

The use of “soft” X-ray radiography in determining hidden construction characteristics in fiber sandals

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Abstract

The use of soft X-ray radiography is evaluated as to its potential use in perishable artifact analysis. Thirty-five plain weave pointed-toed Anasazi sandals were X-rayed and the radiographs examined. This technique permitted the viewing of hidden construction characteristics as well as missing structural features in many of the samples. Soft X-ray radiography is a powerful analytic tool not only because of its potential uses, but also because it is non-destructive, inexpensive, and readily available.

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1. Introduction

In comparison to such datasets as lithics, ground stone, or ceramics, perishable artifacts are a relatively rare find in archaeological contexts. They are usually confined to dry sites such as caves and rock shelters where conditions favor their preservation. Such is the case with Anasazi yucca sandals. Despite the fact that sandal research can help to define cultural groups, interaction, and demography (Hays-Gilpin et al, 1998; Geib, 2000; Taylor, 2003), the research potential of some sandal types has been hampered by our inability to observe internal features as well as some external features absent due to wear and/or decomposition. This article assesses the use of soft X-ray radiography in prehistoric perishable research by analyzing a sample of plain weave pointed-toed Anasazi sandals. The technique is successful in making visible otherwise hidden construction characteristics (warp construction and arrangement) as well as missing structural features (tie systems).

2. Research value of fiber sandals

Prehistoric foot ware has been used by Native American groups in North America for at least the last 10,000 years (Connolly and Cannon, 1999; Geib, 2000), during which time fiber sandals have been one of the most common forms. Sandals can be subsumed under the label of basketry, for, as Adovasio has stated, sandals are “really baskets worn on the feet and thus have the power to elucidate the same range of issues as other formal classes of plant-fiber artifacts” (Adovasio, 2006:2). Much of the construction process involved in the creation of basketry is subconsciously dictated by a culture’s technological norms and passed from one generation to the next with very little change (Adovasio, 1986). As a result, a number of highly standardized technological choices are embedded within these artifacts. In fact, Adovasio states “no class of artifacts normally available to the archaeologist for analysis possesses a greater number of culturally bound yet still visible attributes than does basketry” (Adovasio, 1986:45). In sandals, these embedded technological choices may include the materials used, preparation of the materials, the spin, ply, and twist of warps and wefts, how the wefts engage the warp, the morphological shape of the sandal, and the type of tie system used.

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Variation and continuity of these features can be used to study the diffusion of technology, interaction among groups, and act as temporal markers (Drooker, 2000; Geib, 2000; Hays-Gilpin et al., 1998; Taylor, 2003; Webster and Hays-Gilpin, 1994).

3. Anasazi sandals

The Anasazi (or Ancestral Puebloans) inhabited parts of the American Southwest from roughly 500 BC to 1350 AD. Throughout this time they produced fiber sandals, most of which were made of yucca. Due to differences in embedded technological choices, Anasazi sandals were composed of a number of types based on differing morphological characteristics and construction sequences (Deegan, 1993; Hays-Gilpin et al., 1998). Dating of Basketmaker or Anasazi sandals is problematic, in that the time periods into which they have been grouped have been assigned almost entirely through cross-dating. Anasazi sandal types are generally divided into three categories based on construction technique: twined, braided, and plain weave.

Twined sandals, in one form or another, occurred throughout the Basketmaker and Puebloan time periods (~500 BC to 1300 AD) (Hays-Gilpin et al., 1998 and references therein). Most Anasazi sandal research has been focused on this type of sandal, that although unified by a basic fabric construction method (twining), was composed of a variety of shapes, tie systems, and construction sequences (Kidder and Guernsey, 1919; Deegan, 1992, 1996, 1998; Webster and Hays-Gilpin, 1994; Targe, 1995; Hays-Gilpin et al., 1998). Braided (or plaited) sandals seem to have been the most common type of sandal during the Pueblo III period (~1100–1300 AD), yet examples have also been found in Basketmaker and early Puebloan contexts (Hays-Gilpin et al., 1998). Generally, braided sandals were constructed using either an over-one under-one or over-two under-two pattern, while tie systems were primarily toe-heel and side loop styles (Kidder and Guernsey, 1919; Cattanch, 1980; Morris, 1980; Magers, 1986).

Plain weave sandals have received the least amount of research among the sandal types. This style is recognized as having been used during both Basketmaker and Puebloan time periods, although in differing frequencies and styles. One of these styles was the plain weave pointed-toed sandal that is generally thought to date to the early Puebloan periods (PI–PII, ~700–1100 AD; but see Anderson, 1969 for later examples) (Fig. 1). They were constructed using a plain weave, meaning the warp and weft are set at 90 degrees to one another and usually interlace in an over-one, under-one pattern. Pointed-toed sandals are found throughout the Anasazi region, although their relative distribution has not been studied (Kidder and Guernsey, 1919; Kankainen, 1995; Janetski and Hall, 1983; Judd, 1926; Shutler, 1961; Baldwin, 1938; Bartlett, 1934). Their overall shape and style have been described by Kidder and Guernsey as “neatly made in rights and lefts and shaped to conform to the outline of the foot; the toe is brought to a sharp point, the heel is sometimes square, sometimes rounded” (Kidder and Guernsey, 1919:103).

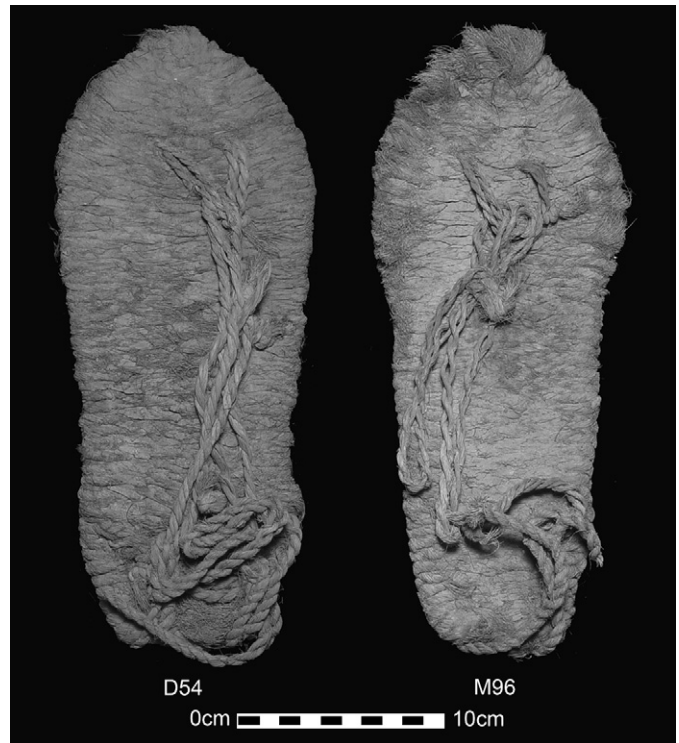


Fig. 1. Examples of pointed-toed sandals from Antelope Cave, Arizona.

4. Shortcomings of current analytical techniques

Unfortunately, a number of construction characteristics that are essential in defining technological boundaries and investigating cultural interaction among the Anasazi are indeterminable for many plain weave pointed-toed sandals. Internal construction characteristics, such as the number, arrangement, ply, and twist of warps, as well as toe and heel formation may be hidden to analysis as a tight weave conceals these characteristics within the body of the artifact. Although the construction features are present, they remain indeterminate as they cannot be seen. Earlier researchers, such as Earl and Ann Morris, resorted to dissecting certain sandal types to determine construction characteristics and sequences (Deegan, 1998), yet this practice is obviously destructive to the artifact and is now avoided. Other sandal features, such as the tie system, are often missing from the sandal, having been removed in antiquity or lost through decomposition. These features suffer not from their hidden presence, but from their conspicuous absence. Currently, the analytical features within both of these categories (present but hidden and once present/now absent) must be classified as indeterminate when performing sandal analysis.

5. “Soft” X-ray radiography

X-ray radiography is commonly used today in both medicine and industry to produce images of the internal structure of an object. To produce such images, X-rays are passed through an item. The higher the density of an object, the less X-rays are able to pass through it. X-rays which encounter

no resistance strike a photographic plate located behind the object and create a black image when processed. The less X-rays to strike the photographic plate (due to the density of the material), the lighter in color the image. Very dense objects (such as bone or metal) are represented by a white or light colored image. An image produced by X-rays, called a radiograph, is actually the shadow of an object bombarded by X-rays (Hiss, 2003).

X-rays are commonly referred to as soft or hard, the difference primarily being the strength of the source. Low photon energy sources of around 30,000 V generally produce X-ray energies between 15 and 30 keV (kiloelectron volt) and are referred to as “soft” X-rays. This type of X-ray is often used in medicine to perform soft tissue analysis, thus their common use in mammograms. Hard X-rays are produced using a high photon energy source and can penetrate denser materials. Although radiography is often used in archaeological applications, usually this involves the use of hard X-rays. For example, Symmons has recently used X-ray radiography to measure bone density of a faunal assemblage from Çatalhöyük (Symmons, 2003), Allen and Munsey used hard X-rays to examine a ceramic figurine wrapped in a Fremont cradle board (Allen and Munsey, 2002), and Rice has noted several applications of hard X-rays in ceramic analysis (Rice, 1987). The use of hard X-rays is unsuitable for many perishable materials of low density, however, as it allows the radiation to pass through the artifact uninhibited and does not produce recognizable images. In contrast, soft X-rays are much more suited to the examination of perishable artifacts such as textiles or basketry (O’Connor and Brooks, 2007a,b). To illustrate this approach, 35 plain weave pointed-toed sandals were analyzed using soft X-ray radiography.

6. The sample

The sandals used in this analysis were recovered from Antelope Cave (1515 NA 5507), located on the Uinkaret Plateau in Mohave County, northwestern Arizona. The cave has been looted since the 1920s and excavated by a number of institutions beginning with Robert Euler of the Museum of Northern Arizona in 1954. Euler’s excavation was relatively small, but recovered 33 complete or nearly complete sandals and 23 sandal fragments. Brigham Young University has been the most recent organization to excavate the site (once in 1983 and again in 1986) and has produced six radiocarbon dates ranging from roughly 2000 BC to 1000 AD (Janetski and Hall, 1983; Janetski and Wilde, 1989). Based on these dates, diagnostic materials (including projectile points and ceramics), site location, and the range of artifacts recovered, Janetski and Wilde concluded that Antelope Cave was a hunting and processing station that was “occupied sporadically over several thousand years, beginning around 3500 years ago until ~1100 AD,” with a period of maximum use around 900–1000 AD (Janetski and Wilde, 1989:104).

For this project a total of 35 specimens were submitted to soft X-ray radiography. All 33 complete or nearly complete sandals recovered during Euler’s 1954 excavation of Antelope

Cave were analyzed, as well as two complete sandals (also from Antelope Cave) donated to Brigham Young University by a private collector.

7. Methods

All X-rays were performed on a General Electric Senogra-
phe mammography unit at Utah Valley Hospital in Provo, Utah in 2006. Preparation of the artifacts was limited to removing any remaining soil matrix left from excavation and small rocks impressed into the bottom of the sandals. Excessive amounts of soil would distort the radiograph making the image less clear, while small rocks appear as solid white objects within the sandal. When the removal of rocks was deemed inappropriate however, a note was made as to their location to account for their presence on the radiograph. Images were usually clearest and showed the most detail when using 35 kVp (kilovoltage peak), although depending on individual artifact thickness settings were adjusted to between 25 and 36 kVp.

Depending on how the film is loaded into the unit, as well as how it is processed, the radiograph produced may appear as a mirror reflection of the artifact. This can cause the researcher interpreting the image to mistake S twist fibers for Z twist and vice versa. A simple way to rectify this situation is to place a metal paper clip bent into a ‘Z’ shape next to the artifact being X-rayed. This ‘Z’ will show up clearly on the radiograph and can be used to orient the reader (see for example Fig. 2).

Radiographs were developed on location and later scanned into a computer using a desktop scanner. A number of options are available when digitizing radiographic images (O’Connor and Brooks, 2007b). As scans of radiographs using reflected light are of very low quality, transmitted light was used. This can be done by using either a scanner with a transmitted light option, or by setting up a light source above the radiograph as it lay on the scanner and leaving the flatbed open. When the second option is used, a translucent piece of plastic must be placed between the radiograph and the light source to evenly distribute the light. Images were scanned in grayscale at 300 dpi.

8. Results and discussion

The results of this study show that previously undetectable features were made viewable using soft X-ray radiography. The use of this technique allowed for the observation of internal construction elements hidden on the inside of the sandal body. One of the primary issues this technique can help to resolve is the arrangement of warps within pointed-toed Anasazi sandals. Previous descriptions have not commented on the internal arrangement of warps or postulated differing patterns (Kidder and Guernsey, 1919; Kankainen, 1995). Kidder and Guernsey (1919:103) suggest that the four or six warp sandals were made by “looping either two or three cords, the open ends of the loops being at the heel, the closed ends forming the toe.” Folding or wrapping the warps at the toe would seem to make sense from a technical standpoint, as this configuration would create a strong structure, is simple, and could be



Fig. 2. Radiographs of four warp pointed-toed sandals. The two inner warps splice into the two outer warps.

constructed quickly and easily. However, radiographic analysis of the four warp sandals from Antelope Cave suggested that the inner warp was not folded, wrapped, or tied to the outer warp; but was instead spliced at the toe with the loose ends running towards the heel (Fig. 2). Physical analysis of three specimens (1515 NA5507 D.97, 1515 NA5507 M.47, 86.017.00. Bag 2) in which the internal toe structure was partially visible confirmed the radiographic data. In all three cases the inner warp was *spliced* into the outer warp. Why this method was employed is perplexing in that splicing the warps would seem to create a structure that was weaker, more complex, and required more time investment than folding or wrapping. Whatever the reasons (which at this point remain unknown), the conclusion that the warps are spliced is particularly interesting and likely an area in which isochrestic variation or technological style could be examined between cultural groups. Although these findings cannot be applied to other Anasazi sandal collections without accompanying verifying analysis, they do represent at least one construction alternative.

Radiographic analysis of the three six-warp sandals from Antelope Cave (1515 NA5507 D.53, NA5507 M.105, NA5507 M.110) suggested that the outer warp was completely unattached at the toe to the inner four warps (Fig. 3). Physical analysis of the one sandal (1515 NA5507 M.110) in which the internal toe structure was partially visible confirmed the radiographic data. The differing construction characteristics used in four and six warp sandals show potential to be important

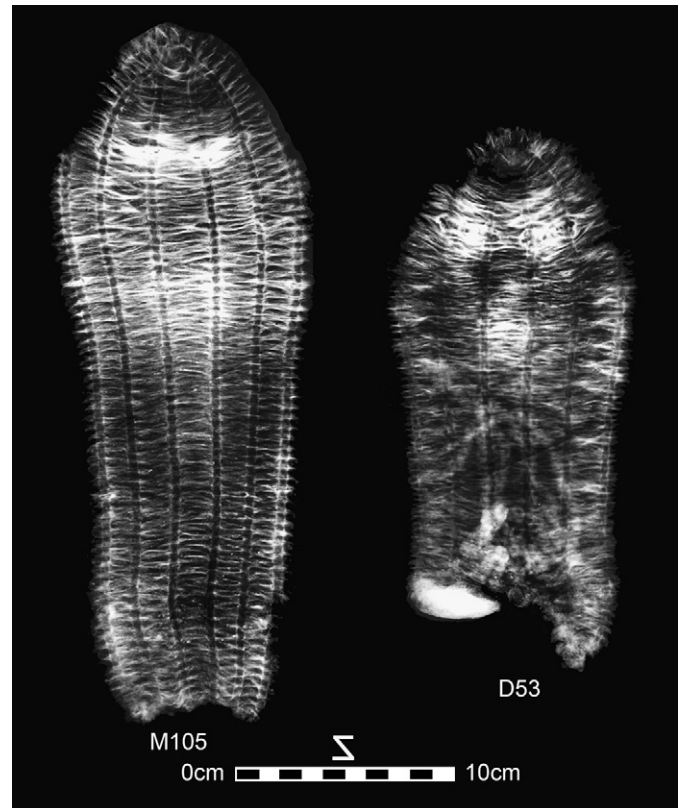


Fig. 3. Radiographs of six warp pointed-toed sandals. Inner four warps are separate from the outer two warps.

features in delineating technological traditions that may represent cultural boundaries.

For sandals in which no warps were exposed, radiographic analysis allowed for the observation of the warp's ply and twist. Sandal number 86.017.003 Bag 2 is an excellent example in which the construction characteristics of the warps can be clearly seen through soft radiography. Based solely on this technique we can classify this specimen as having 2-ply S-spun Z-twist warps (Fig. 4). Particularly interesting in this regard, is the fact that all sandals analyzed had the same warp construction of 2-ply S-spun Z-twist, even though similar yarn used in the tie systems varied in type. Research by Minar (2000), Maslowski (1996), and others (Haas, 2001; McBrinn, 2005; Petersen and Wolford, 2000) has shown that spin, ply, and twist of simply cordage can be an embedded technological choice within a cultural system, and can be used to distinguish between groups. This may also be true for warp elements in Anasazi sandals, although this awaits testing in a larger sample.

In addition to making visible previously hidden construction characteristics, soft X-ray radiography also allowed for the analysis of features once present but now missing. Virtually all sandals must have at one time employed some type of tie system to hold the sandal to the foot. Due to their fragile nature, however, many artifacts are found with incomplete tie systems, or none at all. As the type of tie system may be an important cultural marker, their identification is of particular interest. Fortunately, among the pointed-toed sandals in this

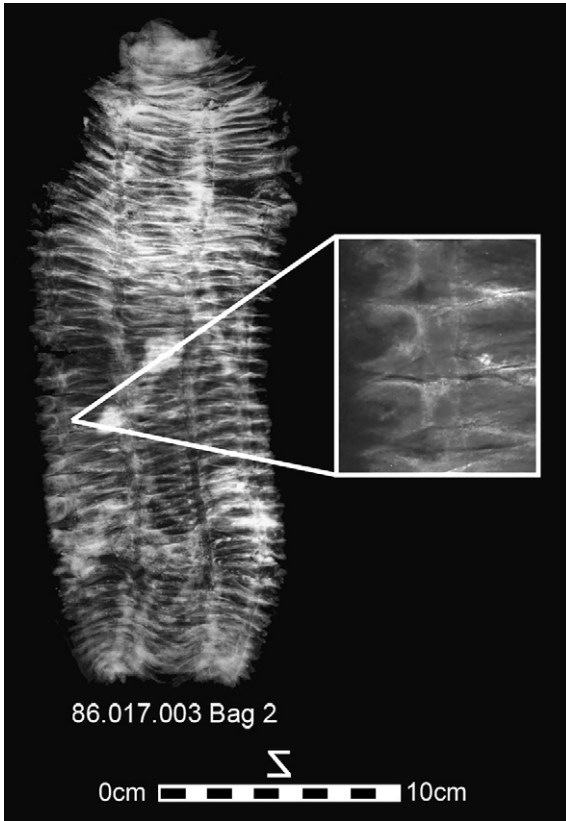


Fig. 4. Radiograph of four warp pointed-toed sandal. Inset shows ply and twist of the warp. Note that the 'Z' reference point above the scale is reversed, meaning that although the warp appears to be 2 ply S twist it is actually 2 ply Z twist.

analysis the tie system is anchored to the warps of the sandal. Although individual elements of the tie system may break off from the sandal, the break usually occurs outside of the body of the artifact, leaving the anchor points still attached within the specimen. These anchor points create dense spots within the sandal that show up clearly in a radiograph. By comparing radiographs of sandals that have retained their tie systems against those that have not, the analyst is able to determine the type of tie system that would have been present in artifacts in which it is now absent (Figs. 5 and 6).

9. Conclusions

Research on prehistoric sandals has often been frustrated by the archaeologist's inability to observe internal construction characteristics as well as features that were once present but have since been removed or deteriorated. The use of soft X-ray radiography has been shown to be effective in determining the number, arrangement, ply, and twist of warps within the sandal body, as well as the type of tie system employed even when the exterior portion is absent. Although these specific uses are beneficial to sandal experts, soft X-ray radiography can assist in the analysis of numerous types of archaeological materials, particularly perishable artifacts. Adding to its desirability are the facts that it is non-destructive, inexpensive, and readily available.

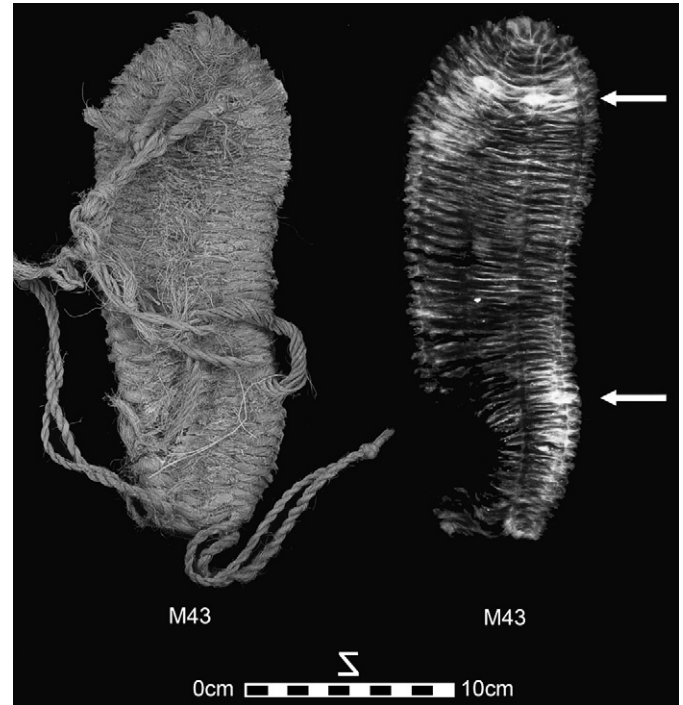


Fig. 5. Photograph and radiograph of sandal M43. Note the position of the anchoring of tie system on the photo and matching white areas on the radiograph.

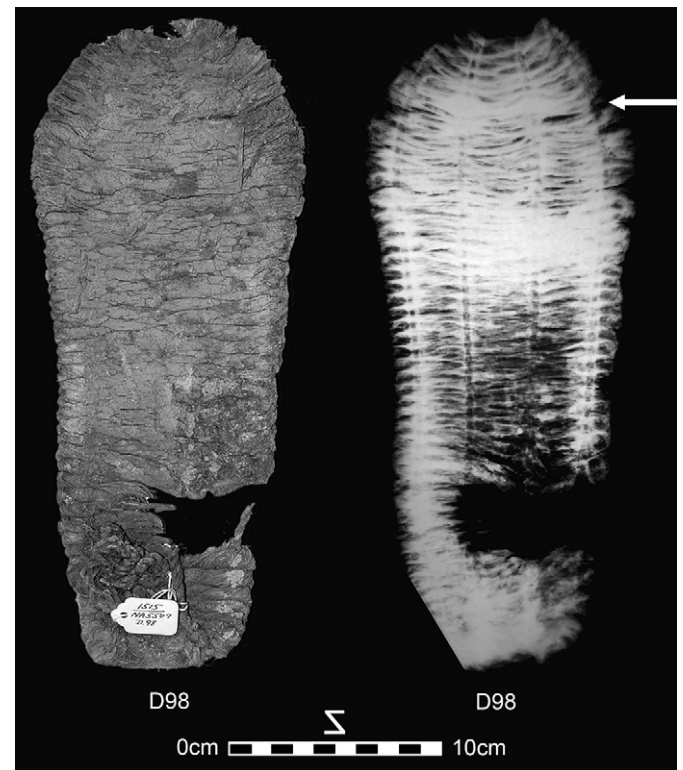


Fig. 6. Photograph and radiograph of sandal D98. Note the absence of tie system in the photo and the white areas indicative of toe-loop anchors in the radiograph.

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