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Technical examination of a bone ornament ensemble from the Himalayan region with comments on handling, treatment, storage, and display

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in Conservation of Archaeological and Ethnographic Materials

by

Ayesha Carol Victoria Fuentes

2014
ABSTRACT OF THE THESIS

Technical examination of a bone ornament ensemble from the Himalayan region with comments on handling, treatment, storage, and display

by

Ayesha Carol Victoria Fuentes

Master of Arts in Conservation of Archaeological and Ethnographic Materials

University of California, Los Angeles, 2014

Professor Ioanna Kakoulli, Chair

This thesis is a technical examination of a bone ornament ensemble from the Himalayan region, currently in the collection of the Fowler Museum at UCLA. This ensemble is used in various practices and performances associated with Vajrayana (Tibetan) Buddhism. The materials used in the construction of this object are examined through both noninvasive and minimally-invasive methods of scientific analysis. A comparative survey on the treatment, handling, storage, and display of similar bone ornaments at museum collections is presented. This study finds that this ritual object is a composite of human bone, bast fiber yarns, pigments, and deterioration products. The thesis includes treatment of the object through minimum intervention, mechanical stabilization, and the development of guidelines for storage, handling, and display.
The thesis of Ayesha Carol Victoria Fuentes is approved.

David Scott

Robert Brown

John Hirx

Ioanna Kakoulli, Committee Chair

University of California, Los Angeles

2014
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1. Introduction

This project examines an assemblage of bone ornaments from the Himalayan region, originally used for ritual and performative purposes, now in the collection of the Fowler Museum at the University of California, Los Angeles (Fowler # X69.300 A-J) (Figure 1.1). Collection and registration information reports that the object was purchased from a Tibetan vendor in Kathmandu though its origins may be Newari; it was collected by the museum in 1969. The assemblage or ensemble includes an apron, crown, arm band, and other assorted similarly constructed ornaments with unidentified function meant to be worn during public performances and private devotional exercises. This type of regalia is traditionally made from human bone, carved into beads and decorative plaques and joined with cordage (strong, multi-ply yarns). Other materials present here include metal bangles and numerous colored deposits or residues on the surface of the object substrate.

This research paper (submitted in partial fulfillment of the requirements for the degree of Master of Arts at the UCLA/Getty MA Program in the Conservation of Archaeological and Ethnographic Materials) investigates the bone ornament ensemble through noninvasive and minimally-invasive methods of analysis for the characterization of materials used in its construction. The following sections also discuss how
materials have been applied in the production of the object: Section 2 reviews literature that informs the objects’ original purpose and function; Section 3 reviews the methodology and findings of the analysis; Section 4 articulates how these results relate to recorded information on material cultural traditions and how the current condition of the object might be related to its historic use; Section 5 presents the results of a survey on handling and treatment of similar objects in museum collections; Section 6 presents the treatment of this object with an emphasis on minimizing handling and physical stabilization.

2. Literature review

‘Bone ornaments’ are a type of regalia consisting of bone girdle or apron, crown, necklace, arm bands, and ear ornaments, not all of which are represented by this assemblage.¹ This regalia, in addition to the thigh-bone trumpet, skull cup, and damaru (two-headed drum), is part of a specific class of ritual objects made from human bone and associated with esoteric practices of Vajrayana or Tibetan Buddhism, as well as public performances of healing or divination in the Himalayan region (Figure 2.1). Scholarship on ritual objects and ornaments made from human bone can be divided broadly into three categories: art historical, ethno-historical, and the religious texts of esoteric Buddhism that address

¹ ‘Bone ornament’ regalia may also include a string of corpse hair, though this is typically reserved for male deities and/or ascetic practitioners.
Bone ornaments are most often used in the context of worship and practices dedicated to wrathful forms of deities. Texts like the *Cakrasamvara Tantra*, for example, relate detailed information about the liturgical use of these objects during devotional practices. However, the great number of variations for these activities make it difficult to relate the textual precedent to practical use or its effect on the objects themselves. Art historical and ethno-historical sources, however, provide some insight into the material concerns of conservation and collections stewardship.

North American and European art historical scholarship on the material culture of Tibetan Buddhism tends to focus on forms most familiar to fine arts audiences: *thangka* (paintings) and sculpture in metal or stone. Tucci (1967) writes extensively of aspects of daily and religious life in Tibet but isolates his discussion of artistic practice to *thangka*, wall paintings, sculpture, and architecture. More recent scholars like Huntington have addressed bone ornaments insofar as they relate to painted or cast images of deities and a 2004 publication (with Bangdel) discusses the arts and material culture of esoteric Buddhism in terms of its endemic practice, religious significance, and categories of use. He connects a bone girdle — or apron, as it will be referred to in this paper — to practices associated with Cakrasamvara and his female consort, Vajravarahi, two deities with wrathful forms that incorporate bone ornaments. Beer (1999) describes bone ornaments based on their iconographic significance in Tibetan arts, where they are often rendered in depictions of certain deities (Figure 2.2). Beer’s exceptionally informative work describes specific iconographic features (long-established based on archaeometric principles) but also relates aspects of the religious history behind the incorporation of these motifs. However, the representation of

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2 See Gray’s annotated translation of the *Cakrasamvara Tantra* (2007) or Edou’s *Machig Labron and the foundations of Chöd* (1996) for details of practical, liturgical, or historic religious use during specific rites or teachings of esoteric Buddhism in the Himalayan region.
bone ornaments in paintings and sculpture is distinct from their existence as regalia. The author’s own unpublished master’s thesis attempts to relate the intangible representation in both art and religious history to the material object through the example of the skull cup, a related topic (Fuentes [2011]).

Ethno-historical literature has been somewhat more informative about aspects of material culture, though much of what was written in the early to mid twentieth century by scholars — who were commendable field researchers — is misleading. Scholars like Rock (1959) and Nebesky-Wojkowitz (1957) wrote of the association of bone ornaments with ‘demons’ and ‘exorcism’ which misrepresents their ritual function in practices associated with wrathful deities and public performances of healing rites. Laufer (1923) overemphasizes the use of human bones in Tibet as a type of magic and simplifies the many and variable religious teachings in which these objects are applied. Many scholars in ethnography and anthropology have presented what Boivin (2009) identifies as a preference to interpret material culture as a ‘system of symbols’ meant to reinforce an intangible reality, without understanding the technology and construction of objects as informational resources for that culture. From a conservation

3 Interestingly, there is fairly little research on bone ornaments as part of costume and textile traditions in the region. Handa (1998), for example, presents the costume tradition in the Western Himalayas without mentioning bone ornaments, though other types of accessories are discussed. It may be suggested that their religious connotations have exempted them from such studies.
perspective, this is manifest in comparatively little field-based scholarship on the technology of these objects or circumstances of their use.

More recently, however, Loseries-Leick (2008) has produced a comprehensive resource on the use of human bone in the material culture of esoteric Buddhism as it is practiced in Tibet and Tibetan exile. Her work describes the contemporary and historical use, production, and religious context of bone ornaments as both scholar and practitioner, without relating information on specific ritual functions or significances, which might violate her role as a student of these esoteric practices. She also describes details of the objects’ constructions; for example, the application of motifs and arrangement of designs is often the prerogative of craftsman commissioned to create the object. Traditional craftsmen specialize in carving bone ornaments, developing and maintaining techniques that are passed to apprentices. Loseries-Leick also presents the technology used to create bone ornaments, including both traditional hand tools and power drills. Designs may or may not be drawn onto the surface before carving, depending on the specific craftsman. The preparation and procurement of raw materials are also discussed where, historically, bones were gathered from human bodies deposed at sky-burial grounds. Historically, these materials have been accessible in Tibet, where sky-burial was widely practiced, partially because of hard, frozen ground and lack of firewood for cremation. However, Losieries-Leick writes, as many Tibetans are now living in exile in India and other areas, there is a relative scarcity. Common substitutions include yak and water buffalo bone; ivory and tortoise shell are also known to have been used. Loseries-Leick presents a broad view of ornaments and ritual objects made from human bone including spiritual, cultural, and technical concerns.

However, the type of early ethno-historical scholarship discussed here is more often incorporated into the collection information for these types of objects, which is likely related to the historical period in which many bone ornaments were collected. Historical museum publications that present bone objects as

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4 Sky-burial is a practice historically used in Tibet to dispose of dead bodies by having them cut into pieces and fed to birds and other wild animals by specially trained laity and religious representatives.
part of North American or European collections are generally from the early to mid twentieth century and often fail to adequately interpret the multivalent character of Himalayan ritual objects. Braunholtz (1930), for example, writes for the British Museum of a “necromancer’s” bone apron. An anonymously written selection for the American Museum of Natural History from 1936 refers to ‘sorcerers’ and the use of bones from criminals as raw material. Unfortunately it seems that many of these historical publications still hold sway in the curation of bone ornaments, most often found in natural history collections where they are interpreted as ethnographic objects with fixed cultural significance. Harris (2012) has recently called for a museological investigation, presenting Tibet and the material culture of esoteric Buddhism in the Himalayan region as contemporary and dynamic.

Finally, there is a dearth of conservation literature on ritual objects from the Himalayan region, though there is a significant amount of scholarship on the materials, techniques, and treatment of thangka (Huntington 1970; Jackson and Jackson 1984; Cotte 2011). Scholars like Hatt (1980) have presented excellent technical information about metal sculpture. Studies of other types of painted surfaces (such as shrines and furniture) have also been conducted (Chao [2011]). Shaftel (2013) writes about the special preventive needs that ritual objects may need in their cultural settings as well as the need for sensitivity when treating works associated with esoteric traditions (Shaftel 1986). The handling of human remains has also been a topic of concern for conservators (McGowan and Roche 1996; Human remains and museum practice, eds. K. Goodnow and J. Lohman 2006), though this is often in the context of archaeological or anthropological specimens where the concerns of ancestors or Native American sovereignty are a priority. Literature addressing the treatment of human bone is generally concerned with adhesives or consolidants for bone in archaeological contexts (Johnson 1994; Storch 2003). It can be said that there is a need for published examples of conservators working with ritual objects from esoteric Buddhist traditions as well as human remains, where the function of the bone is as raw material for cultural properties and not a mortuary
object or specimen. At the same time, Loseries-Leick (2008) writes that human remains, in the tradition of esoteric Buddhism, are inherently powerful; this is the reason for their utilization in ritual objects and should be remembered by those who come in contact with them, whatever the context.

3. Analytical methodology and results

3.1 Description

A variety of noninvasive and minimally-invasive methods were used to document and characterize the materials of this assemblage and its construction. Forensic and analytical digital photography were used to record the condition as well as macro- and microscopic features of the object’s surface including morphology, construction, technique, and deterioration phenomena. The elemental composition of the surface (and subsurface) was characterized using x-ray fluorescence (XRF) spectroscopy. In addition to generating valuable data, noninvasive methods were used to guide decision-making about the use of minimally invasive methods and to devise a sampling strategy. A more precise chemical and physical characterization of the materials and surface features of this object was undertaken through micro-sampling and analysis, using polarized light microscopy (PLM), x-ray diffraction (XRD), micro-chemical tests (MCT), and Fourier-transform infrared spectroscopy (FTIR).

3.2 Noninvasive methods of analysis

3.2.1 Forensic and analytical digital photography

Forensic or analytical photography was used to document and examine the surface characteristics of the object. All digital images were captured with a Nikon D70 Digital SLR camera and Camera Control Pro 2 software, processed with Adobe Bridge CS5.1 software. The following three configurations were used in combination with this camera and software, except where otherwise noted:
Photomicrography: Digital photomicrographs were taken with a Meiji Techno adapter on a Meiji EMZ-TK binocular microscope.

Forensic photography: A SPEX Forensics Mini-Crimescope 400 was used as an excitation source. The Mini-Crimescope is equipped with a 400W metal halide lamp and filter wheels enabling selection of specific broadband excitation wavelengths, given below in Table 3.1. Image capture for this technique used a series of filters on the camera lens to capture reflectance and fluorescence from the object. These filters are given below in Table 3.2 with their relevant information, including transmission range (in nm). As an experiment to record a range of reflectance (capture range: UV-NIR) and fluorescence (capture range: visible-NIR) scenarios at various wavelength bands of both excitation and emission, each broadband excitation wavelength was used in combination with each type of filter for image capture (Table 3.2); only the most informative images from this process will be evaluated.

Table 3.1 Excitation bandwidth ranges used for both reflectance and fluorescence-type forensic imaging

<table>
<thead>
<tr>
<th>Center wavelength (±8nm)</th>
<th>Bandwidth (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>350 (ultraviolet)</td>
<td>80 (310-390)</td>
</tr>
<tr>
<td>415</td>
<td>45</td>
</tr>
<tr>
<td>445</td>
<td>40</td>
</tr>
<tr>
<td>455</td>
<td>70</td>
</tr>
<tr>
<td>475</td>
<td>45</td>
</tr>
<tr>
<td>495</td>
<td>45</td>
</tr>
<tr>
<td>515</td>
<td>45</td>
</tr>
<tr>
<td>535</td>
<td>45</td>
</tr>
<tr>
<td>555</td>
<td>30</td>
</tr>
<tr>
<td>575 (short pass)</td>
<td>175 (400-575 nm)</td>
</tr>
<tr>
<td>600</td>
<td>50</td>
</tr>
</tbody>
</table>

Analytical photography: Photographs were taken using directed white light, provided by the Mini-Crimescope or a tungsten Interfit Halogen 100 lamp.
While the entire object was examined at different wavelength bandwidths for both excitation and capture, only the crown (Fowler # X69.300 B) was photographed with each excitation source and capture/filter set-up. This was due to considerations for the overall safety of the object, based on its fragile nature, and the crown’s complex and intriguing obverse surface. Ultraviolet (UV) reflectance, UV-induced visible fluorescence, and visible-induced infrared (IR) luminescence imaging were all conducted as part of this examination using the settings described above.

### 3.2.2 3-D reconstructed digital micrography

Additional photomicrography of the physical character and morphological features on the surfaces of a few sections of the object were taken on a Keyence VHX-1000 series digital microscope at the UCLA Department of Materials Science and Engineering.

<table>
<thead>
<tr>
<th>Filter set-up</th>
<th>Filter range (in nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peca #916</td>
<td>400-725 (visible range)</td>
</tr>
<tr>
<td>XNite330</td>
<td>330: 330 (peak)</td>
</tr>
<tr>
<td>XNiteBP1</td>
<td>BP1: 330-630, 930-1400</td>
</tr>
<tr>
<td>Used with modified Nikon D90 digital SLR with IR/UV filters removed</td>
<td></td>
</tr>
<tr>
<td>Peca #912</td>
<td>700-1100</td>
</tr>
<tr>
<td>Used with modified Nikon D90 digital SLR with IR/UV filters removed</td>
<td></td>
</tr>
<tr>
<td>50094VS Yellow viewing shield (Spex Forensics)</td>
<td>500+</td>
</tr>
<tr>
<td>50091VS Orange viewing shield (Spex Forensics)</td>
<td>550+</td>
</tr>
<tr>
<td>50089VS Red viewing shield (Spex Forensics)</td>
<td>600+</td>
</tr>
</tbody>
</table>

Table 3.2 Emission capture filters with their transmission ranges

While the entire object was examined at different wavelength bandwidths for both excitation and capture, only the crown (Fowler # X69.300 B) was photographed with each excitation source and capture/filter set-up. This was due to considerations for the overall safety of the object, based on its fragile nature, and the crown’s complex and intriguing obverse surface. Ultraviolet (UV) reflectance, UV-induced visible fluorescence, and visible-induced infrared (IR) luminescence imaging were all conducted as part of this examination using the settings described above.

### 3.2.2 3-D reconstructed digital micrography

Additional photomicrography of the physical character and morphological features on the surfaces of a few sections of the object were taken on a Keyence VHX-1000 series digital microscope at the UCLA Department of Materials Science and Engineering.
3.2.3 X-ray fluorescence spectroscopy (XRF)

Elemental composition spectra were taken with a Bruker Tracer III-IV+ hand-held X-ray fluorescence (XRF) system to characterize surface and bulk materials. Spectra were processed using S1PXRF software. Spots were all run at one or both of two settings, seen below in Table 3.3.

<table>
<thead>
<tr>
<th>Setting 1: general</th>
<th>No filter, vacuum, 40 kV, 1.9 µA, 180 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting 2: heavy metal sensitive</td>
<td>Cu/Ti/Al Filter, no vacuum, 40 kV, 20 µA, 180 sec</td>
</tr>
</tbody>
</table>

Table 3.3 Settings for spectra taken with Bruker Tracer III-IV+ portable XRF

3.3 Minimally-invasive methods of analysis

Micro-samples (< 5 mg) of original material were collected from the object and its surface deposits and analyzed (see Appendix H). Fiber samples were taken with steel hand tools and mounted in deionized water on a glass slide with a cover. Dispersion samples were mounted on a glass slide in Cargille Meltmount (refractive index = 1.662) and then covered with a glass cover slip. Samples were otherwise taken with steel hand tools and a synthetic bristle brush and sealed in aluminum foil in a polyethylene sample vial.

3.3.1 Polarized light microscopy (PLM)

An Olympus BX51 polarized light microscope was used for the examination of organic and inorganic materials. Images were captured using a Martin Microscope Company adapter, the Nikon D90 camera and same software as above. Fiber samples were examined for diagnostic morphological and optical features in transmitted plane and crossed polarized light. These were compared to samples from a reference set by Cargille, Set. No. CF-7, Commercial Fibers. Dispersion samples were used to similarly investigate the inorganic phases of pigments and surface materials.
3.3.2 Micro-chemical testing (MCT) and micro-solubility testing

Micro-chemical tests were performed to characterize surface deposits and deterioration products. These were performed on a glass slide under magnification with the exception of the amine test for proteins, which was carried out in a glass test tube. A glass alcohol lamp was used for heat. The reagents for individual tests are given in Table 3.4. Micro-solubility testing was conducted with small, dry samples of material on glass slides to which drops of deionized water, ethanol, acetone, and/or mineral spirits were introduced. The solvent was evaporated under a heat lamp and then the slide was examined for residues.

All test results were evaluated against reference materials of known chemical composition.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Reagents</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Biuret test</td>
<td>2% (w/v) (aq) CuSO4, 1.2 M NaOH (aq)</td>
<td>(Odegaard, Carroll, and Zimmt [2000] 2005)</td>
</tr>
<tr>
<td>Protein Amino groups</td>
<td>CaO (s), heat, ColorpHast pH-indicator strip</td>
<td>(Odegaard, Carroll, and Zimmt [2000] 2005)</td>
</tr>
<tr>
<td>Mg</td>
<td>NH4Cl, citric acid, Na2HPO4, heat, NH4OH (aq)</td>
<td>(Crawford 2009)</td>
</tr>
</tbody>
</table>

Table 3.4 Reagents for micro-chemical spot tests

3.3.3 Flame test

Flame tests were performed by isolating the sample on aluminum foil over a glass alcohol lamp, under a fume extraction trunk. This technique was used to determine whether a material was organic, inorganic, or a combination thereof.

3.3.4 X-ray diffraction spectroscopy (XRD)

XRD was used to analyze and identify the crystalline inorganic and mineral content of surface deposits. Sample material was mounted on a glass spindle and analyzed using a Rigaku Spider R-Axis X-ray diffractometer. XRD spectra were recorded at 50 kV and 40 mA using a Cu-Kα target. XRD data was
processed and matched against reference spectra from the International Center for Diffraction Data (ICDD) using Jade software v. 8.2.

3.3.5 Fourier-transform infrared spectroscopy (FTIR)

FTIR was used primarily to investigate organic materials or residues on the surface of the object. FTIR was performed at the UCLA Department of Chemistry on a Jasco FT/IR-420 Spectrometer. Approximately 2 mg of well-ground sample material was mixed with 180 mg of potassium bromide (KBr) and compressed into a pellet. Spectra were recorded in % absorbance over a range of 4000 to 400 cm⁻¹ (wavenumbers) and processed using Jasco Spectrum Manager and PerkinElmer Spotlight (v.4.3.3) software.

3.4 Results

Results of the analyses conducted are summarized below; further discussion and conclusions are described in Section 4.

3.4.1 Substrate identification and preparation

Macroscopic attributes of the bulk material or substrate include porous surfaces identical to cancellous bone formations in combination with areas of dense cortical layers displaying Haversian canals suggested the presence of bone (Espinoza and Mann 1999). The identification of the bone as human, and not animal, was achieved in consultation with zooarchaeologist Dr. Thomas Wake and physical anthropologist Dr. Wendy Teeter, both members of the Cotsen Institute for Archaeology at UCLA. The

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5 Dr. Wake, especially, has been helpful in the articulation and interpretation of the microscopically-observed morphological features presented here.
criteria and unique features of the substrate discussed during this consultation are presented in Appendix F, with a suggested protocol for identifying human bone in cultural objects.

Forensic imaging showed a UV-induced visible fluorescence not inconsistent with the appearance of the primary mineral component of bone, hydroxyapatite \([\text{Ca}_{10}(\text{PO}_{4})_6(\text{OH})_2]\) (Figure 3.1).\(^6\) This was observed in all sections of the object, in alternation with occasional areas where the surface was obscured by superficial layers of material. Examination of the surface using high resolution digital microscopy revealed the vascular morphology of capillary beds within the substrate surface (Figure 3.2) as well as grain — the delineation of axial morphology corresponding to the growth of bone — (Figure 3.3) and mineral formation within the bone (Figure 3.4).

XRF spectroscopy of multiple spots on the substrate surface (Figure 3.5) consistently registered the presence of Ca and P as major elements. Other minor and trace elements were also recorded, varying

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\(^6\) NB: The blue-white appearance under UV-induced visible light cannot be used to diagnose the presence of bone minerals specifically as other types of inorganic and organic material exhibit similar behavior. This method can be used as an initial investigation but the identification of bone, specifically, should be supported by more in-depth analysis of morphology and features (see Appendix F).
according to the area being measured. The intensity of peaks for Ca and P were relative to the presence of other materials on the surface such as heavy metals, colored deposits or surface layers (Appendix C).

The preparation of the bone substrate for use in the construction of this object is indicated by features observed through raking light (oblique illumination) and microscopy. Raking light on sections of the arm band (Fowler # X69.300 C) reveal the depth of relief in the carving and the finesse of its execution (Figure 3.6). Raking light on the reverse of a constructed aperture in another element of on the arm band, illustrates — by its smoothed ridges of displaced material — the plasticity of the bone during its manipulation in the production of the object (Figure 3.7). In microscopic examination, it was found that tool

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**Figure 3.3:** Delineations parallel to the longitudinal axis of the bead (red arrow) are grain; other marks are from shaping and tools uses during construction.

**Figure 3.4:** A broken section of cortical bone reveals the patterns of mineral deposition during bone formation.

**Figure 3.5:** Areas of spot analysis using XRF spectroscopy: The numbers correspond to specific samples discussed and their proformas (Appendix H).
marks on the beads alternate between turning type marks which are concentric and perpendicular to the bone grain (Figure 3.8) and short, parallel strokes distributed across the surface, inconsistent with the bone grain, which indicate sanding or other shaping methods (Figure 3.9).

The substrate of the central component of an ornament with unidentified function (Fowler # X69.300G) was markedly different in character from other areas in the object (Figure 3.10). When measured with XRF, it was seen to contain Ca and P, as in other sections identified as bone (Appendix C). Its appearance under UV-induced visible fluorescence is similar to other areas, though in visible light it was seen to be orange-brown in color with a smooth, luster finish. With microscopic examination, the
morphology of this component was documented as uniquely concentric, rather than granular and axial as in other sections of the substrate (Figure 3.11). Variations in coloration, or mottling, that likely correspond to the characteristic formation within ivory known as Schreger lines (Espinoza and Mann 1999) were also recorded (Figure 3.12). There was no indication of how this piece was carved from its surface condition.

Finally, the type of alloy used for the metal bangles on the object was identified through XRF, which registered the characteristic x-rays of Cu, Zn, and traces of Fe (Appendix C). This suggests the bangles are made from brass. Microscopic
examination of the surface of the bangles revealed areas with bright green corrosion (Figure 3.13), characteristic of Cu-containing alloys (Scott 2000).

3.4.2 Fiber analysis

Fiber micro-samples were taken from various locations and applications within the object (Figure 3.14) and examined under PLM. The results for this analysis are summarized in Table 3.5. Fibers were found to be cotton, bast, or a mixture of the two. Cotton was identified by its characteristic shape (flattened tube, lack of central element, twist) and strong birefringence (Figures 3.15 and 3.16). Two types of bast fiber were found, with slight variations in morphology, size, and behavior under cross-polarized light. Both types of bast fibers were observed to have regular markings perpendicular to the axis of growth; these markings were generally smooth and simple in shape, in contrast to scales on animal fibers (Goodway 1987; Leene 1972). Bast fiber type A was larger, with widely spaced and smooth perpendicular bands, an irregular central component, a bright, primarily blue birefringence towards the fiber’s outer surface every 90 degrees, and did not display complete extinction (Figures 3.17 and 3.18). Bast fiber type B has more closely-spaced and irregularly-shaped cross-hatchings, bright pink and yellow birefringence colors, a

Figure 3.14: Locations for micro-sampling to identify fibers used in cordage, tassels, and woven textiles on object.
<table>
<thead>
<tr>
<th>Sample location/Proforma #</th>
<th>Function</th>
<th>Description</th>
<th>Observations</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Tassel</td>
<td>Brownish-grey; Z-twist, single ply</td>
<td>Smooth, slightly curved cross-hatchings perpendicular to axis of growth, evenly spaced; bright blue birefringence colors, no central element</td>
<td>Unidentified bast fiber (type A)</td>
</tr>
<tr>
<td></td>
<td>Cordage</td>
<td>White-grey, Z-twist, 2-S ply</td>
<td>Two fiber types present; one is flattened tube with twist, no surface markings; second has indistinct surface markings, central component with mainly blue also yellow, red birefringence colors</td>
<td>Mixture of cotton and unidentified bast fiber</td>
</tr>
<tr>
<td>36</td>
<td>Cordage</td>
<td>Grey, Z-twist, 6-S-ply</td>
<td>Two fiber types; one is flattened tube with dark central component and orange, yellow, blue birefringence, straight, no surface markings; second is larger with regularly spaced, smooth cross hatching, primarily bright blue birefringence, indistinct central, interior element</td>
<td>Mixture of cotton with unidentified bast fiber (type A)</td>
</tr>
<tr>
<td>37</td>
<td>Cordage</td>
<td>Z-twist, 6-S-ply</td>
<td>Angular cross hatchings with linear central component, primarily bright pink/blue and yellow birefringence; fiber is very straight</td>
<td>Hemp (bast fiber type B)</td>
</tr>
<tr>
<td>38</td>
<td>Tassel?</td>
<td>Black, Z-twist, single ply</td>
<td>smooth, slightly curved perpendicular markings (deteriorated, difficult to see), no extinction, white with blue, red, purple birefringence colors, poorly defined central component; appears dark blue in plane polarized light (dye)</td>
<td>Likely unidentified bast fiber (type A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brown, Z-twist, single ply</td>
<td>Angular, closely-spaced cross hatchings with linear central component, primarily bright pink and yellow birefringence, no extinction; transparent in plane polarized light</td>
<td>Unidentified bast fiber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red, Z-twist, single ply</td>
<td>Two fiber types: first is mostly white in crossed polars with some blue, purple, pink birefringence colors; shape is flattened tube with central component, some twisting, no discernible surface markings/cross-hatchings; second has regular, smooth, curved cross-hatchings with no extinction, blue and yellow birefringence, transparent in plane polarized light</td>
<td>Mixture of cotton with unidentified bast fiber (type A)</td>
</tr>
<tr>
<td>39</td>
<td>Cordage</td>
<td>Blue-ish, loose S-twist, single ply</td>
<td>Closely spaced, angular cross-hatching; cross polars has complete extinction every 90 degrees, straight with linear central component; bright yellow, pink, and blue birefringence</td>
<td>Hemp (bast fiber type B)</td>
</tr>
<tr>
<td>40</td>
<td>Detached textile fragment</td>
<td>Grey-brown, plain-woven; yarn is Z-twist, single ply</td>
<td>Under crossed polars exhibits bright pink and yellow birefringence colors, angular, closely spaced cross-hatchings, no extinction, linear central element</td>
<td>Unidentified bast fiber</td>
</tr>
</tbody>
</table>

Table 3.5: Fiber analysis by PLM with observed behavior and summarized results; n.b. ‘Cordage’ refers to a yarn with the primary function of fastening or connecting carved bone elements.
distinctly linear central component, and extinction of birefringence colors with illumination of cross-hatchings every 90 degrees (Figures 3.19 and 3.20).

Recorded observations of fiber behavior under PLM were compared to a reference set of fibers which included hemp, jute, nettle, and ramie. Considering the morphological and optical characteristics of
the fibers, bast type B is likely hemp (*Cannabis* spp.) but the specific identification of type A and other bast fiber species remains inconclusive. Some unidentified fibers share features with bast fiber type A and may represent different raw materials of the same species.

3.4.3 Surface materials

3.4.3.1 Pesticide residues

XRF measurements of the surface of the object consistently registered Pb. Though Pb-based pigments were also found on the surface of the object (see Section 3.4.3.2, below), there was a persistent presence of signals for Pb on other sections, including measurements taken on a yarn tassel with no evident pigment or residue (Appendix C). The ubiquity of signals for Pb and the object’s collection history strongly indicate an application of Pb-containing pesticide. This was most likely applied as part of an early-mid 20th century collections care regime (Goldberg 1996), though the specific circumstances are unknown.

3.4.3.2 Colored deposits

Observation in visible light as well as forensic imaging revealed an irregular deposition of residue layers on the object surface (Figures 3.21 - 3.24). With the exception of red color inside the eyes of the round, skull-shaped plaques in the apron (Fowler # X69.300 A), the application of colorants to the object surface is seemingly random and do not correspond to carved motifs or shapes.

The materials examined here are discussed as deposits, rather than paints; there was no attempt to distinguish binding media in colored materials or to discern the stratigraphy of successive layers of application. Material types are presented here in terms of their appearance and/or relationship to the object surface. Due to a lack of standard reference material on the luminescence of substances using forensic imaging, this technique could otherwise not yield much diagnostic information about the types of materials
present on the surface of the substrate. Resources on the diagnostic application of forensic imaging is currently being developed and may later provide more information for the interpretation of data presented here.\(^7\)

**Red stain**

Areas of red staining were found primarily on beads, in all sections of the bone ornament ensemble (Figure 3.25). Red stains were also found on the side and reverse surface of plaques and carved decorative elements (Figure 3.26). This red stain is a generally a thin layer, at times transparent, and well-

\(^7\) See Kakoulli, I. and A. North, "Beyond the visible: Macro and micro-analytic forensic imaging for the documentation and investigation of archaeological objects," Paper presented at the American Institute for Conservation’s 41st Annual Meeting, Indianapolis, IN, May 2013.
adhered to the object surface. UV-induced visible fluorescence on areas with red staining showed dull to bright orange, characteristic of shellac, a varnish derived from the exudate of the lac insect (Koob 1998) (Figures 3.27 and 3.28).

XRF spectra of the areas with the red stain was intermittently present on the object surface showed no significant compositional difference from those areas without it; areas with the stain had slightly stronger signals for Fe, Cu, and Sr but no elements were observed unique to areas with color (Appendix C).

Because it is consistent with other areas of the substrate where no colorant is present, XRF data supports...
the assumption that the red stain may be organic in nature and lac dye (a component of shellac, often red) is the assumed material used to create this type of staining (see also Appendix G).

*Red*

There are a number of red-type material deposits on this object ranging in color from light pink to bright orange to crimson. Table 3.6 summarizes results and classifies each type of red or chromatically related material analyzed through noninvasive methods and micro-sampling (Figure 3.29). Eight of these colors were selected for analysis with XRF and micro-analytical techniques. It was found they are generally Pb-based (minium \([\text{Pb}_2\text{PbO}_4]\)) or Hg-based (cinnabar \([\text{HgS}]\)), with impurities or other, unidentified substances creating variations in hue and value.

FTIR analysis on two samples of red material with organic content — as suggested by a flame test — illustrates the complexity of some of the deposits on the object surface (Appendix E).⁸ It should be noted that FTIR spectroscopy was interpreted here in terms of results from other methods of analysis. In

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⁸ Invaluable assistance was provided in the interpretation of these FTIR spectra by Herant Khanjian, Assistant Scientist at the Getty Conservation Institute; other resources consulted were Coates (1999) and Derrick, Stulik, and Landry (1999).
<table>
<thead>
<tr>
<th>Color</th>
<th>Sample position/Proforma #</th>
<th>Method of analysis</th>
<th>Results</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>17</td>
<td>XRF</td>
<td>Hg, Pb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>XRF</td>
<td>Hg, Pb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>53A</td>
<td>XRD</td>
<td>Cinnabar, calcite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>53A</td>
<td>XRD</td>
<td>Cinnabar, calcite</td>
<td>Cinnabar</td>
</tr>
<tr>
<td>Peach</td>
<td>18</td>
<td>XRF</td>
<td>Pb, Hg, Ca, P, Fe, Ba (L lines)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Flame test</td>
<td>Some organic content</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>FTIR</td>
<td>Barite, protein</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>XRD</td>
<td>Barite, minium</td>
<td>Minium, barite with organic content and possibly cinnabar</td>
</tr>
<tr>
<td>Dark pink</td>
<td>51</td>
<td>XRD</td>
<td>Minium</td>
<td>Minium with unidentified colorant</td>
</tr>
<tr>
<td>Dark pink</td>
<td>48</td>
<td>Flame test</td>
<td>Some organic content</td>
<td></td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>FTIR</td>
<td>Calcite, clay, gum?</td>
<td>Organic with possible inorganic colorant</td>
</tr>
<tr>
<td>Peach</td>
<td>21</td>
<td>XRF</td>
<td>Pb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>XRD</td>
<td>Minium, goethite?</td>
<td>Minium</td>
</tr>
<tr>
<td>Orange</td>
<td>26</td>
<td>XRF</td>
<td>Pb, Ca, P, Fe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>46A</td>
<td>XRD</td>
<td>Minium</td>
<td></td>
</tr>
<tr>
<td>Pink</td>
<td>46B</td>
<td>XRD</td>
<td>Minium</td>
<td>Both orange and pink in this area are minium, mixed with unidentified colorant</td>
</tr>
<tr>
<td>Red</td>
<td>30</td>
<td>XRF</td>
<td>Hg, Pb, Ca</td>
<td>Cinnabar</td>
</tr>
<tr>
<td>Pink</td>
<td>42</td>
<td>XRD</td>
<td>Minium, hydroxyapatite</td>
<td>Minium with unidentified colorant</td>
</tr>
</tbody>
</table>

Table 3.6 Red deposits, examined and presented here with analytical methods, results, and interpretation.
to sulfate (SO₄²⁻) in barite (BaSO₄). Proteins are indicated by the broad absorption at 3397 cm⁻¹ (N-H stretching) and amide I and II absorptions at 1638 and 1516 cm⁻¹, respectively.⁹ In the second sample (48), an absorption at 1414 cm⁻¹ may be related to carbonates (CO₃²⁻) in calcite; signals at 534 and 468 can be from Si-O in quartz; and the peak at 3435 cm⁻¹ with that at 1035 cm⁻¹ may come from a gum or other polysaccharide material, which is suggested by the overall spectrum shape as well as similar materials being found in other samples (see below).

**Yellow**

Yellow-colored deposits are composed primarily of barite with other trace components; identification is complicated by limited material for sampling. Table 3.7 presents the methods of analysis attempted with the available samples and results thereof. The material is generally finely powdered and homogeneous.

<table>
<thead>
<tr>
<th>Sample position/ Proforma #</th>
<th>Method of analysis</th>
<th>Results</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>XRF</td>
<td>Al, Si, K, Sr, Ca, P, Ba (L lines), Pb</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>XRF</td>
<td>Al, Si, Ca, P, Ba (L lines), Pb</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>PLM</td>
<td>White crystalline material with smaller, yellow phase associated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>XRD</td>
<td>Barite, calcite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FTIR</td>
<td>Barite, possible clay</td>
<td>Barite with second unidentified yellow component, possibly organic and some clay</td>
</tr>
</tbody>
</table>

Table 3.7 Yellow deposits, examined and presented here with analytical methods, results, and interpretation.

⁹ Derrick, Stulik and Landry (1999) relate that function groups for proteins are generally recognized by a combination of an absorption at 3350 cm⁻¹ in combination with absorptions for amide I near 1650 cm⁻¹, amide II near 1550 cm⁻¹, and amide III near 1450 cm⁻¹.
Analysis by FTIR was inconclusive due to a lack of sufficient sample size (Appendix E). Absorptions at 2363 and 2334 cm$^{-1}$ likely correspond to atmospheric CO2 and signals above 3300 cm$^{-1}$ which might aid in the identification of clays are complicated by possible absorbed water in the sample. As above, absorptions between 1050 and 1200 cm$^{-1}$ can be attributed to the sulfate in barite. PLM shows barite crystals (tabular plate-like rhombic prism) in close association with a yellow material, or alteration phase, with a comparatively smaller particle size (Figure 3.30).\(^{10}\)

**Black/dark brown**

Two types of black or dark brown surface materials are analyzed here: the first is a stain, a coloration of the substrate surface. It was examined by XRF and has a small peak for Cu and a stronger signal for Fe in comparison to the area with no staining (Appendix C) (Figure 3.31). A similar comparison from the reverse of another plaque (Fowler # X69.300 B) shows that areas without the black stain have stronger signals for the substrate (Appendix C).

The other type of dark brown/black deposit examined here shows a more complex composition and relationship with the substrate. Microscopy shows an irregular distribution of the material, which is

\(^{10}\) Resources for the interpretation of materials by PLM included Nesse (2004) and Eastaugh et al. (2008).
generally well-adhered to the surface in a thin layer (Figure 3.32). A flame test for this material confirms that it is organic and an acrid scent produced suggests the presence of proteins. FTIR spectroscopy shows peaks between 460 and 610 cm\(^{-1}\) and above 3500 cm\(^{-1}\) which may suggest the presence of clays in the sample (Appendix E). The broad peak at 3350 cm\(^{-1}\) in conjunction with peaks at 1646 and 1419 cm\(^{-1}\) support an identification of proteins, as suggested by flame test.

Light brown

A light brown material was found in the obverse surface of the crown plaque (Fowler # X69.300 B) (Figure 3.33). A flame test suggests that the material is primarily organic in nature. Micro-solubility tests demonstrated that a portion of the material is soluble in warm water, with a trace
amount responding to acetone. In FTIR analysis, the potential functional groups found in polysaccharides — a gum, for example, which is soluble in warm water — is supported by absorptions at 1054 cm\(^{-1}\) in combination with the broad absorption at 3346 cm\(^{-1}\). The samples were observed to be well-adhered to the surface and homogeneous.

**Off-white**

An off-white colored material was found on a carved plaque at the top of the apron (Fowler # X69.300 A) (Figure 3.34). A flame test was inconclusive with charring but no combustion of material. XRD analysis revealed the presence of quartz, hypercinnabar (HgS, a high temperature phase of cinnabar), and possible clay-like components (alumino-silicates) (Appendix D). The material is a coarsely ground-powder with phases of pink/red particles intermixed.

![Figure 3.34: Position of off-white material on apron (Fowler # X69.300 A).](image)

**Green**

Green was found on an ornament of undetermined function (Figure 3.35). The green layer was thinly applied, opaque, and well-adhered to the surface. XRF analysis taken of this area and immediately
adjacent recorded the characteristic x-rays for Cu where the green material was present and Hg where it was not (there is some red material in this area of the object surface as well) (Appendix C). The two areas consistently showed characteristic x-ray emissions for Ca, P, Fe, and Pb, though signals for Ca and P were stronger where no green was present. XRD analysis of the green material revealed the presence of atacamite \([\text{Cu}_2\text{Cl(OH)}_3]\) and calcite \((\text{CaCO}_3)\) (Appendix D).

3.4.3.3 Deterioration products

A dry, brown, granular substance was noticed separating from pores in the exposed cancellous bone on the reverse of the skull crown (Fowler # X69.300 B). Under the stereomicroscope, it was observed that this material was pliable and came from within the porous structure of this area of the bone (Figure 3.36). The material is a combination of larger dark-brown masses and light red-brown, translucent phases. The results of micro-chemical testing are inconclusive; some phases were soluble in deionized water and proteins were detected with the Biuret (CuSO4/NaOH) test.

White spots were observed on the reverse of an ornament with undetermined function (Fowler # X69.300 D). These spots were seen on top of an area with red stain (likely lac dye) and blackish material (Figures 3.37). Examination under PLM revealed that the material is amorphous (Figure 3.38), appearing waxy, softly-contoured, and glossy. XRF analysis of the area recorded an elemental composition similar to areas of exposed bone substrate, suggesting the black and red layers are likely organic. Further analysis of these white spots was complicated by the limited amount of material. A flame test revealed that it may
be responsive to heat by partially melting and leaving a waxy residue on the surface of a glass slide. Micro-solubility tests with deionized water, acetone, ethanol, and mineral spirits gave inconclusive results. Crystalline substances were found on certain beads, corresponding to boundaries in the natural grain or axial growth layers of the bone (Figures 3.39 and 3.40). This material is closely associated with the substrate; no sampling or further analysis was attempted. Finally, a large amount of powdery, white material on the reverse and, in trace amounts, on the sides and obverse, of the central component of an ornament with undetermined function (Fowler # X69.300 G) was examined to determine its composition (Figure 3.41). XRF spectra were recorded from the front...
and reverse of this component where those from the front had stronger signals for Ca, P, Fe and other trace elements (K, Mn, Ni, Cu) (Appendix C: XRF spectra, 28_X69-300_ivory, etc.). These variations in peak signal strength, however, may be related to the thickness of the deposit on the reverse surface or to the challenge of getting accurate XRF readings from complex shapes. Under BM and 3-D digital microscope, this substance was granular with small, globular formations similar in shape and size to insect egg casings, sometimes closely associated with organic material (Figure 3.42). A flame test demonstrated that this substance is largely inorganic, including the globular, egg-like formations. Under PLM, the material is a number of closely related and difficult to distinguish phases with poor morphology (Figures 3.43 and 3.44). The most prevalent phase is transparent in plane polarized light, white to yellow in crossed polars with
poorly formed crystals and undular extinction every 90 degrees. A second phase of opaque, dark brown material which appeared to be amorphous. Micro-chemical testing revealed the presence of Mg and using XRD, it was confirmed that this white material is a combination of calcite, newberyite \([\text{Mg(HPO}_4\text{)} \cdot 3\text{H}_2\text{O}]\), and hydroxyapatite (Appendix D).

4. Discussion

Specific materials found in this investigation are generally consistent with available published information about the construction of bone ornaments. Table 4.1 summarizes the results of the analytical examination. The following discussion is intended to contextualize these findings and make estimations about how the object’s condition and constitution reflect its construction and material history. Section 5 will reflect specifically on how the findings of this investigation compare to other, similar bone ornament assemblages.

The finding that the substrate for this object is human bone, with an ivory component, is consistent with long-standing traditions about materials used for this type of ritual object. Loseries-Leick (2008) comments that though some substitutions — camel, buffalo, or mule bones — have no significance, the

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Human bone, ivory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibers</td>
<td>Hemp, unidentified bast fiber, cotton</td>
</tr>
<tr>
<td>Surface materials</td>
<td>Minium (red lead), cinnabar, barite, atacamite</td>
</tr>
<tr>
<td></td>
<td>Clay (alumino-silicate), quartz, calcite</td>
</tr>
<tr>
<td></td>
<td>Lac dye</td>
</tr>
<tr>
<td>Surface materials presumably related to substrate deterioration or reactivity</td>
<td>Proteins, newberyite (magnesium phosphate), hydroxyapatite</td>
</tr>
</tbody>
</table>

Table 4.1 Summarized results of analytical investigation of materials used in object construction or found on the surface.
use of ivory may be a deliberate attempt to enhance the value of the object. She also reports that different kinds of wood are traditionally recommended as substitutions. It should be noted that ivory is not native to all regions of the Himalayas (e.g., Tibet) and may have been imported from India. It is not known from which species this ivory comes though its concentric morphology and region of provenance suggest elephant. The types of tool marks on the bone elements provide inconclusive information about how the object was shaped though it can be said that a variety of techniques were used. In her study of contemporary Tibetan bone carvers in exile, Loseries-Leick (2008) notes the used of metal hand tools and the absence of text-based references for traditional or pre-modern carving techniques. Microscopic examination revealed areas where bone material was displaced in smooth ridges during working and this can be interpreted to illustrate plasticity in the bone during its manipulation. By extension, this indicates that the bone was somewhat freshly harvested during manipulation and had not yet become embrittled due to loss of collagen during biological decay (Teeter, personal communication; Wake, personal communication). It has been observed here that different types of bone have been utilized differently in the object: the crown (Fowler # X69.300 B) and arm band (Fowler # X69.300 C) plaques are both carved from cranial pieces while all other sections seem to have been made from lower limbs, primarily femur (Teeter, personal communication; Wake, personal communication). These bones, specifically, are thick and dense enough to support the intricate carvings of medium to high relief found on bone ornaments. It can be assumed that the beads, which are generally dense and highly polished, have been created from assorted bones and that these also are human, though no comprehensive review of micro-morphological features in the beads has been undertaken.

In terms of fiber identification, results are consistent with available reference resources. The use of cotton in woven fabrics, especially as plain-woven support for thangka, is well-documented (Huntington 1970; Jackson and Jackson 1984; Cotte 2011). Many types of bast fibers — including hemp, nettle, and
mulberry — are also commonly used for textiles and cordage in the Himalayan region (Brennan, personal communication). Furthermore, there are also native species used as sources for bast fiber for which there is little published information: *Girardinia diversifolia* — Himalayan giant nettle or *allo*, as it is known in Nepali — is one such resource (Singh and Shrestha 1988). Fiber identification was undertaken in comparison to available resources including reference sets and the *Fiber Reference Image Library* (fril.osu.edu) though the lack of conclusive identification for this object may be a symptom of limitations in commonly available resources. In a study of textile traditions of the Western Himalayan region, Handa (1998) focuses exclusively on the use of wool and cotton. Further work with a botanical specialist may provide more conclusive results that those offered here. In this object, both cordage and yarns used for weaving are primarily bast fiber (either hemp or an unidentified species), with some cotton being used in both cordage and decorative yarns (tassels). Yarns and cords are consistently Z-twisted with S-twist ply; some samples initially recorded as S-twist were found to be the unwound ply of larger yarns or cords. Some yarns were colored blue and pink, and though dyes were not analyzed as part of this project, indigo and madder have well-recorded use in the region (Jackson and Jackson 1976).

The variety of materials found on the surface of the object indicates the complexity of this bone ornament assemblage’s material history. Minium (red lead), cinnabar, atacamite, and red lac dye have been used as pigments or colorants in *thangka* (Jackson and Jackson 1976; Jackson and Jackson 1986; Mass et al. 2009). Red lac dye is also seen on other bone ornaments, similarly applied to the beads at irregular intervals (Figure 4.1). Calcite and quartz have been documented as part of ground layers or

Figure 4.1: Yellow arrow indicates area where red lac dye has been applied to the surface of beads on a bone ornament (Image: Courtesy of Dr. Jinah Kim).
white pigments in wall paintings and thangka (Mazzeo et al. 2004; Huntington 1970). Atacamite and other basic copper chlorides have been used as pigments in this region but it is not certain if these represents true pigments or are the result of chemical transformations from other cuprous materials (Scott 2000). Yellows from this region are typically found to be arsenical (e.g. orpiment and realgar) or iron-based (e.g. yellow ochre) and the findings here of a yellow compound that is primarily barite (a white mineral) are provocative. For example, Chao (unpublished, 2011) records barite used as a white pigment in a Bhutanese shrine. PLM analysis shows barite as white crystals with a closely associated and finely particulate yellow phase but it is yet unclear what this colored material might be. Scholars have remarked on the variability of the palette in the region due to intra-regional trade and, in recent centuries, industrialization and the availability of commercially produced paints and pigments (Jackson and Jackson 1984; Mass et al. 2009). Whether the barite is being used as an extender for a modern paint or as the substrate for a lake with an organic yellow colorant is uncertain.

Clay minerals may be related to the object’s production. Loseries-Leick (2008) describes a method for transferring designs onto raw bone material that involves covering the substrate in thin layers of watery clay, into which the image is traced by removing material. The bone is then lightly fired, charring the bone where the surface is unprotected by clay, fixing the image onto the substrate surface. After this, the clay is removed. This technique is not used by all traditional craftsmen and, in general, it seems that the contemporary practice of bone carving is highly idiosyncratic (Loseries-Leick 2008). Archaeometric texts and their commentaries may offer more technical information about historical practices but these sources have yet to be investigated thoroughly. Nonetheless, findings of alumino-silicate materials and quartz in some samples might be related to this or other techniques used during production.

What is especially curious about the materials found here, however, is the pattern of their deposition on the surface. It is highly irregular, almost entirely with no correspondence to the carved
decorations. At the same time, colored deposits are ubiquitous and random on the object: small dots of yellow material will be found in areas of red; smudges of bright orange are found on the reverse of some plaques; red lac dye is applied to beads as well as plaque sides and backs, etc. (Figures 4.2 and 4.3). Many of these materials are used in the production of other forms of material culture while bone ornament ensembles are always depicted as white in historical and contemporary images of use. This author knows of no instance in which they are decorated with color applied directly to the surface.\textsuperscript{11} Three possible explanations are suggested: the first is that the origin of these colors and materials on the object surface is in some way related to a previous owner/user’s private ritual practice. The second is that the materials were deposited on the surface by practitioners honoring the object through the common practice of \textit{puja}, wherein a devotee places his/her fingers first in a pigment, fragrant powder, or other precious material and

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.2.png}
\caption{Skull-shaped plaques on the bone apron or girdle (Fowler \# X60.300 A) are the only elements to which color has been applied in a manner that corresponds to the carved decoration. Here the recesses of the carved area are covered in cinnabar; the yellow arrow indicates a small dot of yellow material on top of the red layer.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.3.png}
\caption{A red arrow shows the position of an area of orange, minium-based pigment on the side of a plaque on the crown (Fowler \# X69.300 B).}
\end{figure}

\textsuperscript{11} See Section 5, following, for a comparison of this object to bone ornaments found in other collections.
then touches the object, leaving some of that material on the object surface. Dr. Jinah Kim (personal communication) has suggested this origin, noting similar practices in Nepal towards manuscripts and other sacred objects. A third solution to the mysterious origins of the materials found on the object surface might be suggested by their variety, which includes clays and pigments as well as possible binding media like proteinaceous glues and/or gums. Potentially the object, before its purchase in Nepal, was housed in a workshop that produced other types of decorative or artistic works and its complex surface character is the result of its interaction with this space and its inhabitants. This object also has layers of accumulated and unidentified surface grime that complicate analysis and testify to this ensemble’s heavy use, in whichever setting, before its collection. At any rate, it can be said that the materials found on the surface of the object represent a complex mixture of uncertain origins.

Finally, there are a few materials that qualify as deterioration products or are uniquely tied to the object substrate. Proteins found on the reverse of the crown (Fowler # X69.300 B) are being shed by the porous, exposed cancellous bone and are certainly related to the material’s biological nature and the preparation (or lack thereof) of raw material during production. Hydroxyapatite — and possibly calcite — found on the surface is likely related to the mineral components of bone being mixed into the sample, either through their chemical reactivity or sampling technique. Newberyite, a magnesium phosphate, was useful in determining that the ivory component (Fowler # X69.300 G) was in fact ivory and not bone, though this determination was made primarily through the observation of morphological features. Magnesium phosphates have been found on elephant and mammoth ivory as the result of diagenetic processes during burial and on cultural objects in collections previously treated with peroxides (Freund et al. 2002). Newberyite is a hydrated magnesium phosphate and needs high relative humidity in order to form. Possibly this mineral formed in greater abundance on the reverse of the ivory component because its

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12 See Birstein (1975) as well as any of the above-mentioned sources that present the techniques of thangka painting for discussion of binding media used in this region.
hollow shape harbored water vapor which then condensed on the substrate surface. The curious egg-like form of this deterioration product is a mystery, however, and may have formed through minerals precipitating out of solution at the surfaces of droplets or be the result of some insect activity that utilized or activated the surface minerals. Further analysis is needed to give a conclusive explanation for this.

5. Survey of bone ornaments in other collections

As part of this thesis, a comparative survey of bone ornaments in North American and UK-based collections was undertaken. Seven museums, in addition to the Fowler Museum at UCLA, participated by allowing the author access to bone ornaments in storage or on display in their collections with the purpose of recording key features and condition. Representatives of these institutions generously shared information on conservation issues and the objects’ histories. This section presents observations on the iconography, handling and display strategies, as well as material histories of these objects in order to provide insight on the ways in which these ritual objects have been interpreted and treated in museum collections. The summarized results of this comparative study can be found in Table 5.1. It should be noted that only objects for which there was sufficient information available on condition, handling, and collections history are included in this table. Many other bone ornaments were examined virtually through images, correspondence, and online collections databases.

Loseries-Leick (2008) remarks that the decorative iconography of bone ornaments is largely the invention of the craftsman who executes the design. It is likely, however, that it was also subject to the approval of the person or institution commissioning the object and therefore somewhat predetermined.

13 Special thanks to Chris de Brer at the Fowler Museum at UCLA; Joan Cummins at the Brooklyn Museum, Brooklyn, NY; Michelle Bennett at the Rubin Museum of Art, New York, NY; Karl Knauer at the American Museum of Natural History, New York, NY; John Clarke at the Victoria and Albert Museum, London, UK; JP Brown and Ruth Norton at the Field Museum, Chicago; Annie Kuang at the Pacific Asia Museum, Pasadena, CA; and Sydney Hengst, Susan Tai, and Nancy Rodgers at the Santa Barbara Museum of Art, Santa Barbara, CA for their knowledge, time, and encouragement.
<table>
<thead>
<tr>
<th>Ornament Type(s)</th>
<th>Estimated Period of Creation</th>
<th>Year of Acquisition</th>
<th>Type of Collection</th>
<th>Documented Place of Origin</th>
<th>Integrated Support (pre-acquisition)</th>
<th>Storage Strategy</th>
<th>Display Strategy</th>
<th>Residues on Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apron, crown, arm band, etc. (Fowler # X69.300 A-J)</td>
<td>N/A</td>
<td>1969</td>
<td>Ethnographic</td>
<td>Nepal/Tibet (?)</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Red lac dye, various pigments, miscellaneous materials, varnishes, etc.</td>
</tr>
<tr>
<td>Crown</td>
<td>N/A</td>
<td>1974</td>
<td>Ethnographic</td>
<td>Nepal</td>
<td>Looped into fabric cap</td>
<td>Attached to textile belt</td>
<td>Reinforced textile belt used to mount apron on mannequin</td>
<td>Red pigments on large decorative plaques</td>
</tr>
<tr>
<td>Apron</td>
<td>16th c.</td>
<td>1924</td>
<td>Fine art</td>
<td>Tibet</td>
<td>None</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Apron</td>
<td>18/19th c.</td>
<td>2006</td>
<td>Fine art</td>
<td>Tibet/Nepal</td>
<td>None</td>
<td>Suspension on clear acrylic support (before plexiglass); loop is attached to reverse of apron</td>
<td>Textile belt along top of apron</td>
<td>N/A</td>
</tr>
<tr>
<td>Apron</td>
<td>X69.300 A-2)</td>
<td>1999</td>
<td>Ethnographic</td>
<td>Nepal</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 5.1: Summarized results from a comparative survey of eight North American and UK collections

(continued)
Table 5.1: Summarized results from a comparative survey of eight North American and UK collections

<table>
<thead>
<tr>
<th>Ornament type(s)</th>
<th>Estimated period of creation</th>
<th>Year of acquisition</th>
<th>Type of collection</th>
<th>Documented place of origin</th>
<th>Integrated support (pre-acquisition)</th>
<th>Display strategy</th>
<th>Storage strategy</th>
<th>Residues on surface</th>
<th>Photographs (pre-display)</th>
<th>Photographs of acquired objects</th>
<th>Orange (ype(s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apron</td>
<td>179th c.</td>
<td>1984</td>
<td>Fine art</td>
<td>Tibet</td>
<td>None</td>
<td>N/A</td>
<td>N/A</td>
<td>Red, pink</td>
<td>Under individual plaques only</td>
<td>Anchored to fabric-wrapped board with steel pins</td>
<td>N/A</td>
</tr>
<tr>
<td>Apron</td>
<td>N/A</td>
<td>2001</td>
<td>Fine art</td>
<td>Tibet</td>
<td>Textile belt along top of apron</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Apron</td>
<td>Mid-19th c.</td>
<td>N/A</td>
<td>Fine art</td>
<td>Tibet</td>
<td>None</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Apron</td>
<td>19th c.</td>
<td>1781</td>
<td>Fine art</td>
<td>Tibet</td>
<td>Leather belt at top of apron</td>
<td>N/A</td>
<td>N/A</td>
<td>Yellow, peach, red, orange, peach</td>
<td>Anchored to fabric-wrapped board with steel pins</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

Note: The table above contains information about the display and storage strategies used for different ornamental pieces from various collections. The table includes details such as the type of ornamental piece, the period of creation, the year of acquisition, the type of collection, the documented place of origin, and additional notes on integrated support, display strategy, storage strategy, and residues on the surface.
Common elements are acanthus leaves, skulls, sun and moon motifs, deities associated with esoteric practices, starbursts, flowers, and conch shells. Gega Lama, in his study of Tibetan archaeometry (1983), notes that iconography should be appropriate for the types of ritual practices for which the object is intended: Wrathful deities are therefore likely figures in bone ornaments. Gega Lama also notes that an apron should consist of 64 plaques with bells and strings of beads. This specificity, however, seems more directed toward conventions of rendering bone ornaments in paintings of deities.

There are some consistencies in the shape and composition of bone ornaments discussed here. Bone aprons, or girdles, are generally square or rectangular and are by far the most common type of bone ornament to be found in museum collection. Some aprons are triangular, tapering from the top to bottom and Loseries-Leick (2008) remarks that this is likely a regional variation. Triangular-shaped aprons are likely to be from Nepal, she writes, though this claim needs deeper investigation to be proven. Aprons can have between five and thirteen main decorative plaques. These are generally two by five to six inches in dimension, often made from femurs (which have a characteristic curve and density), ornately carved with figures, and are oriented along the top of the apron (Figure 5.1). In the object examined as part of this research, these large, ornate plaques are missing or have been substituted by flat bone plaques with no carved designs (Figure 5.2). Often there are also large, apotropaic figures along the bottom and at the top corners as well (Figures 5.3 and 5.4). Bronze bells and bangles are also common elements for bone aprons. In some illustrations and examples from museum collections, the apron is attached to a painted backing cloth or belt (Figure 5.5). Many apron plaques in museum collections have several empty holes drilled through the substrate, seemingly original to the object suggesting that these were once used to secure the object to a backing cloth. Less often found than aprons, crowns also popular in museum collections. These usually have five large plaques, shaped as skulls with flaming crowns (Loseries-Leick 2008); this is true of the objects examined here, including Fowler # X69.300 B. The carved elements are
often sewn to a fabric cap or band (Figure 5.6). Other types of bone ornaments are less well collected and documented, and therefore harder to formulate generalizations on.

The reuse and substitution of components also complicates the articulation of standard forms and compositions in bone ornament ensembles and the issue of pastiche is unavoidable in a discussion of
These objects in museum collections. Evidence for pastiche includes condition records that mention consultations on composition for restringing, inconsistent rendering styles and wear patterns on the edges of plaques, and the fragmentary or incomplete condition of many examples of bone ornament, including the object examined as part of this thesis. It can be hypothesized that as international trade, especially with North America and Europe, increased after the late nineteenth century, competition drove decision-making about commercially viable forms of artistic practice. There is certainly evidence that techniques and materials have changed and adapted in the twentieth century (Loseries-Leick 2008; Mass et al. 2009) and economical considerations must be taken into account when evaluating the “integrity” of these objects. Considering this investigation, it can also be said that the re-configuration of bone ornament ensembles may be at the hands of anyone in the object’s journey: from the original user/practitioner, vendor, private collector, curator, to the conservator.

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14 Condition reports and collections records for several objects have been reviewed by the author and paraphrased here to anonymize those institutions that generously gave access to their resources for a critical review.
Finally, from a conservation perspective, the objects studied during this evaluation present an intriguing range of conditions and handling strategies. As Table 5.1 shows, there is a variety of storage and display systems and the surface condition of each object differs greatly. Some examples were highly polished and bright white, some were — like Fowler # X69.300 A-J — covered in layers of surface grime and discolorations of the substrate surface. A few also had red lac dye on the beads (but not the plaques) and colored deposits on plaques in the bone apron. It has been observed by the author that the majority of bone ornament ensembles in North American collections are in natural history museums as ethnographic or anthropological materials. It was also found that very few (if any) fine art museums include a bone ornament as part of their permanent collection on display. Further study on this subject could include a survey of materials used in bone ornaments or the expansion of a discussion of material and collections history to include other types of Himalayan ritual objects made from human bone.

6. Treatment and recommendations for handling, storage, and display of the Fowler Museum object # X69.300 A-J

Though the focus of this thesis was technical examination and research on handling, some minor conservation treatment was also completed. After an initial examination of the object’s condition (see Appendix A), it was determined that the bone ornament ensemble’s greatest vulnerability is structural compromise through unsafe handing. Other condition issues that were determined to require conservation intervention included the white material (determined through analysis to be hydrated magnesium phosphates) on the reverse of the central component of Fowler # X69.300 G; a broken plaque in the crown, Fowler # X69.300 B; and adhesive residues on a section of the apron, Fowler # X69.300 A. This section describes how these issues were addressed, based on a principle of minimum intervention.
6.1 Removal of white material from the reverse of Fowler #X69.300 G

White deposits on the reverse of the ivory component of Fowler # X69.300 G were identified through XRD as newberyite, a hydrated magnesium phosphate (see Section 3.4; Figure 6.1). Due to the potential hygroscopicity of these deposits, they were removed mechanically through light cleaning with cotton swabs and deionized water (pH 6.5). (It is suggested by Freund et al. (2002) that these minerals will not form on ivory objects stored below 55% relative humidity). In order to minimize the amount of moisture introduced to the ivory substrate, cleaning was restricted to the reduction of white deposit and not on its complete removal (Figure 6.2).

6.2 Repair of broken plaque on Fowler # X69.300 B

A broken plaque on the skull crown (Fowler # X69.300 B) was repaired with PVA-AYAF in acetone, 40% (w/v) (Figures 6.3 and 6.4). PVA, or polyvinyl acetate, is generally recommended for use on bone as an adhesive or consolidant (Storch 2003, Johnson 1994).
6.3 Removal of adhesive residue from plaque in Fowler # X69.300 A

During the initial condition reporting, adhesive residue was noted on a carved plaque on the apron, at top (Figure 6.5). Treatment records provide no information on the origin of this residue and the unknown adhesive was found to be flexible, slightly yellow, and translucent. The residue swells in acetone and was removed mechanically with steel hand tools. After removal, the break edges on the plaque were observed to be smooth and it is believed that these breaks originated sometime during the object’s use before its collection. Because this can be considered evidence of original use, it was decided that no new
6.4 Stabilization of bone ornament ensemble through mechanical methods and construction of mount for handling, storage, and display

Taking into consideration the strategies for display and storage of similar bone ornament ensembles in other museums, as well as the literature review completed as part of this research, the object has been mechanically and physically stabilized with a fabric backing cloth, mimicking a possible original appearance of some bone ornaments (Figures 6.6-6.8). There is evidence that the Fowler bone ornament ensemble was once similarly attached to a woven fabric, fragments of which are preserved on the object (Figure 6.9).

A 100% acrylic, solution-dyed fabric — engineered for outdoor use to be microbiologically and UV resistant — was selected as a support cloth for the construction of a mount that would facilitate handling, storage, and display. This cloth — trade-name Sunbrella® — is known to be used as a lining material for canvases in paintings conservation (CAMEO). A 100% polyester, solution-dyed, heavy weight sewing thread was selected for construction of the fabric mount and to secure the object to the support with hand-stitching. Tissue paper was used to make templates for the support, based on the size and shape of...
the original object (Figures 6.10 and 6.11). Two layers of fabric were used for strength and durability. Accession numbers were embroidered in white, 100% polyester thread on the reverse of the fabric supports (Figure 6.12).
The ornaments were joined to their fabric mounts using robust existing holes in the substrate or by loosely anchoring cords in beaded sections (Figures 6.13 and 6.14). Sections with broken cords were secured to the support cloth in configuration that was determined to best represent the original position of the individual elements (Figures 6.15 and 6.16).

Finally, because of the organic materials used in the object’s construction as well the use of cinnabar, it is recommended that this object be stored and displayed under a minimum amount of direct visible and UV light. It should also be noted in handling guidelines that Pb-based pesticide residues have been found on all sections of the object. The backing cloth should be used in handling to minimize direct exposure. Suggested environmental conditions, based on the nature of the materials, is a 60-70°F with a maximum RH of 55% (Storch 2003; Freund et al. 2008).
Figures 6.15 and 6.16: Before (above) and after (below) images of bone apron, Fowler # X69.300 A; the fabric mount physically stabilizes the object and facilitates handling, storage, transport, and display.
**Materials:**

Nikon D70 Digital SLR camera, Nikon Inc., Melville, NY.

Nikon D90 Digital SLR IR/UV modified camera, Nikon Inc., Melville, NY.

Camera Control Pro 2 software, Nikon Inc. Melville, NY.

XNiteBP1 band pass filter, LDP LLC, Carlstadt, NJ.

Peca camera lens filters, Peca Products, Inc., Beloit, WI.

SPEX Mini-Crimescope 400, SPEX Forensics (Horiba Instruments), Edison, NJ.

Meiji binocular microscope EMZ-TK, Meiji Techno, Tokyo, Japan.

Olympus BX51 microscope, Olympus Corp. Of America, Center Valley, PA.

Bruker Tracer III-IV+ portable handheld XRF, Bruker Corporation, Billerica, MA.

S1PXRF software, Bruker Corporation, Billerica, MA.

Microscope adapter (Olympus BX-51), Martin Microscope Company, Easley, SC.

Cargille Meltmount, Cargille Industries, Cedar Grove, NJ.

VHX-1000 series digital microscope, Keyence Corporation Of America, Itasca, IL.

Rigaku Spider R-Axis X-ray diffraction unit, Rigaku Corporation, The Woodlands, TX.

Jade 8 XRD software, Jade Software Company, Toronto, Canada.

ColorpHast pH-indicator strip, Merck Inc., Darmstadt, Germany.

Jasco FT/IR-420 spectrometer/Spectrum Manager software, Jasco, Inc., Easton, MD.

PerkinElmer Spectrum (v.4.3.3) software, PerkinElmer, Inc., Waltham, MA.

PVA-AYAF resin pellets, Talas, Brooklyn, NY.

Sunbrella outdoor fabric, Glen Raven Custom Fabrics, LLC., Glen Raven, NC.

UV-resistant polyester sewing thread, Coats and Clark, Inc., Greenville, SC.

Beckman ϕ 340 pH meter (with temperature), Beckman Coulter, Inc., Brea, CA.
Object: Costume
Culture: Tibetan/Newari (?)
Dimensions: Variable
Object no.: X69.300 A-J
Materials: Human bone, yarns, pigment, cuprous alloy
Date: Unknown
Owner: Fowler Museum at UCLA
Date of exam: 31 January 2013
Conservator: Ayesha Fuentes

1. Description

The object is an assemblage of fragments from a beaded Himalayan apron and associated accessories (Figure A.1). Individual components range in shape from small, round beads (approximately 1
Appendix A: Condition report and treatment proposal

cm diameter) to ornately carved plaques several centimeters wide, positioned at regular intervals within a yarn lattice. The piece is in good condition, preserved as several fragments with surfaces that range from polished to heavily stained.

2. Materials and techniques

It is the goal of this thesis to learn more about the materials and techniques of this specific object and to comment on evidence of its material history and previous uses. Traditionally, the plaques, beads, and associated ornaments of this assemblage are carved from human bone, though substitutions of ivory or animal bone are known in other examples (Loseries-Leick 2008). The beads and plaques are joined by fibrous yarn which are tied to fix them in place. There are also small metal ornaments and seemingly random deposits of paint or pigment. Small, woven textile fragments attached to the object indicate that it previously had a textile component, which is also common to these objects. There is very little art historical or technical scholarship on the construction of bone ornaments in the Himalayan region; related texts tend to articulate concepts of the objects’ significance as a component of traditional iconographies within Vajrayana Buddhist arts.

Figure A.1: Bone apron worn around the waist by traditional practitioner. Crown, arm bands, and other accessories (such as pectoral ornament, seen here) may also be worn as part of same ensemble. (Image from Loseries-Leick 2008)
Based on initial observations, the object is primarily composed of bone or a substitute of similar properties in terms of color, texture, opacity, and workability. The identification of bone is facilitated by areas of exposed cancellous bone in cross section or on the reverse of larger carved plaques. Beads, plaques, and other carved elements are almost all made of this same hard, dense, off-white material though the color and texture of each varies according to pigments, stains, or other residues. There does not seem to be any deliberate or iconographic application of small areas of pigment; colors on the surface of the object appear randomly distributed. The arrangement of colored residues are likely not the result of weathering or loss in an original painted layer. Beads and plaques have been strung on fiber yarns in pattern determined by the ritual tradition in which the object was made (Huntington and Bangdel 2003).

In visual comparisons to other bone aprons from the same area and religious tradition, key diagnostic features of the objects’ iconography are missing: namely, the five ornately carved ‘shields’ along the object top, now represented by flat, rectangular pieces stained slightly black to which the ornate shields were likely fastened (see ‘3.2.1 Condition: Apron- Structure’). This is supported by the general trend toward pastiche in the preparation of bone aprons in North American collections (see ‘Survey of similar objects, etc’ in later version of this report). Because the material culture of Vajrayana Buddhism relies heavily on strict iconometric regulation (Lama 1983; Loseries-Leick 2008), it should be possible to infer the specific ritual tradition to which a given bone apron correlates based on the carved decoration and represented figures on the object. Because this piece is fragmentary and original components have been removed (e.g. carved shields along top row of apron), this type of iconographic assignation is somewhat problematic.

To better discuss and analyze the object, it was first reorganized into an arrangement that corresponds to its original use and (presumed) composition. This rearrangement is based on literature
Appendix A: Condition report and treatment proposal

Figure A.2: Apron (Fowler # X69.300 A) with beaded fragments from other sections (Fowler #s X69.300 A and F, respectively). Fragments have been rearranged to represent presumed original position within the object.

Figure A.4 (above): Additional bone ornaments with unspecified relationship to ensemble (Fowler # X69.300 H-J).
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review as well as observations of similar objects in North American and UK collections. It is further
supported by observed technical and material similarities in fragments in terms of the knotting pattern of the
yarns between beads and bead size or color. The reorganization and distribution of individual pieces has
been mapped in Figures A.2-4, with respective Fowler accession numbers. This representation was key to
understanding the object in its fragmentary state and identifying individual components of the costume
including an apron, skull crown, arm band, and other fragments with unidentified function. The discussion
on the object condition and technical features that follows will identify sections of the costume in terms of
both their function (i.e. ‘crown’) and/or Fowler accession numbers.

3. Condition

The condition of the object is generally fair. It is physically and chemically stable with few structural
instabilities though insufficient support to the flexible elements might aggravate incipient damages from
original use or further disrupt the surface. Thumbnails of sections will be provided next to the condition
assessment for clarity.

3.1 Apron (Fowler # X69.300 A and F)
3.1.1 Structure

Yarns connecting the various elements have been broken in several places and some beaded sections of yarn have been lost. Broken yarns are prevalent along the top of the apron, particularly on the proper right (PR) side. The upper proper left (PL), near the carved corner piece, has several broken attachment points as well. Further breakages are found in the beaded length of yarn along the PL side, in
the far and middle PL short elements that extend from beneath the plaques, and in areas around the five skull plaques in the bottom row. For detailed locations of broken attachments, see Figure A.5. There are also some, short lost sections of beads and yarn but these may correspond to remaining fragments associated with the object which have yet to be re-placed. Some old breaks

Figure A.5: Locations of broken yarns between beaded sections; some breakages associated with loss of section.

Figure A.6: Arrow indicates position of an earlier repair using thread to secure a fragile connection point; the thread is different in ply, finish, and color from surrounding yarns.
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have been previously mended with thread (Figure A.6) which differs in finish and color from the other yarns in the object.

Connections are made by yarns strung through holes in the material and tied to fasten. Almost every plaque — including the skulls and smaller cross pieces in the mid-section and the large, flat and darkened pieces at top — has holes through which no yarns are connected. This may reflect rearrangement of the connections at some point in the life of the object or the absence of original material. Skull-shaped elements along the top row have been tied to the flat pieces; additional holes in the flat pieces likely indicate the previous connections of carved pieces which have been removed, lost, or destroyed (Figure A.7).

Structural problems within individual pieces are few. The upper PR corner piece has been broken along the outside edge, the fragment tied in place with yarns. Also along the top, in the PR corner, a replaced section (originally part of Fowler # X69.300 A fragments) has evidence of previous adhesive repair to the element. There are small losses on a few individual pieces but these have all been darkened with the same layer of dark brown grime or finish as the rest of the object surface, suggesting that they are not new.
Appendix A: Condition report and treatment proposal

Figure A.8: Distribution of colored residues or stain on material. Dark red squares indicate areas of staining (Figure A.9) or red paint; orange and yellow are pigment deposits (Figure A.10).

3.1.2 Surface

The entire surface of the object exhibits a similar finish in terms of the mottling of dark-brown and black residues with occasional areas of red staining and pigment or paint deposit (Figure A.8). There is no apparent pattern to the general distribution of colored materials except a prevalence of red material on the skull-shaped plaques, particularly in or around the recesses of their eyes. Colored materials are both stain (Figure A.9) and accumulated paint or pigment (Figure A.10), typically in recessed areas of the carved decoration. In some areas, colors have been deposited over each other, areas of red stain, or the dark brown layer. There is very little color on the reverse of the object, only small areas of red staining.

Metallic components (Figure A.11) have some compact corrosion layers and spot of lighter green but closer examination is needed to determine their condition. They appear stable.
Appendix A: Condition report and treatment proposal

The surface of the individual components is generally highly polished. Some areas, such as the reverse of larger plaques on the upper section, have potential evidence of wear and high polish from use. On some beads in the mid-PR bottom row of hanging beaded yarns have a small amount of crystalline, light grey substance forming within microscopic cracks.

3.3 Crown (Fowler # X69.300 B)

3.3.1 Structure

The bone material in this section is particularly rich in diagnostic information consistent with bone and particularly the cranium, including growth lines and cross sections revealing both cortical and cancellous bone.

There are broken yarn attachments on either side of the plaque to the PL of center. The surviving attachment here is fragile. There is a small vajra, or thunderbolt, shaped carving attached to the PR side of
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this piece with yarn. This same piece has a break along the base of the plaque, across the carved skeletal face (Figure A. 12).

As with plaques in the apron (Section 3.2), there are several holes to which no yarn is attached, indicating the object may have been rearranged or additional elements lost.

3.3.2 Surface

Pigments or paints are identical in appearance to those found on the apron and in a similar random distribution of small deposits in areas of recess. Areas of material with no coloration range in color from tan to dark brown. The lower section of the center plaque has a thicker, matte black surface deposit.

The reverse of the object reveals that areas of relief are highly polished and there is little stain or pigment. There is an area of black deposit on the mid-PR plaque. There are also less dense surfaces, which may represent the way in which the bone was prepared during object production or deterioration phenomena. A closer examination and consultation with appropriate resources is needed.

3.4 Arm band (Fowler # X69.300 C)

There are no broken connections in this section of the costume. However, some fragments in the assemblage (i.e. Fowler # X69.300F) may be associated with this section. The PL side plaque has empty
connection holes. This same piece has a small loss at the edge. Some beads in this section may be substitutions of wood or other material as they vary significantly in terms of finish, density, and color.

The surface of the object exhibits the same distribution of small areas of red staining on both beads and plaques. The plaques also have some paint/pigment deposits in colors similar to those seen in other sections. There are some older abrasions and surface disruptions that might represent tool marks on the central plaque. These have collected the same dark brown layer seen on the rest of the object surface. The reverse of carved plaques reveals features potentially useful for diagnosing the material (i.e. growth lines).

3.5 Other associated fragments (Fowler # X69.300 D - J)

The following objects are fragments or sections belonging to the ensemble but with as-yet-undetermined function.

3.5.1 Fowler # X69.300 D

There is a fragile yarn attachment on the PL plaque. All plaques have holes to which no yarn is attached. The surface is consistent with others within this costume assemblage in terms of light-dark brown color, red staining, and small deposits of paint in similar colors. The reverse of the object shows diagnostic features of bone as well as some areas of black deposit. The PL plaque also has some small spots of white, crystalline material which may be a deterioration phenomenon. Microscopic documentation and examination is needed.
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3.5.2 Fowler # X69.300 E

This section has two components with similar appearance and condition. Each plaque on both components has empty holes, indicating lost elements or rearrangement of the elements. There is a consistent distribution of red staining and pigment/paint deposit. On the flat, rectangular plaque of one section there is an area of green staining unique to this assemblage. The surface is generally polished with the brown layer in recessed areas.

3.5.3 Fowler # X69.300 F

This represents a collection of beaded fragments, some of which have been reintegrated into other areas of the assemblage (Figures 2 and 3). These are consistently light to dark brown in color with small areas of red stain. A collection of 11 beads on a newer, whiter yarn has been included in this section.

3.5.4 Fowler # X69.300 G

There is a broken yarn attachment to one side of a flat, rectangular side piece. The central component of this section is made with a material that is denser than the rest of the assemblage. Both flat pieces have additional, empty holes with no yarns attached.
Appendix A: Condition report and treatment proposal

There is a similar distribution of red staining and small areas of pigment and a polished surface with light to dark brown color. The exception is the central, round plaque which is darker in color with brown, orange and black residues. The reverse — and to lesser extend the obverse — of this piece also has a widespread formation of white, crystalline material on the surface (Figure A.13). There is evidence of tool marks on the reverse of the flat, rectangular pieces.

3.5.5. Fowler # X69.300 H-J

These three elements are similarly round and detached from any other section. Each has empty holes in four ‘corners’ to which no strings are currently attached, though there are fibers in the holes of # X69.300 I. All three of these sections have an inconsistent thickness across the breadth of the piece, revealing less processing of the original material in manufacture. Fowler # X69.300 J has an inconsistent finish on the carved surface where one area is more porous than the rest. This may indicate deterioration phenomena or be original to the object. All three of these elements have similar surface appearance, though slightly varied in color, with polish on areas of relief and traces of similar paints or pigments to the rest of the assemblage.
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4. Technical investigation and treatment proposal

The purpose of this research is to learn more about the materials and technology that have shaped this object and to assess its condition. The proposed scientific investigation utilizes both non-invasive imaging and spectroscopic techniques and minimally invasive analysis for the characterization of the fibers, beads, carved plaques, textile fragments, and applied colorants or residues found on the assemblage. This includes a thorough examination of the surface as well as the substrate and its attempted confirmation as human bone or an alternative material. Following a policy of minimum intervention, the emphasis of this project is a thorough characterization and assessment of the materials and stabilization, rather than treatment. The proposed investigation and treatment includes:

Non-invasive methods:

Documentation
- Comprehensive documentation and condition report
- Digital photography (cm)
  Reflected ultraviolet (UV) and visible (Vis) light
  Florescence photography (UV and Vis-induced)
- Digital reflected photomicrography (mm and micron)
  Construction of textile fragments
  Surface condition of metallic elements
  White, crystalline surface deposits on # X69.300 G and areas of apron
  Pigments applied in layers
  Tool markings
  Bone surfaces where structural diagnostic features are revealed or deterioration is suspected
- Reflectance Transformation Imaging (RTI)
  Morphological and manufactured features of carved plaques
Appendix A: Condition report and treatment proposal

X-Ray Floescence (XRF) spectroscopy
  - Examination of elemental composition of surface, particularly in colored areas
Consultation with appropriate experts on bone surface features
  - Tom Wake, zooarchaeologist at Cotsen Institute of Archaeology, UCLA
  - Wendy Teeter, physical anthropologist, at Wendy Teeter Center/Cotsen Institute of Archaeology

Minimally invasive methods (requiring micro-sampling of materials):
Polarized light microscopy (PLM)
  - Fiber analysis of yarn and textile
  - Pigment examination
X-ray diffraction (XRD) spectroscopy
  - Pigments
  - Crystalline accretions on bone surface, particularly # X69.300 G
Fourier-transform infrared (FTIR) spectroscopy
  - Analysis of compact dark brown surface residue pervasive on object

Treatment
  - Stabilization with appropriate adhesive of broken component on skull crown (# X69.300 B)
  - Solubility testing of adhesive residue on apron top component and replacement with suitable material if necessary
  - Preparation of stabilizing and compact storage mounts for object which reflect the use and shape of individual sections
  - Create recommendations on handling and display based on the findings of materials’ analysis and comparison with similar objects in other collections as well as research into the assemblage’s construction and function within its original ritual setting
Appendix A: Condition report and treatment proposal

References:


Hirx, J, Objects Conservator at Los Angeles County Museum of Art. Personal communication, 2 November 2012.


Appendix B1: Before treatment

X69-300_A_BT_1
Appendix B1: Before treatment
Appendix B1: Before treatment

X69-300_B_BT_02

X69-300_C_BT_01
Appendix B1: Before treatment
Appendix B1: Before treatment
Appendix B1: Before treatment

X69.300 E
Before treatment

X69-300_E_BT_02

X69.300 F
Before treatment

X69-300_F_BT_01
Appendix B1: Before treatment
Appendix B1: Before treatment
Appendix B1: Before treatment
Appendix B1: Before treatment

X69-300_I_BT_01

X69-300_I_BT_02
Appendix B1: Before treatment

X69-300_J_BT_01

X69-300_J_BT_02
Appendix B2: After treatment

X69-300_A_AT_01
Appendix B2: After treatment

X69-300_A_AT_02

X69-300_B_AT_01
Appendix B2: After treatment
Appendix B2: After treatment
Appendix B2: After treatment

X69-300_F_AT_02

X69-300_G_AT_01
Appendix B2: After treatment
Appendix C: XRF Spectra

15_metal bangle

17 (red) and 33 (blue)_skulls on apron bottom red comparison_detail_overlay_red filter
Appendix C: XRF Spectra

18_peach on apron top_detail_no filter

19_black stain on substrate (red) vs area with no black stain (blue)_detail_overlay
Appendix C: XRF Spectra

20. Crown plaque with dark stain (red) and without (blue) detail overlay

21. Peach on crown face detail no filter
Appendix C: XRF Spectra

21_peach on crown face_detail_red filter

23_bead with red stain (red) and without (blue)_detail_overlay
Appendix C: XRF Spectra

24. yellow (red) and adjacent area no yellow (blue) on horse_detail_overlay

26. orange on crown_detail
Appendix C: XRF Spectra

27_green (red) and adjacent area without (blue)_detail_overlay

28_X69-300_ivory_reverse (red) vs front (blue)_detail_overlay
Appendix C: XRF Spectra

29_yellow (red) and adjacent with no yellow (blue) on round element_detail with Ba L lines

30_dark red and black bead_detail_red filter
Appendix C: XRF Spectra

34_tassel_pesticide check_red filter

yellow on round element_detail
Appendix D: XRD Spectra

X69-300_41-white

X69-300_42-pink
Appendix D: XRD Spectra

X69-300_43-yellow

X69-300_43-yellow2
Appendix D: XRD Spectra

X69-300_44-green

X69-300_46A-bright orange
Appendix D: XRD Spectra
Appendix D: XRD Spectra

![XRD Spectra](image1)

![XRD Spectra](image2)

97
Appendix D: XRD Spectra

X69-300_52_beige_2
Appendix D: XRD Spectra

X69-300_53A_red

X69-300_53B_red
Appendix E: FTIR Spectra, measured in absorption

43_yellow_smoothed (red) and without smoothing (blue)

45_brown on crown
Appendix E: FTIR Spectra, measured in absorption

47_black

48_dark pink
Appendix E: FTIR Spectra, measured in absorption

50_pink on apron
Appendix F: Identification of human bone as a material in cultural objects

In museum practice, modified human bone is most often handled as an anthropological or archaeological artifact and less as a raw material for objects of cultural value. The following describes some of the criteria by which this assortment of bone ornaments was determined to be human and is intended to serve as a template for conservators or other non-specialist investigators interested in determining the species of origin for bone objects. The emphasis here is on noninvasive methods; during the course of this project no sampling was intended or undertaken to determine the special origin of the substrate materials.

Hydroxyapatite [Ca\(_{10}\)(PO\(_4\))_6(OH)\(_2\)] is the primary mineral component of bone. In this project, the presence of bone was first suggested by UV-induced visible fluorescence, where it fluoresces bright white (Figure F.1) and supported by XRF with the emission of characteristic x-rays for Ca and P (Figure F.2; see Section 3.4.1 as well as Appendix C). (Note that the white fluorescence of bone under UV light cannot be used exclusively to diagnose the presence of bone as other minerals fluoresce similarly.) XRF readings taken from the ivory

![Figure F.1](image1.png)

**Figure F.1** (left): UV-induced visible fluorescence image (\(\lambda_{ex}=300-400\)nm, 400-700nm capture) of crown (Fowler # X69.300B) showing blue-white fluorescence of bone mineral; dark areas are due to thicker layers of surface residue.

![Figure F.2](image2.png)

**Figure F.2** (right): Detail from an overlay of two XRF spectra with signals for Ca and P (Bruker handheld XRF, 40 keV, 1.9 \(\mu\)A, no filter, no vacuum, 180 seconds).
component on Fowler # X69.300 G displayed Ca and P from dahllite \([\text{Ca}_{10}(\text{PO}_4)_6(\text{CO}_3)\text{H}_2\text{O}]\), the main mineral component of ivory. Microscopic features must be used to distinguish between ivory and bone and the presence of Haversian pits in cortical or compact bone (the dense, outer layer) confirms the use of bone in the object (Espinoza and Mann 1999).

Haversian pits, or canals, are indicative of the Haversian system of bone formation and are critical in making determinations about the species of bone origin. These can be seen in cortical bone in transverse section (parallel to exterior surface) as dark apertures (Figure F.3) or in longitudinal section as lines parallel to bone grain (Figure F.4). Generally only humans, nonhuman primates and small mammals exhibit Haversian systems - also referred to as secondary osteons - exclusively (Hiller and Bell 2007). Other species, including large mammals, have both Haversian systems and plexiform bone, a formation without layers of concentric lamellae of bone mineral around a pit and, in transverse section under high magnification, resembles softly contoured and spongy stratigraphic layers with a 'maze-like' appearance (Figure F.5). Plexiform bone tends to have a linear orientation of osteons in comparison to bone with Haversian systems - also called lamellar bone - which has a more random distribution of canals surrounded by concentric layers of bone material. Generally speaking, adult humans do not have plexiform bone, except in areas of trauma where bone is quickly regrown and the presence of plexiform formations in cortical bone would exclude a human origin (Greenlee and Dunnell 2010).
With scanning electron microscopy (SEM), it is possible to examine the concentration of Haversian pits on the surface of a cortical bone, as well as average canal and/or system diameter (total diameter of concentric lamellae surrounding a pit, i.e. the diameter of the secondary osteon). These three features can be used to determine that a bone may be human, based on size and distribution, but cannot be used exclusively to determine the species of bone. Human Haversian system density is similar to that of chimpanzees; canal diameter is similar but generally larger than sheep and the range of human Haversian system diameter is within that of both goats and sheep and is similar to cow (Hiller and Bell 2007). It should be noted that humans have the greatest range of variation in the size of these morphological features (Greenlee and Dunnell 2010). These specific criteria of micro-structure can be assessed non-invasively with access to a polished transverse surface and sufficient magnification (> 500x). Thin sections are also an option (as is DNA testing) where

Figure F.5: Concentrically formed secondary osteons indicative of Haversian system in an adult human (left) vs plexiform bone, with linear, banded arrangement of primary osteons in a pig (right) (Greenlee and Dunnell 2010).

Figure F.6: Cortical bone used as substrate in the object was consistently between 3 and 19 mm thick with an average thickness of 6-8 mm.
Appendix F: Identification of human bone as a material in cultural objects

To better determine the species of origin for bone, gross morphological features are most useful. The cortical layer of human bone, especially in lower limbs and the cranium, is remarkably thick and dense amongst vertebrate species (Teeter, personal communication; Wake, personal communication). In the bone ornament ensemble examined here, the substrate for all components were between 3 and 19 mm thick (Figure F.6). The porous, cancellous (interior) bone had been removed by the original fabricators (Figure F.7) and only the cortical layer — wherein lies the diagnostic information discussed here — was used. In sections believed to be crania (4-6 mm thick with curved shape) the interior face (the reverse of the carved surface) was marked by the vascular morphology of capillary beds characteristic of the human cranium (Figure F.8). It is therefore the consistent thickness of areas of cortical bone — relative to its shape, density and micro-morphological features — that is most useful in diagnosing a human origin.

In summary, human bone can be distinguished from other vertebrates through micro-morphological features in cortical areas such as the presence of Haversian systems - and absence of plexiform formations.

Figure F.7: This piece was likely made from the lower limb of an adult human; note the thickness of the cortical layer and removal of porous, fragile cancellous material (Fowler # X69.300 A, reverse).

Figure F.8: This piece is an average of 5 mm thick with a curve and the characteristic patterning of capillary beds (instead of cancellous material) on the reverse indicating that it is a human cranium (Fowler # X69.300 C, reverse).

Figure F.9: The thickness of the cortical section of this bone (with cancellous material removed) and its density is indicative of human lower limb (Fowler # X69.300 D, reverse).
Appendix F: Identification of human bone as a material in cultural objects

- and their average diameter (190-325 µm), the average canal diameter (30-175 µm) and system density (5-42 per mm²) (Hiller and Bell 2007). These should be evaluated in relation to macroscopically observed features like a sustained area of thick (> 4 mm), dense and non-porous cortical bone. Cortical bone diameter can distinguish lower limbs (Figure F.9) and curved pieces that might be crania should be evaluated for the patterning of capillary beds on the interior surface. Because of their size and thickness, lower limbs and crania are, for the purposes of cultural objects, the most useful, durable, and likely materials (Teeter, personal communication; Wake, personal communication). If there is any ambiguity, the best suggestion for conservators is to consult with a professional forensic anthropologist or zooarchaeologist who can interpret bone features at a macro or microscopic level and provide the best estimation of the species of origin.

<table>
<thead>
<tr>
<th>Method of analysis</th>
<th>What to look for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it bone? XRF</td>
<td>Ca and P</td>
</tr>
<tr>
<td>UV-induced visible fluorescence</td>
<td>Bright white</td>
</tr>
<tr>
<td>Microscopy (low magnification)</td>
<td>Haversian pits/canals on transverse surface of cortical bone</td>
</tr>
<tr>
<td>Is it human? Macroscopic examination</td>
<td>Average thickness of cortical bone between 4 and 16 mm; Capillary bed patterning on curved cortical surfaces (average thickness 4-7 mm) strongly indicate human crania</td>
</tr>
<tr>
<td>Microscopy (high magnification)</td>
<td>Absence of plexiform (maze-like formation) bone</td>
</tr>
<tr>
<td>Microscopy (high magnification)</td>
<td>Average canal diameter (30-175 µm)</td>
</tr>
<tr>
<td></td>
<td>Average system diameter (190-325 µm)</td>
</tr>
<tr>
<td></td>
<td>Average system density (5-42 per mm²)</td>
</tr>
<tr>
<td>Microscopy (high magnification)</td>
<td>Random distribution of systems/pits or short linear arrangements of osteons</td>
</tr>
</tbody>
</table>

Table F.1: Summarizing the distinction of human from other species by non-invasive examination of macro and micro-morphological features of cortical bone.
Appendix G: Analysis of lac resin with experimental and UV-induced visible fluorescence imaging

During review and documentation of the condition of the object, a red stain was noticed on several components of the bone ensemble (Figures G.1 and G.2). The stain is most often on beads but also the reverse and sides of carved plaques (Figure G.3), though never on the obverse face. With microscopy, the stain was observed as a coloration of the substrate surface and not as a distinct layer of applied material with appreciable thickness. Under UV-induced visible fluorescence imaging, areas of the red stain appeared as shades of orange, red, and purple, ranging in intensity from dull where trace amounts were present to bright where the stain survived as a thick layer (Figures G.4 and G.5). The orange-colored fluorescence is a noted feature of shellac (Koob 1998). Shellac is a resin produced by the lac insect (*Kerria lacca*), a native to areas of south and southeast Asia, and comes in colors ranging from yellow to brown to scarlet.

There is ample evidence for the historical and continued use of lac dye, the colorant in shellac, used in the material cultural of the Himalayan region, most notably as an ink for thangka paintings (Jackson and Jackson 1976; Jackson and Jackson 1984; Mass et al. 2009). Jackson and Jackson (1976) provide a detailed explanation of the refinement of stick lac (raw, resinous material excreted on sticks) into lac dye by master dye-makers in the Himalayan region. The stick lac is refined by heating in solution and the addition of a...
Appendix G: Analysis of lac resin with experimental and UV-induced visible fluorescence imaging

Figure G.4 (above): Reflected visible light shows red staining irregularly applied to the beads

Figure G.5 (below): UV-induced visible fluorescence imaging (λex=300-400nm, 400-700nm capture) show variety of colors included orange (red arrow) and purple (yellow arrow)
Appendix G: Analysis of lac resin with experimental and UV-induced visible fluorescence imaging

Figure G.6: Solution without added sodium bicarbonate (left) is brownish-orange after three hours of cooking; on the right the more basic solution is purple

Figure G.7: Two solutions have been cooked a total of 6 hours and are dark red/purple in color; the color of the water in the boiler reveals that the dye is water soluble

basic (ph>7) material such as the native zhu-mkhan (species unknown) leaf or soda. The authors note that the cooking time and temperature are crucial for controlling the color of the dye.

To gain a better understanding of the processes described by Jackson and Jackson (1976) and their relationship to the object, an experimental was undertaken to refine stick lac resin into lac dye. Approximately 10 mL of stick lac resin (20% w/v solution with ethanol) was divided into two test tubes and placed in a double boiler over low heat (50°C) for three hours. The resin in ethanol was a brown, opaque solution with 1-3mm sized black and dark brown particles. Approximately 3 mg of sodium bicarbonate (NaHCO3) was added to one test tube at the beginning of heating; after three hours without coming to a boil, this solution was a dark purple color and the other was brownish-orange (Figure G.6). These solutions were left for three days, after which the solution to which the soda had been added was further divided into three parts. The first part was left as it was at the end of the first cooking; the second was put in a test tube in double boiler; the third was also placed in a test tube in the double boiler with the addition of a further 3 mg of sodium bicarbonate. Each tube was given an additional 2 mL of deionized water. These two were cooked for an additional three hours without boiling. After heating, both were dark red/purple in color (Figure G.7) and left to cool. All four solutions were tested with a Beckman ϕ 340 pH meter with pH probe; the results are given in Table G.1, below.

The four solutions were painted onto a chicken bone that had been manually sanded and polished (Figure G.8). Like human bone, chicken bone is composed largely of hydroxyapatite [Ca10(PO4)6(OH)2]. The bone, with four solutions of lac resin dried on the surface, was documented with reflected visible light...
and UV-induced visible fluorescence, in comparison with a section of beads from the object with red staining (Figures G.9 and G.10). Though the fluorescence of the beads was faint, close examination reveals areas of orange and purple fluorescence. The experimental chicken bone also displayed chromatic variations relative to the preparation of the resin, with different shades of orange and red.

Table G.1: Tabulated results of experimental refinement of stick lac resin

<table>
<thead>
<tr>
<th>Solution number</th>
<th>Color</th>
<th>Length of cook time</th>
<th>Amount of NaHCO3 added</th>
<th>pH</th>
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<tbody>
<tr>
<td>1</td>
<td>Dark orange/brown</td>
<td>3 hrs</td>
<td>0 mg</td>
<td>4.8</td>
</tr>
<tr>
<td>2</td>
<td>Red orange</td>
<td>3 hrs</td>
<td>3 mg</td>
<td>5.8</td>
</tr>
<tr>
<td>3</td>
<td>Purple</td>
<td>6 hrs</td>
<td>3 mg</td>
<td>9.4</td>
</tr>
<tr>
<td>4</td>
<td>Maroon/purple</td>
<td>6 hrs</td>
<td>6 mg</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Figure G.8: Each lac resin solution has been applied to the surface of a polished chicken bone with a synthetic bristle brush; the position of each solution has been numbered according to the information in Table G.1
Appendix G: Analysis of lac resin with experimental and UV-induced visible fluorescence imaging

Figure G.9 (above): Reflected visible light shows red staining on beads and painted chicken bone.

Figure G.10 (below): UV-induced visible fluorescence imaging ($\lambda_{ex}=300-400\text{nm}$, $400-700\text{nm}$ capture) shows variety of colors on chicken bone and, faintly, on beads included orange (red arrow) and purple (yellow arrow).
Appendix G: Analysis of lac resin with experimental and UV-induced visible fluorescence imaging

It can be suggested that there is more than one type of lac dye present on the object, where different colors under UV-induced visible fluorescence may correspond to different dye batches or methods of preparation. It is difficult to assess chromatic variations in reflected visible light because of the condition of the object surface. Variations in color may, however, also be attributed to other materials on the surface of the object mixed with or laid over the red stains, the age of the red stain, the amount of surviving stain given the object’s use in its original setting, or other factors not reviewed here.
<table>
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<th>Material type/Target</th>
<th>Object type</th>
<th>Fowler #</th>
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<tr>
<td>1</td>
<td>PMG</td>
<td>White crystalline in bone grain</td>
<td>Beads</td>
<td>X69.300 F</td>
</tr>
<tr>
<td>2</td>
<td>PMG</td>
<td>Compact green corrosion product</td>
<td>Metal bangle</td>
<td>X69.300 A</td>
</tr>
<tr>
<td>3</td>
<td>PMG</td>
<td>Black stain on substrate</td>
<td>Crown plaque</td>
<td>X69.300 B</td>
</tr>
<tr>
<td>4</td>
<td>PMG</td>
<td>Dark brown grains from cancellous bone</td>
<td>Crown plaque</td>
<td>X69.300 B</td>
</tr>
<tr>
<td>5</td>
<td>PMG</td>
<td>Black layer</td>
<td>Crown plaque</td>
<td>X69.300 B</td>
</tr>
<tr>
<td>6</td>
<td>PMG</td>
<td>Red stain, tool marks</td>
<td>Beads</td>
<td>X69.300 C</td>
</tr>
<tr>
<td>7</td>
<td>PMG</td>
<td>Bone substrate</td>
<td>Arm band plaque</td>
<td>X69.300 C</td>
</tr>
<tr>
<td>8</td>
<td>PMG</td>
<td>Bone substrate, tool marks</td>
<td>Arm band plaque</td>
<td>X69.300 C</td>
</tr>
<tr>
<td>9</td>
<td>PMG</td>
<td>Red, black layers</td>
<td>Plaque</td>
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<td>Textile fragment</td>
<td>Textile</td>
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<tr>
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<td>PMG</td>
<td>Tool marks</td>
<td>Beads</td>
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<td>White-grey deposits, substrate</td>
<td>Plaque (ivory)</td>
<td>X69.300 G</td>
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<td>White-grey deposits</td>
<td>Plaque (ivory)</td>
<td>X69.300 G</td>
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<td>Yellow deposit</td>
<td>Plaque</td>
<td>X69.300 J</td>
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<tr>
<td>15</td>
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<td>Cuprous alloy</td>
<td>Metal bangle</td>
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<tr>
<td>16</td>
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<td>Cuprous alloy</td>
<td>Metal bangle</td>
<td>X69.300 A</td>
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<td>X69.300 A</td>
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<td>Plaque</td>
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<td>Composite deposit layers</td>
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<td>X69.300 B</td>
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<td>XRF</td>
<td>Red stain</td>
<td>Beads</td>
<td>X69.300 C</td>
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<td>X69.300 D</td>
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<td>25</td>
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<td>Red, black layers</td>
<td>Plaque</td>
<td>X69.300 D</td>
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<td>Green deposit</td>
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<td>X69.300 E</td>
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<td>X69.300 J</td>
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<td>Dark brown grains from cancellous bone (proteins)</td>
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<tr>
<td>32</td>
<td>MCT</td>
<td>Dark brown grains from cancellous bone (proteins)</td>
<td>Crown plaque</td>
<td>X69.300 B</td>
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<td>Red deposit</td>
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<td>Fiber (pesticide residues)</td>
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<td>Plaque</td>
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<td>FT, PLM</td>
<td>White, waxy spots</td>
<td>Plaque</td>
<td>X69.300 D</td>
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Appendix H: Proformas

**Proforma_01**

- **Families:** Feb. 2020
- **Proforma:** No. 1
- **Date:** 20/20
- **Families:** Feb. 2020
- **Proforma:** No. 3

**Proforma_02**

- **Families:** Feb. 2020
- **Proforma:** No. 2
- **Date:** 3/3/13
- **Families:** Feb. 2020
- **Proforma:** No. 4

**Proforma_03**

- **Families:** Feb. 2020
- **Proforma:** No. 2
- **Date:** 3/3/13
- **Families:** Feb. 2020
- **Proforma:** No. 4

**Proforma_04**

- **Families:** Feb. 2020
- **Proforma:** No. 2
- **Date:** 3/3/13
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- **Proforma:** No. 4
### Appendix H: Proformas

#### proforma_05

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</tr>
<tr>
<td>Date</td>
<td>Proforma ID</td>
<td>Description</td>
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<tr>
<td>------</td>
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<td>-------------</td>
</tr>
<tr>
<td>3/1/11</td>
<td>#6</td>
<td>Method of analysis: PM0, reflected light. Description of crest: reverse surface with black layer, possibly deposit of both, worn-out PVA. Notes: dark layer is thin, compact, but well-varied thickness; some debris; quartz or similar material at bottom of crest. Notice: mast point or polished area over dark layer, which has some protein or deposit. <strong>Note:</strong> On 15 Jan, under microscope, mast at 7x.</td>
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<td>Method of analysis: PM0, reflected light. Description of crest: reverse surface with black layer, possibly deposit of both, worn-out PVA. Notes: dark layer is thin, compact, but well-varied thickness; some debris; quartz or similar material at bottom of crest. Notice: mast point or polished area over dark layer, which has some protein or deposit. <strong>Note:</strong> On 15 Jan, under microscope, mast at 7x.</td>
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<td>------</td>
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<td>3/1/11</td>
<td>#8</td>
<td>Method of analysis: PM0, reflected light. Description of crest: reverse surface with black layer, possibly deposit of both, worn-out PVA. Notes: dark layer is thin, compact, but well-varied thickness; some debris; quartz or similar material at bottom of crest. Notice: mast point or polished area over dark layer, which has some protein or deposit. <strong>Note:</strong> On 15 Jan, under microscope, mast at 7x.</td>
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# Appendix H: Proformas

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<td><strong>Method of analysis:</strong></td>
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<tr>
<td><strong>Description:</strong></td>
<td>Fragment of fabric/fragment of textile with white crystalline material on surface, includes also on surface with dark brown /gray as well</td>
</tr>
<tr>
<td><strong>Purpose of sampling:</strong></td>
<td>FMC only, record of white substance on surface</td>
</tr>
<tr>
<td><strong>Image:</strong></td>
<td><img src="image_url_1" alt="Image" /></td>
</tr>
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**Note:** There is a hole in the center where a metallic wire is visible on top of the fabric, brown layers material is very thin, can be removed but it is well adhered to surface.

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<table>
<thead>
<tr>
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<td>Fragment of fabric/fragment of textile with white crystalline material on surface, includes also on surface with dark brown /gray as well</td>
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<td><strong>Image:</strong></td>
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</tr>
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</table>

**Note:** Yellow and brown with black and cyan paint in detail, fabric is grey, worms, pearls are painted, larger ring, parts of ring are 2.3 mm, 7.5 mm.

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**Note:** Spots of white crystalline material on painted area ofaming face (to be debated), some evidence of fine pigment as well as dark brown /gray layer on surface beneath white crystalline spots, areas of high-relief are split.

Also some beige deposits (unidentified?)

Surface then back then beige then yellow spots.

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Appendix H: Proformas

proforma_13

proforma_14

proforma_15

proforma_16
Appendix H: Proformas

proforma_17

proforma_18

proforma_19

proforma_20
Appendix H: Proformas

**proforma_21**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Very strong Pb signals in this area, with smaller peaks from Cu, Pb, etc.
2. Strong Sb signal

**proforma_22**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Very strong Pb signals in this area, with smaller peaks from Cu, Pb, etc.
2. No Pb signal

**proforma_23**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

**proforma_24**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)
2. No Pb signal

---

**proforma_25**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

**proforma_26**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

---

**proforma_27**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

**proforma_28**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

---

**proforma_29**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

**proforma_30**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

---

**proforma_31**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)

**proforma_32**

- **Method of analysis:** XRF
- **Sample:** Earliest STR, ear, vacuun

**Notes:**
1. Small peaks for Pb, Cu, Al, Cu, and Pb (very small)
Appendix H: Proformas

**proforma_25**

Method of analysis: XRF
No fire, 450°C, 1,000°C, vacuum

Description of area: obsidian/plaque with black layer and red/pigment; over these layers there are visible deposits of white crystalline material

Purpose of sampling: to evaluate elemental composition of layers close to surface with goal of eventually assessing their relationship to white deposits

Notes:
- Ca, Mg, K (loss not noticed this on other specimens), with Fe, Ni, Zn, Cu, Sn
- No fire
- Is the surface layer organic? Pyrolysis needed

**proforma_26**

Method of analysis: XRF
No fire, 450°C, vacuum

Description of area: obsidian/plaque that is solid black with bright orange pigment within cracks

Purpose of sampling: to evaluate elemental composition of bright orange pigment on surface

Notes:
- Denser Fe peak, no Al peaks
- Few Fe and Ni in base
- No fire
- Contact is not close but spectrum looks good; placement also not precise with small areas of pigment on surface

**proforma_27**

Method of analysis: XRF
No fire, 450°C, 1,000°C, vacuum

Description of area: obsidian/plaque that is solid black with white crystalline material

Purpose of sampling: to evaluate elemental composition of white deposit on surface

Notes:
- Rb, Sr, Ti, Mg, Fe, Cu, Zn, Ni, Sn
- Contact is not close but spectrum looks good; placement also not precise with small areas of pigment on surface

**proforma_28**

Method of analysis: XRF
No fire, 450°C, vacuum

Description of area: obsidian/plaque that is solid black with bright orange pigment within cracks

Purpose of sampling: to evaluate elemental composition of bright orange pigment on surface

Notes:
- Denser Fe peak, no Al peaks
- Few Fe and Ni in base
- No fire
- Contact is not close but spectrum looks good; placement also not precise with small areas of pigment on surface

---

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Appendix H: Proformas

proforma_29

proforma_30

proforma_31

proforma_32
### Appendix H: Proformas

<table>
<thead>
<tr>
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<th>Description</th>
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<td>proforma_37</td>
<td>Description of seeds: color is dark brown; texture is not specified. Purpose of sampling: to determine type of fiber used for construction.</td>
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<tr>
<td>proforma_38</td>
<td>Description of seeds: color is brown; texture is not specified. Purpose of sampling: to determine type of fiber used for construction.</td>
</tr>
<tr>
<td>proforma_39</td>
<td>Description of seeds: color is dark brown; texture is not specified. Purpose of sampling: to determine type of fiber used for construction.</td>
</tr>
<tr>
<td>proforma_40</td>
<td>Description of seeds: color is dark brown; texture is not specified. Purpose of sampling: to determine type of fiber used for construction.</td>
</tr>
</tbody>
</table>

**Notes:**
- Regular internal markings perpendicular like others; regular exostosis with smooth central component, very straight; innermost is oblong yellow and peculiar in regard internal, beads have local spines.
- At 25x, very straight fibres; some other fibres.
- At 50x, central part parallel to axes, starting to look very dense but having trouble getting an exposure of this feature/case.

**Families:**
- Faura sp. (not specified)
- Faura sp. (not specified)
- Faura sp. (not specified)
- Faura sp. (not specified)

**Image:**
- Image of seeds with fibrous texture.
- Image of seeds with fibrous texture.
- Image of seeds with fibrous texture.
- Image of seeds with fibrous texture.
Appendix H: Proformas

**proforma_41**

**proforma_42**

**proforma_43**

**proforma_44**
Appendix H: Proformas

**proforma_45**

**Families:**

**Date:** 5/2/13

**Method of analysis:** pyrolysis, FTIR

**Description:** a large, brown, opaque deposit on surface of container, color uniform, intact, solidified material well-adhered to surface and container (crude resin), solidified material, color incorporates fine particles of material, material is removed from areas of defoliation, erosion.

**Purpose of sampling:** to determine composition of unaltered material.

**Image:**

**Notes:**

- Pyrolysis: clearly organic, burned very quickly with little ash/charred.
- Material is large with spots of darker brown, particularly in raised areas.
- Material is slightly soluble in xylene, but soluble in xylene, and very slightly soluble in acetone.
- Color varies from brown to dark brown, indicates presence of gums and small amount of inorganic material.

---

**proforma_46**

**Families:**

**Date:** 5/2/13

**Method of analysis:** XRD, FTIR

**Description:** a large, brown, opaque deposit on surface of container, color incorporates fine particles of material, material is removed from areas of defoliation, erosion.

**Purpose of sampling:** to determine composition of unaltered material.

**Image:**

**Notes:**

- A-line powder, easily delaminated from container, color consistent throughout material layers.
- B-came off faster, more difficult to separate from substrate.

---

**proforma_47**

**Families:**

**Date:** 5/2/13

**Method of analysis:** pyrolysis, FTIR

**Description:** a large, brown, opaque deposit on surface of container, color incorporates fine particles of material, material is removed from areas of defoliation, erosion.

**Purpose of sampling:** to determine composition of unaltered material.

**Image:**

**Notes:**

- Material comes down from fiber substrate, easily lighter brown, where disturbed.
- Pyrolysis: small crystals, birefringent, organic material.

---

**proforma_48**

**Families:**

**Date:** 5/2/13

**Method of analysis:** pyrolysis, FTIR

**Description:** a large, brown, opaque deposit on surface of container, color incorporates fine particles of material, material is removed from areas of defoliation, erosion.

**Purpose of sampling:** to determine composition of unaltered material, whether it has organic component as well as inorganic.

**Image:**

**Notes:**

- Color is consistent throughout layers of material, somewhat well-adhered to substrate.
- Pyrolysis: confirms birefringent, organic material is incorporated.
### Appendix H: Proformas

**proforma_49**

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<th>Fossil accession</th>
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<td>568.302.2</td>
<td>568.302.2.B</td>
<td>49</td>
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</table>

**Method of analysis:** XRD

**Description:** SEM bright field at tip of flake. Hard shell attested to by thin lamellae running parallel to crystal surface. Yellow grains, generally oriented into crystal faces and depressions, also in surface. Pores filled with eosin-positive, amorphous material. Lamellae run parallel to lamellae.

**Purpose of sampling:** To determine mineral composition of porcelain material

**Image:**

**Notes:**
- Well-adhered to surface, color consistent throughout sample

---

**proforma_50**

<table>
<thead>
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<th>Date</th>
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**Purpose of sampling:** To determine mineral composition of porcelain material

**Image:**

**Notes:**
- Well-adhered to surface, color consistent throughout sample

---

**proforma_51**

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<th>Fossil accession</th>
<th>Proforma ID</th>
</tr>
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<td>51</td>
</tr>
</tbody>
</table>

**Method of analysis:** XRD

**Description:** SEM bright field at tip of flake. Hard shell attested to by thin lamellae running parallel to crystal surface. Yellow grains, generally oriented into crystal faces and depressions, also in surface. Pores filled with eosin-positive, amorphous material. Lamellae run parallel to lamellae.

**Purpose of sampling:** To determine mineral composition of porcelain material

**Image:**

**Notes:**
- Difficult to separate, very well-adhered to surface in sample comes off as a fine powder

---

**proforma_52**

<table>
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**Description:** SEM bright field at tip of flake. Hard shell attested to by thin lamellae running parallel to crystal surface. Yellow grains, generally oriented into crystal faces and depressions, also in surface. Pores filled with eosin-positive, amorphous material. Lamellae run parallel to lamellae.

**Purpose of sampling:** To determine mineral composition of porcelain material

**Image:**

**Notes:**
- Difficult to separate, very well-adhered to surface in sample comes off as a fine powder

---

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proforma_53

proforma_54
References:


Brennan, J. 2013. Personal communication, 23 April 2013.


Fiber Reference Image Library. fril.osu.edu. (Accessed 20 April 2013)


Kim, J. 2013. Personal communication, 22 April 2013.


