Riveting technology! The documentation of Mississippian metalwork

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Abstract

Copper objects, recovered from archaeological Mississippian period contexts in the Southeastern United States, form the nucleus of this paper. These objects are made from native copper that has been hammered into thin sheets, riveted and embellished with symbolic motifs. Several methods were used to capture fundamental visual data from these elaborate artifacts including: drawings; digital photography and microphotographs; X-radiography; and 3D non-contact structured light scanning. The images acquired allow the worked surface to be studied in greater detail, so that comparisons can be made between similar working patterns found over a selection of artifacts, and different working patterns found on the same artifact. Through this research it has been possible to elucidate significant aspects of sheet copper fabrication and its various applications in a Mississippian metalsmith's workshop. The documentation tools have been used to create an extensive database, which will become part of the Smithsonian Institution's National Museum of the American Indian documentation for subsequent researchers.

Résumé

Les objets en cuivre, mis à jour dans le Sud-Est des Etats-Unis sur des sites archéologiques de la période mississippienne, constituent le centre de cet article. Ces objets ont été fabriqués avec du cuivre natif qui a été martelé pour en faire de fines feuilles, rivetées et décorées de motifs symboliques. Plusieurs méthodes ont été utilisées pour reproduire les données visuelles de ces artéfacts complexes : dessins, photographies numériques et microphotographies, radiographie X et digitalisation 3D par lumière structurée sans contact. Les images obtenues permettent d'étudier plus en détail la surface, de telle sorte qu'il est possible de comparer des motifs semblables trouvés sur une sélection d'artéfacts, et des motifs différents trouvés sur un même artéfact. Cette recherche a permis d'élucider des aspects significatifs de la fabrication des feuilles de cuivre et ses différentes applications dans l'atelier d'un forgeron du Missisipi. Les outils documentaires ont servi à créer une grande base de données, qui fera partie

Keywords

3D imaging, x-radiography, digital photography, repoussé, rivets, native copper, Mississippian

Introduction

The Smithsonian Institution's National Museum of the American Indian (NMAI) houses an extensive collection of archaeological artifacts from the Mississippian period. The objects selected from the NMAI collection for this research are native copper ornaments excavated from two sites in Florida (Grant Mound and Mount Royal), three sites in Alabama (Moundville, Henry Island and Jackson), the Citico Mound in Tennessee and the Spiro Mound site in Oklahoma. These objects were selected based on the following criteria: they are fabricated from native copper, which was initially formed into thin sheets, the surfaces are embellished, and the sheets are riveted. This paper will identify and evaluate several methods used to capture visual data in order to study the objects in greater detail. Methods discussed include: drawings; digital photography and microphotographs; 3D non-contact structured light scanning; X-ray images texture mapped onto the 3D digital data from the surface scan; and 3D image manipulation software to capture precise metrological data.

Background

The cultural tradition known as the Mississippian, is generally thought to have established by 900 CE in southeastern North America. This fluorescence was manifest in a succession of towns, ceremonial centers and fortified capitals of chiefdoms and state-like societies and continued until the arrival of European explorers (Goodman 1984:2, Townsend 2004:18).

Beautiful and delicately rendered objects manufactured from copper were common in Mississippian mortuary mounds. Until the late 19th century, most

de la documentation du Musée National des Amérindiens du Smithsonian pour les futurs chercheurs.

Synopsis

Los objetos de cobre, recuperados de los contextos arqueológicos del periodo Misisipiano en el sudeste de los Estados Unidos, conforman el núcleo de este artículo. Estos objetos están hechos de cobre en estado nativo, forjado en láminas, remachado y adornado con motivos simbólicos. Se emplearon varios métodos para obtener documentación visual sobre estos objetos: dibujos, fotografía digital y microfotografías, rayos X y escaneado 3D sin contacto de luz estructurada. Estas imágenes obtenidas permiten estudiar con más detalle la superficie trabajada, de modo que se pueden realizar comparaciones entre modelos de trabajo símiles, encontrados a partir de una selección de objetos, y modelos de trabajo diferentes, hallados en el mismo objeto. Gracias a esta investigación, ha sido posible aclarar aspectos significativos de la fabricación de las láminas de cobre y de sus diversas aplicaciones en un taller de forja del periodo Misisipiano. Con esta documentación se ha creado una extensa base de datos, que formará parte del Museo Nacional de los Indios de América de la Institución Smithsonian, y que podrá ser consultada por futuros investigadores.

archaeologists assumed that many of these finely crafted copper objects found in archaeological contexts were fabricated of European copper by European craftsmen, and subsequently traded to Native Americans by early explorers from Spain, England and France. The general consensus was that, though much of the creative imagery appeared of Native American origin, the large thin sheets of metal from which the work was created must have been fabricated by European rolling mills or stamping machines (Cushing 1894). In addition, no significant evidence of smelting, nor the requisite iron or steel tools thought necessary to manufacture sheet copper objects could be found in the archaeological record (Goad 1978:46).

Recent research indicates these Mississippian craftsmen accumulated significant technical expertise throughout the Mississippian period (Schroeder 1968:162, Childs 1992). Indigenous metalworkers alternately hammered, annealed and hammer welded native copper to make sheet (Schroeder 1968, Smith 1968, Vernon 1985, Vernon 1990), which they then ground, riveted, perforated, bent, and embellished with embossed designs or figurative elements using repoussé and chasing techniques to create bas-relief surfaces of astonishing complexity (Vernon 1985, Vernon 1990, Martin 1999:63).

In the United States, native copper exists mainly in three locations: in the southwest, in the northeast around the Great Lakes region, and in the southeast in the Appalachian Mountains. Trace element analysis indicates that of these three areas, the two principal sources of copper for Mississippian craftsmen were the Great Lakes region and the Appalachian Mountain region (Rickard 1934:267, Hurst 1956, Goad 1978:48).

Copper in its native form is malleable, and this physical characteristic, along with an abundant, accessible supply of the raw material, meant that Mississippian craftsmen did not have to develop smelting, casting, and alloying to create the extant pieces. No evidence of these procedures has yet been found in the archaeological record (Smith 1968:242). Mechanical joins, such as rivets, were the principal means used to attach pieces of metal together. Visual data, which illuminates the manufacturing and repair sequences applied by Mississippian metalsmiths, can broaden our understanding of the technology used to join sheet metal to create and maintain ornamental sheet copper repoussé artifacts.

Documentation

The importance of documentation to any conservation effort is well understood, and the documentary tools available to the conservator are increasing in number and sophistication. The objective of this paper is to explore a particular combination of non-destructive methods for recording visual information about the selected objects, information that is presently being used to create a visual database for future research. The visual documentation of Mississippian sheet copper artifacts from the NMAI collection is one component of a larger research project investigating the use of rivets in these ornaments as a means of understanding fabrication sequences (Cullen Cobb *et al* in press). Due to the limited space available, this paper will focus on the information that can be gathered using a selection of documentation methods and will not attempt an in-depth description of the workings of each visual tool or the significance of the metalsmithing information that the documentation tools reveal.

The following documentation methods were used in this study:

- drawings
- digital photographs
- x-radiography
- 3D imaging
- digital image manipulation.

In order to adequately cover the documentation methods only three objects from the study group will be highlighted in this paper. All three pieces, currently in the collection of the NMAI, are made from native copper that has been hammered and hammer welded into sheet, pierced, embellished and riveted. These objects were selected to demonstrate, through the application of the documentation methods discussed in this paper, construction methods that are not as easily elucidated in other study pieces.

Drawing

Illustrations of the objects were created by the author, by rendering objects in pencil on paper, and a select number were recreated in ink on polyester film. Following typical archaeological drawing conventions, lines and dots were used to outline the object, including any large interior pierced areas, or an area of loss. Prominent features on the object were graphed onto the drawing by making numerous measurements on the object and transferring the locations onto the drawing. In this manner an overall outline of each piece was initially created, which was later shaded to emphasize raised or chased patterns. The entire process was repeated when creating the drawing of the reverse of the objects. If an ink drawing was subsequently created, the polyester film was laid over the pencil drawing and the image was traced in ink. The front and back drawings for each piece took between two and five hours to complete, depending on the size of the object and complexity of surface detail.

Digital photography

Photography was completed at the NMAI conservation laboratory. A Nikon D200 DSLR Camera, and Nikon Capture 4.4 and Adobe Photoshop CS2 software were used to capture digital data in RAW mode and convert the data to an 18 MB TIF file. The objects were photographed on plate glass, elevated two inches above a gray background fabric, with a single light source set at approximately 45 degrees from the photographing plane. Where further clarification was warranted, magnified images of surface embellishments, tool marks, rivet heads and pierced holes were taken with a digital camera mounted to an extension tube on a Leica MZ8 stereomicroscope. The photography of each piece, including images taken under magnification, took less than one hour to complete.

X-radiography

At the Smithsonian Institution's Museum Conservation Institute (MCI), adjacent to the NMAI Cultural Resources Center, Senior Paintings Conservator Roland Cunningham used a Philips MG 101 Constant Potential X-Ray Unit to capture X-radiographic images of the objects. Kodak M-100 film was used to record the images. Exposure time and working distance varied with each object.

The X-radiography of each object took less than one hour to complete. A digital reproduction of the X-radiographic film was created by NMAI staff photographer Ernest Amoroso. He photographed the X-ray film on a light box, captured the digital data in RAW mode and converted the data to a 20MB TIF file. Each image took approximately ¼ hour to complete, including set-up.

3D imaging

A 3D non-contact structured light scanner was used to record high-resolution 3D images of the surfaces of the artifacts. Vicky Karas and Melvin Wachowiak from the MCI captured the 3D images. The scanner, a Breuckmann triTos™ (GmbH), was used to scan six copper artifacts. The key components of the triTos™ scanner are the controller, sensor bar (5 cm long), projector and camera. The sensor bar, projector and camera were mounted on a tripod. The camera lenses and the sensor bar on the triTos™ are interchangeable to give varying fields of view. The triTos™ system software (Optocat 2006.2) was run on a Hewlett-Packard laptop with 4 GB of RAM.

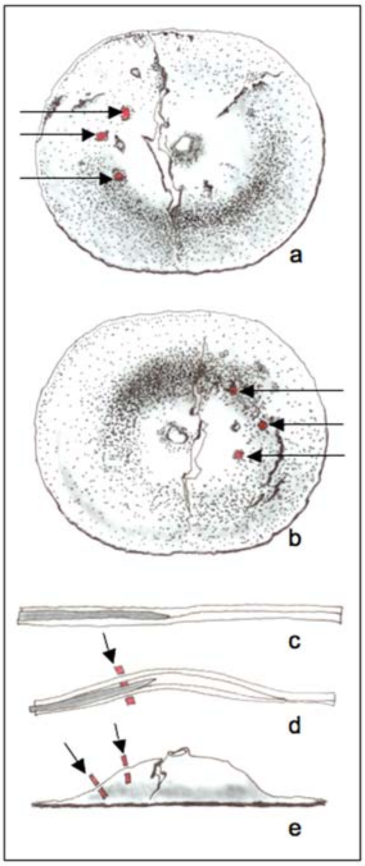

Figure 1. Illustration of embossed copper sheet ornament, Florida, Putnam Co., Mount Royal, H. 5 cm, arrows indicate rivet locations; (a) front; (b) back; (c) possible cross section of laminated sheet; (d) possible cross section with delaminating sheet stabilized with rivet; (e) side view with rivet positions identified; Cat. no. 17/0129

In brief, the scanner projects a sequence of organized patterns of structured light on the scan subject as it is simultaneously photographed using a digital camera that is specially aligned with the projector. The photographic images show the distortion of the projected light pattern as it strikes the scan subject. Associated software processes the projected light pattern distortion and color information disclosed by the digital photographs and generates point cloud data. Position (XYZ) and color values (RGB) are recorded together so that the color information is registered exactly with its corresponding 3D point.

The raw data produced by the scanner was processed by Vicky Karas and imported into the 3D graphic software in a binary file format, used to store 3D data. 3D graphic software called Rapid Form™ (2006), from INUS Technology, was then used to fill any holes in the digital data files.

It took approximately six hours to scan and process the raw data for each piece.

Results of documentation methods

Drawing

The first intensive study of the pieces occurred at the drawing stage. The illustrations were intended to be a record of visual information, and a means of noting and capturing subtle construction and decorative elements, which would be followed up with further study using the methods mentioned above. As such they provided a stimulating first look at the types of features visible in these remarkable objects, and an exciting preview of the clarification that the study of a group of objects like these might provide regarding Mississippian metalsmithing techniques.

For example, during the drawing of one object, rivet heads that appeared to have been hammered flush with both top and reverse sides of the object were noted. The piece is an oval domed sheet copper ornament (NMAI 17/0129), excavated at Mount Royal in Putnam County, Florida by Clarence B Moore in 1894 (Figure 1). This piece was acquired by the museum in 1930. An area of delamination, overlooked during the initial examination, also became apparent. It was at the drawing stage of the documentation process that initial questions were formulated concerning the role rivets may have played in solving fabrication problems in the absence of other pyrotechnological solutions.

Digital photography

Visual documentation using digital photography facilitated the intensive examination of the objects. Enlargements of digital data, viewed on a color monitor, increased the opportunities for selective study of areas of interest that were difficult to clarify in the physical object. The enlarged images of key features, including those captured using a stereomicroscope, provided an extensive suite of visual information, and raised several more questions regarding the possible problems that a Mississippian metalsmith's fabrication choices may have been addressing.

For example, the following are images of a copper repoussé bi-lobed arrow headdress with a bone pin (NMAI 15/0868), excavated at Citico Mound in Hamilton County, Tennessee (Figure 2a). It was part of the W E Meyer collection and was acquired by the museum in 1905. The images captured using a stereomicroscope helped to clarify the physical appearance of rivets in the headdress (Figure 2a). The magnified image of rivets from the central spine of the headdress, in Figure 2(c), have a higher profile and are visually more prominent than the rivets next to the bone pin, in Figure 2(b), which appear flush with the surface of the object, leading one to speculate: are the rivet heads in Figure 2(c) larger because they are intended to be visually obvious; does their size have something to do with their structural function; or do they appear different because they were applied by a different craftsman with different technical skills and sensibilities?

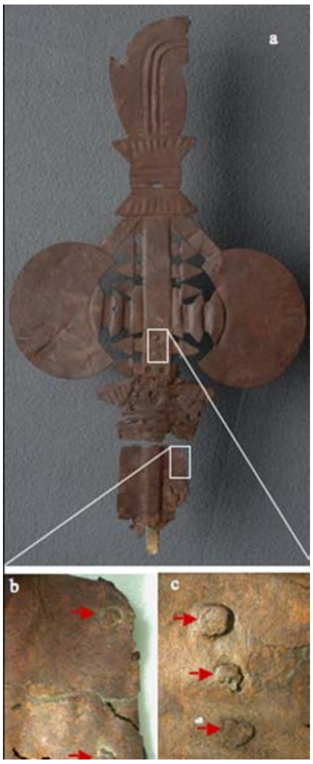

Figure 2. Copper repoussé bi-lobed arrow headdress, Tennessee, Hamilton Co., Citico Mound, H. 26.6 cm; (a) digital photograph; (b) close up of rivets with large domed, splayed heads; (c) close up of rivets flush with metal surface; Cat. no. 15/0868

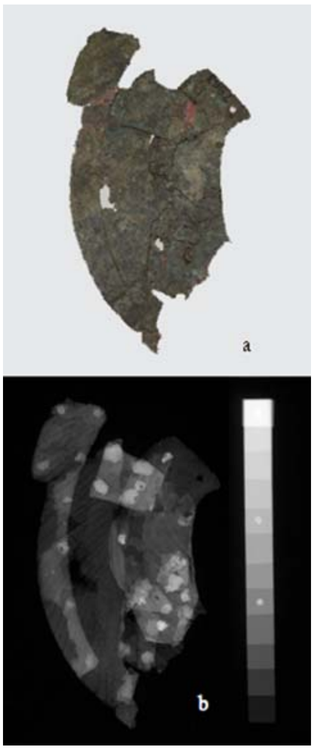

Figure 3. Copper ornament fragment, Alabama, Jackson Co., H. 6 cm; (a) Digital photograph; (b) X-radiograph; Cat. no. 00/7963

X-radiography

X-radiography clarified the specifics of construction features in each of the objects. The digital format of the X-ray film made it possible to enlarge, manipulate and enhance the contrast of the X-radiograph, making visible information that was less accessible to the human eye in the 1:1 scale of the X-radiograph film. Figure 3a is a fragmented ornament of sheet copper (NMAI 00/7963) excavated in Jackson County, Alabama. It was part of the Joseph Jones collection and was acquired by the museum in 1906. Figure 3b is an X-radiography of the fragmented ornament. The bar to the right of the image is a copper step gauge created by the author as a thickness or density scale held together by coiled rivets that appear as lighter round areas on the gauge. The square at the bottom of the gauge is 0.1 mm thick, the second to last square at the top of the gauge is 1.1 mm thick, and the top most square is 1.4 mm thick. Using the step gauge as a guide to studying the areas of density on the X-ray two significant features became obvious: the numerous patches of metal incorporated into the piece, which appear as lighter or denser areas in the X-ray image; and the numerous rivets that hold these patches in place, which appear as brighter roundish areas on the patches. The number of patches and rivets used to assemble this piece has led to considerable speculation; are the patches indicative of a limited supply of raw material; do they indicate a preference for a specific metal with specific properties; was the object expanded in size at some point during its use, incorporating metal from other sources; or was it subject to considerable wear and continual refurbishment? Even the size of the rivets changes from one area to the next leading to questions regarding the fabrication sequence and the possible involvement of more than one craftsman in the restoration or repair process over the span of time that the object was used.

Manipulating x-radiograph images

The TIF file of the X-ray film was imported into a public domain image processing and analysis program, called *Image/J*, created at the *National Institutes of Health* and available on their website. *Image/J* provides many standard image processing functions including the ability to make planar area measurements of the overall objects and features such as rivets and patches on the objects. This method of calculating area does not take into consideration the undulating surface of the worked sheet metal, however, given the low profile of most of the surface embellishments the difference was modest and the area values were still considered useful. The surface area measurements and the measurements of each of the above mentioned features were tabulated. These numbers provided preliminary information that was used to formulate questions regarding the prevalence of rivets and patches and the possible correlation to use, wear, or importance.

3D imaging manipulation

The 3D digital data of the artifacts were viewed and manipulated in virtual space using two freeware software packages, *Rapidform Basis* and *InnovMetric Image View*. Various features of the software allowed the lighting angles and surface color of the objects to be manipulated. Raking light was selected in order to see fine surface details, and the surface color was removed so that surface details were easier to interpret.

Digital data captured using non-contact 3D scanning provided a way to virtually examine and document the fragile worked surface and details of construction on the copper artifacts without extensive physical manipulation of the object. The digital images of the artifacts provided accurate, high resolution archival records, which can be used in any number of applications, including interactive web exhibits, virtual study and physical replication of the surfaces in any material and at any scale. None of the restrictions of handling a fragile object come into play.

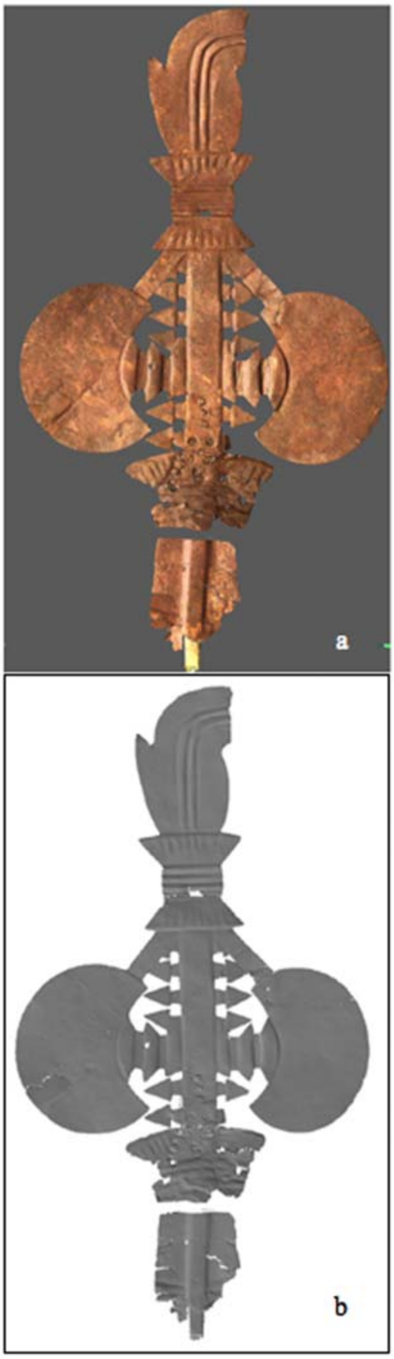

Figure 4. Copper repoussé bi-lobed arrow headdress, Tennessee, Hamilton Co., Citico Mound, W. 18.4 cm; (a) 3D scanned image of front; (b) 3D scanned image of front with color removed; Cat. no. 15/0868

The extreme delicacy of all the sheet copper objects in this study, which are thinner than 0.1 mm in places, meant that it was not possible to scan around the edge of the pieces. There simply was not enough surface area on the edge of the objects for the scanner to capture. Therefore the virtual images were only visible as one-sided sheets without corresponding details on the reverse side. The images were manipulated in virtual space and could be viewed on edge to clarify surface morphology. Nonetheless, for each piece the detail on the front and back had to be viewed separately. This limitation also eliminated the opportunity to create 3D replicas of the objects. However, it is possible to make a negative replica of each surface that can be used to study surface morphology such as tool marks, rivets and decorative surface embellishments and to carve supports for some of the more delicate pieces.

Figure 4a is a 3D image of the bi-lobed arrow headdress (NMAI 15/0868). Figurative details in the headdress were somewhat obscured by the mottled color of the metal. However when the *Rapidform Basis* software was used to remove the surface color and enhance contrast, surface details were more clearly resolved and easier to interpret as can be seen in Figure 4b.

In contrast with the approximate area measurements collected using the *Image/J* software, the precise metrological data captured by 3D scanning made quantifiable area and point-to-point measurements possible using tools in the *Rapidform Basis* software. The measurements of similar features within the object and among the group of study objects, such as tool marks, the depth or height of a particular chased or embossed feature, the size of a pierced or perforated hole, or the overall area of a rivet head could be recorded and compared. This information was used to evaluate fabrication methods, and broadened the scope of questions that could be posed from the data collected. For example it was possible to view, study and measure the profile of the bas-relief surfaces of the objects and pose questions regarding the types of tools needed to manipulate the material, and how these surfaces may have been created or controlled during fabrication. This information was used to compare and contrast attributes within an object and across the study group.

Texture mapping x-radiographic images onto the 3D image

Melvin Wachowiak suggested the additional exploration of texture mapping TIF files of the X-radiograph film onto the 3D graphic data during processing of the digital data (Figure 5). Using the *Rapidform Basis* program to manipulate the image it was possible to study how the surface morphology, visible in the 3D image (Figure 5a), correlates with the internal structures apparent in the X-radiographic film (Figure 5b). The X-radiographic image can be manipulated in virtual space and enlarged as needed. Viewing the data with this technique substantially enriched the images, and the opportunities for investigation and documentation.

Discussion

The early steps taken to draw the objects provided a close initial study of the objects and generated several questions that helped to guide the acquisition of documentation images.

Photography, another traditional and fundamental starting point for object documentation yielded useful enhanced details of the objects, through magnification with a stereomicroscope or by zooming into a digital image on a computer screen, and generated more questions regarding metalsmithing problem solving strategies. The digital files made from the X-radiographic film also captured detail about the shape and size of rivets, and often illuminated the locations of rivets that were not otherwise apparent.

The precision with which information was captured using 3D scanning technology made the tool useful on many levels which have a significant impact on conservation practices, principal among them being that fragile objects can be virtually manipulated and closely studied without being

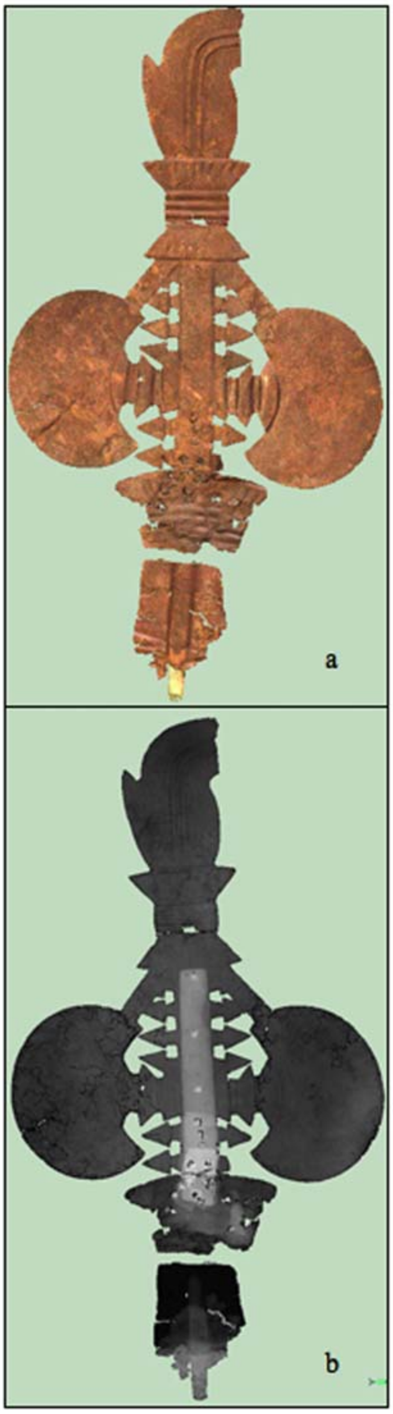

Figure 5. Copper repoussé bi-lobed arrow headdress, Tennessee, Hamilton Co., Citico Mound, W 18.4 cm; (a) 3D scanned image of front; (b) x-radiograph texture mapped onto 3D scanned image; Cat. no. 15/0868

handled. The freeware software provides sufficient tools to manipulate the object and acquire a satisfying amount of information. The only drawback with this technology is that objects with thin profiles, such as those in the current study, do not offer enough surface area for the technology to capture sufficient detail to enable the information to be stitched together into a digital 3D object. However this did not inhibit the study of the object or detract from the usefulness of the data. Extending this 3D imagery by texture mapping digital files of x-radiographic film enhanced the opportunities for understanding fabrication methods well beyond what can be captured from study of the physical object alone.

Conclusion

The four documentation techniques, and corresponding tools discussed in this paper, used individually and in various combinations, can provide the researcher with data of considerable depth regarding fabricated sheet copper objects of the Mississippian type. The use of these tools in combination revealed that numerous metalsmithing techniques were augmented by complex methods of attachment and repair involving the use of rivets. The documentation tools have been used to create an extensive database, which will become part of the NMAI documentation for subsequent researchers.

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