric identification hierarchy within which element, portion, and segment of the bone are identified. In addition to the identification hierarchy, Church and Burgett (1996) incorporate basic bone properties and taphonomic attributes. The properties fields constitute size, age, sex, fusion/development, and pathological conditions. The taphonomic attributes include weathering, gnawing, modification, breakage, burning, and trauma. While this system deals with fragmentary remains far better than the *Standards* (Buikstra and Ubelaker 1994) approach for human remains, it still has several shortcomings. The element, portion, and segment identification hierarchy can often become cumbersome when dealing with small identifiable fragments. The analyst decides whether an element is included in the calculation of the MNE or MNI. Small fragments typically do not represent the entire coded specimen and are given a "partial" or "fragment" segment code within this system. Clearly, the inclusion of partial/fragment codes in the summary analysis would result in overestimations of both the MNE and MNI, while excluding these specimens could seriously underestimate the MNE and MNI for fragmentary samples. This is problematic, given that an accurate estimation of the number of individuals represented in an assemblage is often crucial to the interpretation of site formation processes. Often with cremated and extremely fragmentary commingled remains, it is possible to identify very small fragments to side and exact position. However, these identifications may not be such that can be incorporated into an existing database or calculation system. Absent in the literature to date is a detailed recording system in biological anthropology that allows an analyst to accurately assess and estimate the MNE and MNI for commingled human remains.

Many of the problems considered herein are confronted in the technique developed by Marean and colleagues (Abe et al. 2002; Marean et al. 2001). A customized ArcView extension, *BoneEntryGIS,* utilizes an element-specific GIS to calculate MNE estimates. In effect, this approach facilitates a systematic means to overlay all identifiable elements, thereby generating a count of the minimum number of each element present in an assemblage. For the Walker-Noe site, we use this approach as a means to overcome the inadequacies of traditional inventory systems in managing fragmentary and highly modified remains such as cremated samples. The GIS approach provides a visual inventory and an efficient method to quantify the MNE. In the present discussion, we focus on the cranial elements of an archaeologically derived assemblage from the Walker-Noe site, Kentucky. In an attempt to thoroughly document both the number of individuals represented in the collection and taphonomic attributes of heat exposure as an indicator of cremation practice, identifiable bone fragments were digitized and assessed using a modified version of the *BoneEntryGIS* software extension. The results highlight the utility of this system for documenting highly fragmentary and taphonomically modified human remains, while also identifying potential problems in the application of this technique to human bone assemblages from both archaeological and forensic contexts.

Walker-Noe (15Gd56)

The Walker-Noe site (15Gd56) represents a small, early Middle Woodland period mound situated in the south-central Bluegrass Region of Kentucky (Fig. 13.1), supported by radiocarbon dates spanning from 170 B.C. to A.D. 130 (Pollack

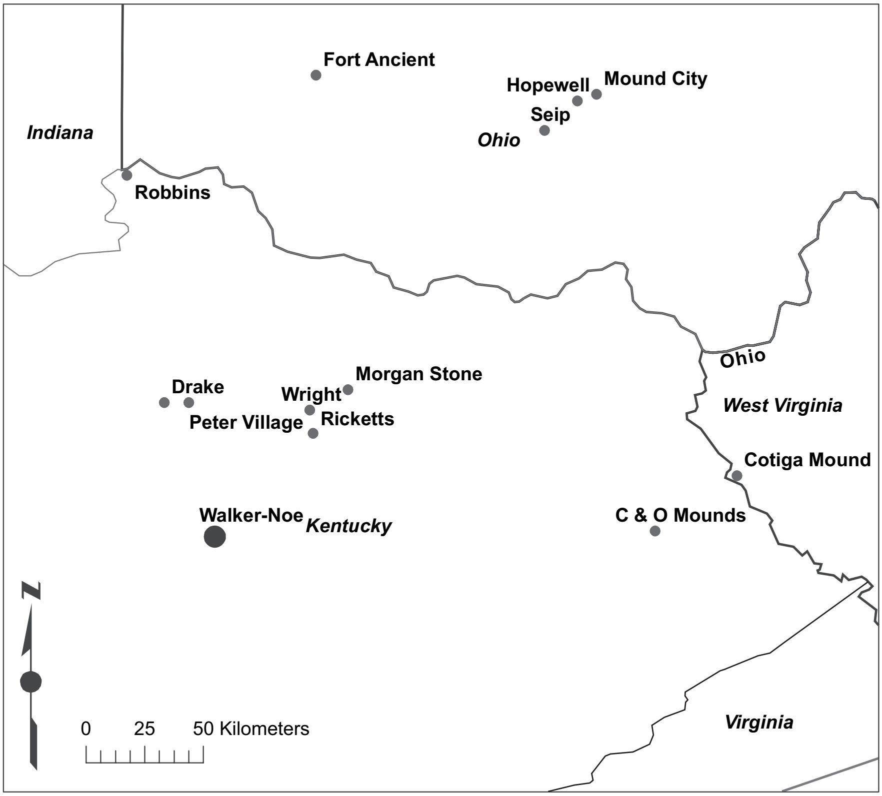

Fig. 13.1 Map of Adena sites found near the Kentucky Bluegrass region (modified from Pollack et al. 2005)

et al. 2005). Excavations at the site were conducted during the fall of 2000. Ceramics and lithic artifacts associate activity at the mound with the Adena culture. The radiocarbon dates firmly place the Walker-Noe site within the Middle Woodland period of the eastern United States. Adena is typically considered an early woodland culture throughout much of the Ohio River Valley; however, Late Adena does extend into the Middle Woodland period (see Anderson and Mainfort 2002; Clay 1998, 2002; Railey 1990). Commonly, Adena mounds identified in Kentucky are characterized by extended interments with few cremations within large mounded burial facilities (Railey 1990). Walker-Noe can be considered as "event-centered" site a là Clay (1998, 2002), but it is not an accretional mound. Walker-Noe appears to have been a short-use facility where the local population cremated a small number of their dead (see Pollack et al. 2005).

The extensive presence of cremains at Walker-Noe suggests a fairly unique crematory pattern from that of other documented Woodland Period mounds both in design and in use in this region. In particular, Walker-Noe is rather distinct in the apparent existence of *in situ* cremations evidenced by substantial burned soils. The site is marked by a centrally located feature, a 1.25-square-meter deposit

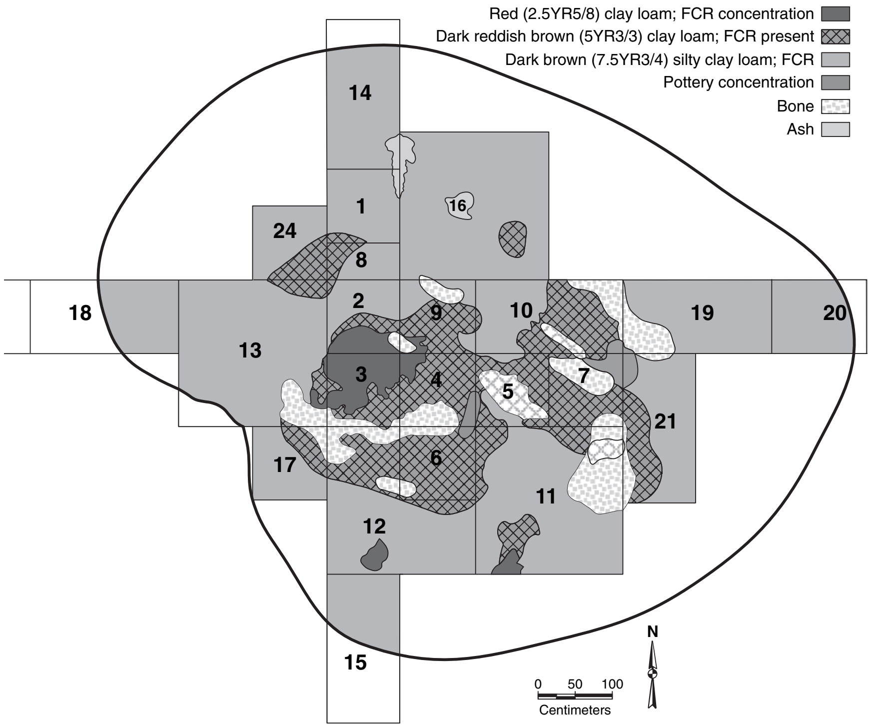

Fig. 13.2 Plan map of the Walker-Noe mound (modified from Pollack et al. 2005)

5 centimeters in depth, of burned clay loam (Fig. 13.2). The area of burned soil surrounding the central feature contained large amounts of fire-cracked dolomite (150 kilograms in total). Concentrations of cremated bone were identified directly above and around the central burned area. In addition, aggregations of burned bone were present in peripheral regions of the site. All skeletal material was located in association with wood charcoal, ash, and burned soils (Pollack et al. 2005). Several recovered projectile points/knives (PP/K) demonstrate attributes that suggest a contextual association with the cremation practices at the mound. Six PP/Ks do not exhibit any use-wear, interpreted to represent their preparation as ceremonial objects. However, two PP/Ks demonstrate heat alteration, indicating direct association with cremation practices. The Walker-Noe mound has been posited as a primary site for both cremation and interment, as supported by excavation and artifactual evidence (Pollack et al. 2005).

Walker-Noe Skeletal Analysis

A thorough examination and analysis of the human remains recovered at Walker-Noe is crucial in characterizing the mound as a crematory. Fieldwork yielded over 18 kilograms of charred and calcined human bone. The majority of fragments are less than 3 centimeters in diameter, with nearly all specimens exhibiting classic characteristics of extensive heat alteration, extreme fragmentation, and particular surface colors. All elements exhibit burning on both the internal and external surfaces. Little variation in color was noted across the cremation sample, with nearly all fragments displaying surface colors of gray and whitish gray, which is evidence of calcination. Surface colors associated with incomplete combustion of the organic components (i.e., browns and blacks) were not observed. In addition, fragments display extreme shrinkage and moderate degrees of warping, though the latter does vary throughout the assemblage. In addition, surface cracking and fracturing are apparent on the majority of specimens, on both endocranial and ectocranial surfaces. The condition of the skeletal material from the Walker-Noe site reflects a thorough incineration process. The consistency of these heat alteration attributes across the sample may be indicative of intentional processing and/or repeated exposure.

Preliminary assessments of the osseous material from Walker-Noe demonstrated that (1) identifiable cranial fragments far exceeded recognizable postcranial elements, and (2) the bone fragments examined in this study represent the commingled remains of numerous individuals (Bennett Devlin et al. 2006; Herrmann et al. 2005). We suspect that identification of cranial fragments over postcranial remains is common in most archaeologically derived cremains. The concentration of discrete and recognizable hard-tissue features of the skull compared to undifferentiated features of long bone shafts makes the use of cranial fragments more appropriate. Given this pattern, the present discussion incorporates data only from select cranial material.

GIS Analysis

The examination of the fragmentary human remains was conducted in several stages. Bone fragments were initially sorted into three categories of cranial, postcranial, and indeterminate elements. When possible, fragments were identified to particular element, though they were not sorted to side of the body. Due in part to this result, we focus upon several craniofacial elements: frontal, zygomatic, maxilla, and mandible. These elements were selected for several reasons: (1) They have a high likelihood of recovery; (2) these elements are readily identifiable (by osteologists) in fragmentary form; and (3) these four craniofacial elements possess multiple features that facilitate recognition of small, cremated fragments as a particular portion of the bone. The last of these criteria is the most important given the structure of the *BoneEntryGIS* system and approach.

Shapefile templates of the four cranial elements were created according to the methods described by Abe and Marean (n.d.). Within *Adobe Photoshop*, composite images of the four craniofacial elements were created that displayed both endocranial and ectocranial surfaces as well as other important elemental surfaces. For paired elements, these images were flipped horizontally to create the antimere image. The composite images were then georeferenced to four coordinate points within *Erdas Imagine*. The coordinate points are visible as the four symbols on the

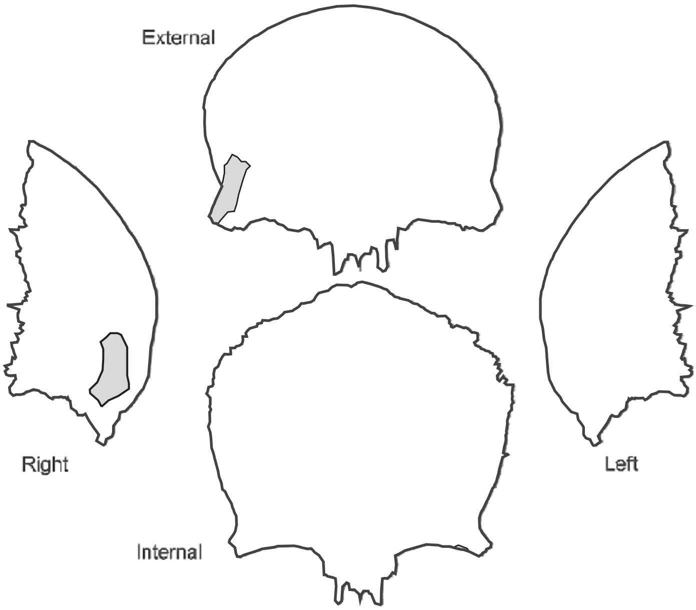

Fig. 13.3 Frontal bone template with single placed fragment digitized

images (see Figs. 13.3 and 13.4 for examples). The images were converted to a 1-bit grid and then changed to a shapefile to capture the perimeter of the bone surfaces. The element shapefile could then be edited, cut, and coded based on the observed fragments.

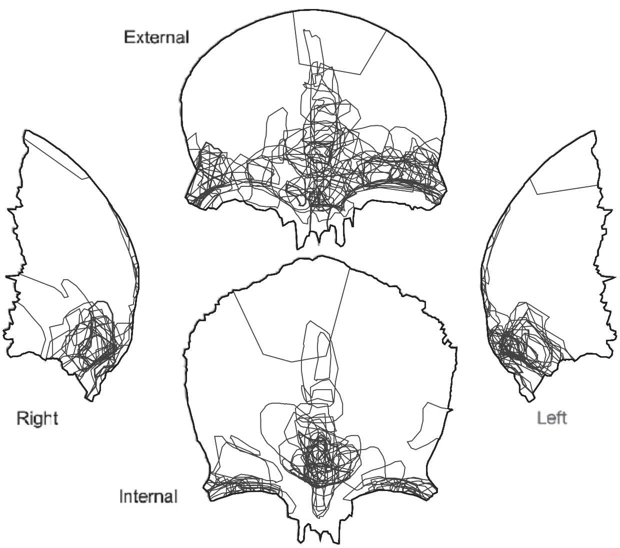

Fig. 13.4 Outlines of all placed frontal bone fragments from Walker-Noe

Fragmentary specimens were initially identified to one of four bones of the craniofacial skeleton. Fragments were separated based on field data. Subsequent examination sought to identify the particular area or region of the bone that the fragment represents. A substantial number of fragments were identifiable to a particular bone but did not contain specific features to facilitate identification to an exact location and were not digitized. A total of 396 specimens was subjected to further assessment (see Table 13.1). These specimens were identifiable to an exact location on the complete bone, herein referred to as "placeable." Researchers were able to "place" 112 frontal, 45 zygomatic, 59 left and 58 right maxillae, and 122 mandibular fragments to a particular location on the respective element. In addition, these fragments were macroscopically assessed in terms of surface colors, level of distortion, apparent degree of shrinkage, and overall fracture and cracking patterns. Each of these placeable fragments was assigned a specimen identification number as dictated by the *BoneEntryGIS* extension, which incorporated the field specimen number (fs) to enable consideration of fragment distribution across the site and site formation processes.

Surface colors were assessed on all identifiable specimens using an *X-rite CA22* spectrophotometer. This handheld device systematizes color evaluation by measuring areas on the sample greater than 1/4 inch and relays color data to a host computer running *Matchrite ColorDesigner* software. As illustrated in Table 1, major and minor surface colors were noted and are represented as an average across the sample in the Mean Color column. Color data were recorded in the Lab color system, a numerical-based system that represents colors in terms of three dimensions. The extreme light and dark colors were also noted, as they are indicative of more unique heat exposure situations. Lab color values were then converted to Munsell colors (Munsell Soil Color Charts 2000) using the Munsell Color Conversion software (version 6.5.17; http://wallkillcolor.com/). Although time-intensive, the GIS system as used here provides the means to accurately quantify fragmentary and taphonomically modified skeletal material.

The nearly 400 placeable fragments were digitized using a modified version of the *BoneEntryGIS* software for ArcView 3.3 (Marean et al. 2001). Utilizing the software extension, skeletal fragments were recorded by location on two-dimensional images of the complete element. Multiple views of each element are included to ensure proper placement of each bone fragment. Figure 13.3 illustrates the process involved in "placing" a single fragment of the frontal bone. The overall shape,

Table 13.1 Lab and Munsell Color and MNE Estimate by Elements

Element	Placed Elements	Mean Color	Extreme Light Color	Extreme Dark Color	MNE
Frontal	112	8.9YR 6.4/2.8	9.7YR 8.8/1.0	8.6YR 3.4/2.1	26*
Malar	45	9.0YR 6.4/2.9	8.6YR 8.4/2.2	1.3Y 5.1/1.5	17
Maxillae R/L	59/58	8.9YR 6.2/3.0	9.3YR 8.1/2.4	9.5YR 4.5/2.1	20/21
Mandible	122	8.9YR 6.4/2.9	8.9YR 8.3/2.3	8.2B 4.5/0.48	21
Total	396				21

*Please see discussion of MNE determination in text.

location, and dimensions of the fragment are recorded as the specimen is positioned on the appropriate images that illustrate all views of the element. Each entry is saved as a shapefile, which can be merged (or layered) to demonstrate the density (i.e., numbers present) at a particular skeletal location. Figure 13.4 illustrates all of the data cells for identifiable fragments of frontal bone. Note the overlapping outlines of fragments. This information can then be interpreted and quantified as representing the number of elements present. Further, data such as fracture pattern, external and internal color, and other traditional human skeletal characteristics (pathology and discrete variants) can be recorded into a linked database. Data concerning recovery location may also be managed in this system. This technique generates a system that enables quantification of the MNI (and MNE) and allows collection and management of data illustrative of taphonomic processes, undoubtedly facilitating interpretation of numerous aspects of site use and formation.

Based on a weighted consideration of the number of identifiable fragments for each of the five cranial elements, an MNI of 21 individuals is indicated. Each craniofacial element was assessed individually, as illustrated in Fig. 13.5 and reported in Table 13.1. The highest density of "placeable" fragments per element, signified by an increasingly darker color, reflects specimen overlap, i.e., redundancy in fragments. The variation in MNE values noted for the individual elements examined reflects the fragmentation process due to thermal damage. For example, fragments from the orbital margin of the frontal are highly identifiable and placeable. However, delaminated endocranial surfaces of the frontal and fragments of the frontal plate are not locationally distinct and, as such, these fragments could rarely be specifically placed. The parietal bone was not selected for this study for these exact reasons.

Analysis of the frontal fragments indicates a maximum of 26 shared locations, or cells, within the GIS, indicating the minimum number of elements recovered from the site. Malar/zygomatic specimens support a minimum number of 17 elements. Fragments of the mandible and right maxilla indicate 21 elements, while the left maxilla suggests a minimum of 20 elements present. Although per-element MNE values range from 17 to 26, and the nature of MNI estimation suggests this should be the value presented for this collection, based upon the limited degree and the particular location of fragment redundancy, it is proposed that an MNI of 21 is most appropriate. No other skeletal element examined produced MNE values close to the lateral frontal determination of 26. All other elements fall near an MNE of 21. The marked difference in MNE values highlights a specific problem with template selection and digitizing of fragments. The lateral view of the frontal, specifically at the orbital margin, represents the entire depth of the frontal bone from nasion to the zygomatic process. The ability of the observer to accurately "place" or digitize a frontal bone fragment on either an anterior or posterior view is relatively simple. Determining accurate outlines of the same fragment in a lateral view is difficult, and we suspect that digitization errors have resulted in the high MNE estimate for the frontal bone based on the lateral view. The compression of three-dimensional distance across two-dimensional space will lead to digitizing problems for any analyst. We would argue that areas encompassing substantial depth should be identified and eliminated from the final MNE determination. Recent three-dimensional

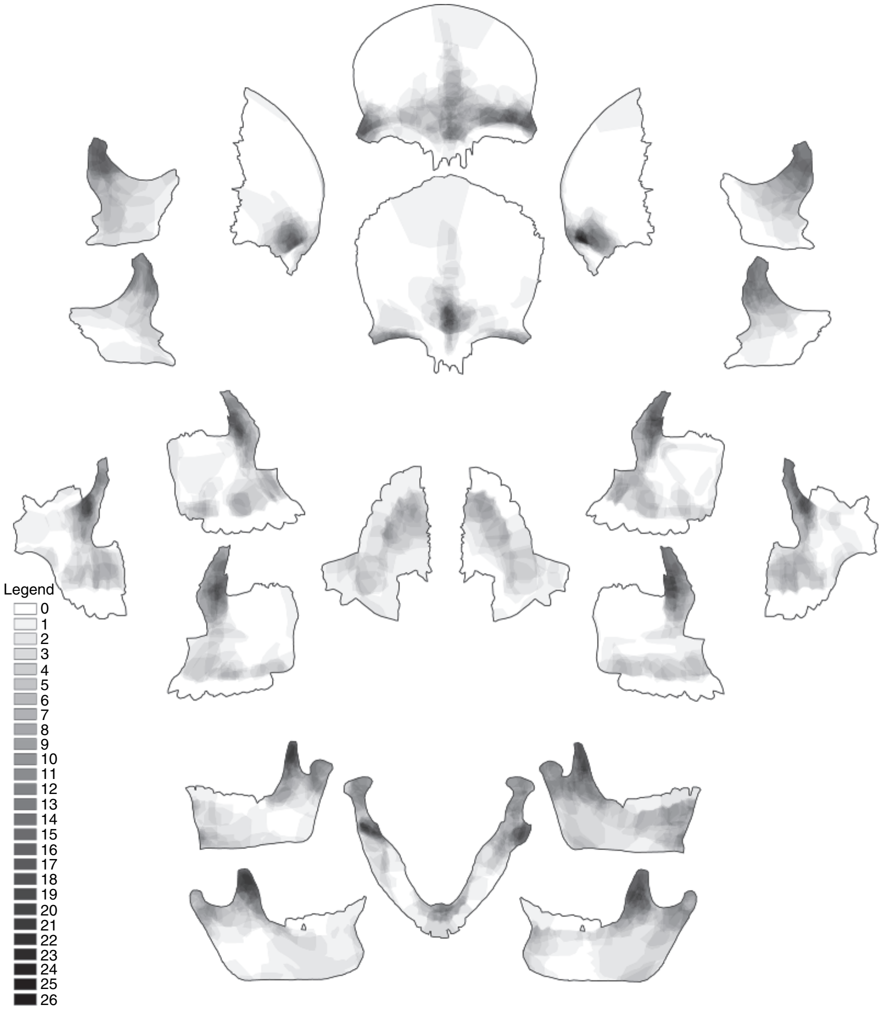

Fig. 13.5 Composite image of all cranial elements examined in this study

technologies would allow for the capture of all fragments either by computer tomography or by three-dimensional laser scanning. The scanned fragments could then be placed on a generalized three-dimensional element template. Such an approach would eliminate the problem associated with digitizing on a two-dimensional template.

Of interest is that the high representation of cranial fragments at Walker-Noe may also result from the common practice at Adena mortuary sites of including isolated crania, or trophy heads, in the burial context (Fenton 1991; Webb and Baby 1957). However, the *in situ* relationship of the skeletal material on the central platform is unknown due to a prior disturbance. No cutmarks were observed on any cranial elements, while several fragments did have surface fractures and cracking suggestive of a dry bone cremation. As such, it may be desirable to calculate an MNE from postcranial elements to compare with the cranial value. However, as previously stated, identification of highly fragmented postcranial elements is more difficult than cranial element recognition. We are currently evaluating the utility of a specific bony landmark inventory approach to deal with postcranial elements.

Conclusion

The initial cursory examination of the material from the Walker-Noe site indicated an MNI of less than 10 (Sharp et al. 2003). With application of the method described here, the value increased tremendously. Additional data concerning each fragment are collected during the laboratory analysis. Such information can be project-specific and allows the recorder to address specific research questions. In this case, we recorded surface modification and color changes related to heat. The implications for site use at Walker-Noe are directly impacted by findings from this study.

Although the GIS technique cannot be criticized for artificially inflating the values, it can, however, be faulted on several levels: (1) the extreme length of time involved in identifying and recording data for each fragment; (2) the reliance upon elements that include clearly identifiable and unique attributes; and (3) to be accurate and effective, the analysis *must* be completed exclusively by highly skilled osteologists. Although there may appear to be limitations to this image-based approach, in particular with regards to individual and population morphological variations, these concerns are manageable. Cranial and postcranial templates for infants and younger subadults should be developed separate from the adult templates. The database can be formulated to enable compilation of major skeletal parameters such as age distinctions (e.g., between adults and older subadults) or sexual dimorphism. Age and morphological variation does not impact the digitization of fragments. In effect, size and shape particulars are disregarded during the digitizing process, as all are reproduced onto the same generalized element created for the system. The element shapefiles produced in this approach reflect a standardized presence of the bone fragments, while the linked database provides fragment specific information for user queries. A key to this approach is template creation and selection. Specific element surfaces with significant depth should be reviewed and possibly eliminated from final templates to reduce the potential for MNE inflation due to fragment placement errors.

The accuracy of this method may result in higher counts for assemblages than those generated using more traditional quantification approaches. This system allows extremely precise estimation of the number of elements and individuals represented and further provides a systematic means for tracking patterns across an assemblage.

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