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THE BASKETMAKER II FIBER INDUSTRY OF BOOMERANG SHELTER, SOUTHEASTERN UTAH: A SYNTHESIS OF CORDAGE MORPHOLOGY ANALYSIS AND EXPERIMENTATION

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ABSTRACT

The analysis of archaeological fiber industries encompasses the study of cordage and associated materials such as tools, raw materials, and byproducts. In addition to cordage, this research explores dimensions of fiber analysis that archaeologists often neglect. The Basketmaker II people of Boomerang Shelter left behind clues of an important industry that drew upon the faunal and botanical fibrous materials of the local landscape. From the many fibrous materials, most notably *Yucca angustissima*, the early agriculturalists of the Colorado Plateau created cordage as an essential part of their material culture. This study of the Boomerang Shelter Basketmaker II fiber industry explores the implications of site use and labor input through an analysis of archaeological fiber assemblage and experimental archaeology.

RESUMEN

El análisis arqueológico de la industria de las fibras abarca el estudio del encordado y los materiales asociados: herramientas, materias primas y derivados. Adicionalmente al encordado, esta investigación explora las dimensiones del análisis de fibras que los arqueólogos generalmente ignoran. Los pobladores del Boomerang Shelter en el periodo Basketmaker II dejaron rastros de una importante industria que utilizaba materiales botánicos fibrosos y la fauna del paisaje local. Los primeros agrónomos de la Meseta de Colorado (Colorado Plateau) crearon el encordado de la multiplicidad de materiales fibrosos, principalmente *Yucca angustissima*, como una parte esencial de su cultura material. Este análisis de la industria de las fibras del periodo Basketmaker II en el Boomerang Shelter indaga las implicaciones del uso del lugar y de la mano de obra mediante un análisis arqueológico del ensamble de las fibras y arqueología experimental.

Just as kinship systems bind the people of small-scale societies into cultures, so do fiber industries bind the technologies of such cultures. Fiber processing and the resulting cordage are a central technology for preindustrial societies. Understanding the processes of fiber and cordage industries can provide archaeologists with critical lifeway information. Unfortunately, the remains of prehistoric fiber industries rarely survive decomposition, and fibers usually only survive in rare waterlogged environments or extremely dry archaeological sites.

Basketmaker II people were the first farmers of the Colorado Plateau (Smiley and Robbins 1997), and like all prehistoric societies, depended heavily on fiber industries. Basketmaker II cave sites are extraordinary in the preservation of fiber and many other perishable artifacts. Here I present a study of the fiber industry from one such site, Boomerang Shelter (42Sa24771), located on Comb Ridge in southeastern Utah (Figure 1). The site was excavated under the direction of Dr. Francis Smiley of Northern Arizona University during the summer of 1999 when a portion of the rock shelter was excavated. This research represents an analytical and experimental pilot study of archaeological cordage and the associated materials constituting a fiber industry assemblage. More specifically, the study focuses on the labor processes and spatial implications of yucca fiber processing.

The excavations of Boomerang Shelter recovered 423 cordage artifacts, totaling more than 60 m in length and 130 g of weight of cordage and representing a large portion of the site's artifact assemblage. My purpose in examining the Boomerang Shelter fiber assemblage was to observe trends in the Basketmaker II cordage industry. Previous literature only touches upon the subject of archaeological cordage in the northern Southwest, and most conclusions about Basketmaker cordage remain speculative and ambiguous. As Kent (1983:43) asserts, "The dominant impression emerging from this discussion of fibers...must surely be that there is a need for precise, intensive analyses of [the] raw materials, using archaeological specimens of known origin." The report that follows derives from analysis of archaeological specimens and the use of experimentation to arrive at a model for cordage analysis in Southwestern archaeological sites.

IDENTIFYING MATERIAL TYPES AND SPECIES

Material variation is a primary variable of a fiber study. Knowing the materials that a society used for twisting into cordage dictates the direction of the analysis because each fiber type requires one or more specific processes to procure and extract the fibers from the plant or animal. Fibers are elongated cells that are associated with the vascular tissue of plants or that constitute various animal tissues. The term cordage encompasses all manner of twisted or braided fibers (Hoover 1974). Fibrous plant materials fall into four categories including structural, bast, bark, and seed fibers (Abril 1999; Emery 1966; Hoover 1974; Kent 1983). These include the hard leaf fibers of monocots, the bast fiber sources of herbaceous dicots, and the inner bark of woody dicots (Abril 1999; Emery 1966; Hoover 1974; Kent 1983). Monocots and dicots have distinct arrangements of fibers. Simple parallel veination characterizes the leaves of monocots, as with the leaves of yucca, cattail, and rush. The leaves of dicots contain a dendritic veination, and the stems contain a ring-like fibrous layer under the bark known as the cambium, as with juniper, milkweed, and Indian hemp. Botanists term the structural fibers of monocots "hard" fibers because a chemical called lignin

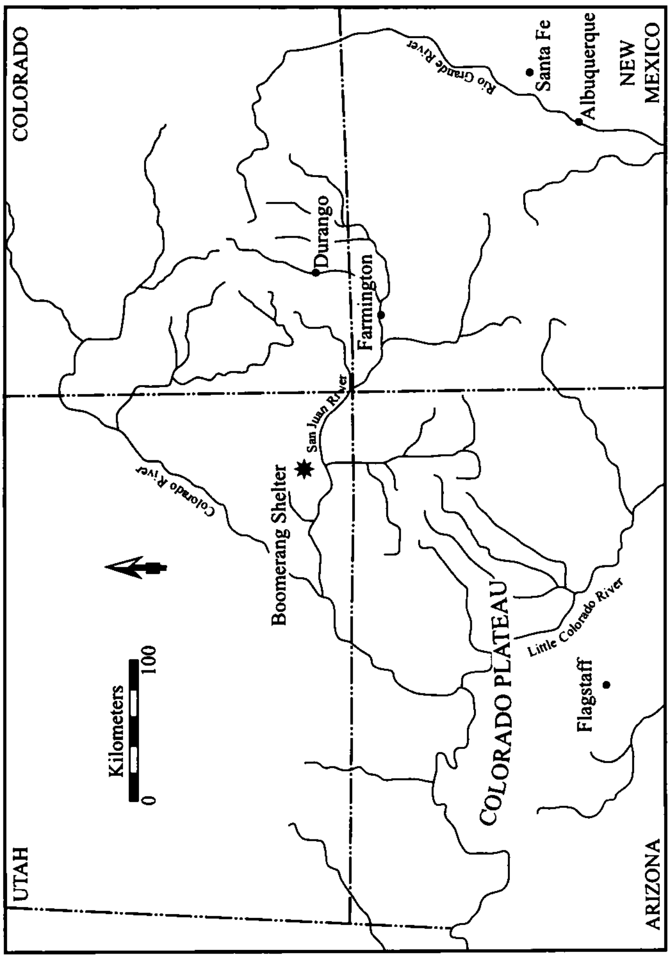

Figure 1. Location of Boomerang Shelter in the Four Corners region of Utah.

cements many smaller fibrils together to constitute the stiff fibers. Dicot fibers do not contain lignin and are termed "soft" fibers.

Basketmaker II peoples expended significant amounts of energy on harvesting and processing such fibers. In the vicinity of Boomerang Shelter, suitable botanical fibers for cordage manufacture include the leaf fibers of yucca (*Yucca* sp.), cattail (*Typha* sp.), and rush (*Juncus* sp.). Suitable bark fibers for cordage manufacture include the cambium fibers of the cottonwood tree *(Populus fremontii)* and the juniper tree (*Juniperus* sp.). Plants in the vicinity of Boomerang Shelter that produce bast fibers include milkweed (*Asclepias* sp.) and Hooker's Primrose *(Oenothera hookeri)*. Indian hemp *(Apocynum cannabinum)* has also been suggested as a Basketmaker II bast fiber source on the Colorado Plateau (see Guernsey and Kidder 1922; Kidder and Guernsey 1919; Lindsay et al. 1968), but the plant has not been reported to exist in the Boomerang Shelter Wash or nearby Comb Wash. In addition to plant fibers, Basketmaker II people could have had access to such animal fibers as sinew, rawhide, tanned hide, gut, animal hair, and human hair. Only hair (human and perhaps dog) and sinew occur in the form of cordage in the Boomerang Shelter cordage assemblage, but with a relatively low frequency.

Before analyzing the archaeological cordage from Boomerang Shelter for material type, I first developed a comparative collection. Samples of these fiber types were collected within 1 km of Boomerang Shelter in the summer of 1999. Various methods were used to process the fibers of each plant into workable cordage materials, each of which was plied into two-ply Z-twist cordage with a thigh-rolling method. I then observed the plied fibers of each at 40X magnification. This level of magnification made it possible to distinguish the basic types of structural, bast, bark, sinew, and hair fibers. In a few important instances, distinctions could be made to the genus level, but because 40X does not allow the viewer to see the cellular morphology, it was not possible to differentiate between most species at that magnification (see Bell and King 1944; Jakes 2000 for a discussion of fiber analyses at higher levels of magnification). Nonetheless, observations at this level of magnification revealed identifying markers that may be useful for material identification in the field, especially when trying to differentiate between bast and yucca fibers.

My examinations of the various fiber types led to the following observations. Yucca fibers differ from rush and cattail fibers in the diameter of the fibers and the presence or lack of pulp. Yucca fibers are round to flat in cross section and have little or no pulp when processed. Yucca fibers can also occur in an extremely fine form. The fibers of the yucca plant consist of many finer fibers called fibrils (see Figure 2), which can be separated from the primary fibers. Some of the yucca cordage in the Boomerang Shelter assemblage (26%) consists of these fine yucca fibers. Observing the primary fibers amidst the fibrils in fine cordage makes possible the distinction between bast fibers and fine yucca fibers at a macro level. Cattail and rush have weaker fibers that cannot be separated from the pulp without destroying the fibers, and thus, cordage of cattail and rush show no degree of fiber extraction.

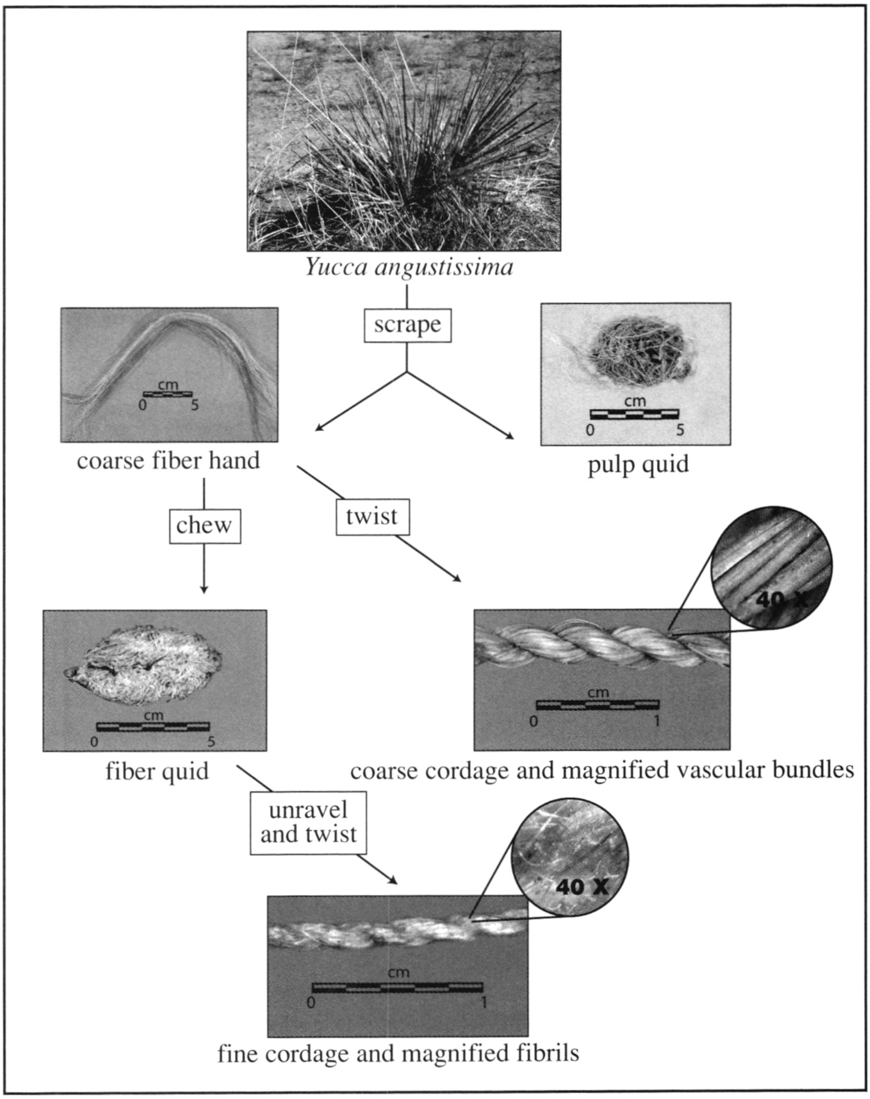

Figure 2. A flow chart depicting an experimental method for processing coarse and fine yucca cordage. Examples from each stage of processing were found in the Boomerang Shelter fiber assemblage.

Table 1. Cordage Fiber Material Frequencies and Proportions at Boomerang Shelter

Material	Frequency	Combined Mass (g)	Combined Length (cm)
Yucca sp.	409 *(96.7%)*	123.7 *(94.2%)*	5901.6 *(96.3%)*
Hair (human and animal)	7 *(1.7%)*	3.4 *(2.6%)*	125.8 *(2.0%)*
Yucca/Hair Combination	1 *(0.2%)*	1.4 *(1.1%)*	— —
Juniperus sp.	3 *(0.7%)*	2.2 *(1.7%)*	40.6 *(0.7%)*
Sinew	1 *(0.2%)*	0.4 *(0.3%)*	48.7 *(0.8%)*
Unknown	2 *(0.5%)*	0.2 *(0.1%)*	13.7 *(0.2%)*
Total	423 *(100.0%)*	131.3 *(100.0%)*	6130.4 *(100.0%)*

Bast fibers consist of the fine fibers of dicots and usually comprise the cambium of herbaceous plants. A fine degree of separation and a silky texture distinguish bast fibers from most other fibers. My experimental bast cordage had flakes of bark adhering to the fibers. The inner bark of woody plants, known commonly as bark fibers, are distinguishable by a poor degree of fiber separation. These fibers tend to cluster in relatively thin flat sheets. Juniper fibers are easily distinguishable by their reddish brown color.

Animal fibers, such as sinew and hair, vary greatly. Sinew fibers exhibit a gray to white color and the fibers cement together when wetted and twisted. Hair fibers, whether from human or animal, are distinct. Under low magnification, the fibers are round in cross section, relatively thick, and smooth. I did not distinguish between human, dog, and other animal hair fibers at 40X.

Using the comparative collection, I was able to identify the fibrous materials that constitute the 423 fragments of cordage from the Boomerang Shelter site. Table 1 summarizes the types and frequencies of cordage material excavated at Boomerang Shelter. The data show that yucca made up the material of choice of people at Boomerang Shelter for fiber manufacture.

In the past, some archaeologists have identified a percentage of Basketmaker II cordage at other sites as the bast fibers Indian hemp *(Apocynum cannabinum)*. Although *A. cannabinum* is known to occur in archaeological sites in the American Southwest, the extent of its use as a fiber source may be overestimated due to misidentification (Kent 1983:20). I believe that much of the fiber identified in the literature as *Apocynum* may in fact be yucca, and that this misidentification stems from the fact that archaeological yucca fibers exist in both coarse and fine forms. Although yucca fibers are considered "hard" fibers, fine yucca fiber cordage equals and even exceeds the softness of many "soft" bast fibers (see also Cosgrove 1947; Kent 1983). Lindsay et al. (1968:80) recovered 17 percent of what they considered bast fiber cordage from Sand Dune Cave, a multi-component site with a Basketmaker II component. This number is comparable to the 26 percent of fine yucca cordage from Boomerang Shelter. Lindsay et al. (1968) admitted difficulty in distinguishing bast and structural fibers and suggested that some of the cordage that they identified as bast fiber might, in fact, be finely shredded yucca fiber. At first glance, cordage made from such fibers resembles neither coarse yucca fibers nor bast fibers.

The degree of refinement of yucca fibers results from the degree of maceration, or the degree of separation, of the coarse fibers. Fine yucca fibers resemble bast fibers in texture and color, but a closer look at the fibers under a binocular microscope reveals that many of the archaeological cordage fragments, which first appear to be bast fibers to the unaided eye, are actually fine yucca fibers. The distinction becomes clear when one observes grades of yucca fiber that fall between coarse and fine. In such instances, both the hard fibers and the fibrils are visible. Even in the finest yucca cordage, remnants of the primary fibers may still be evident.

After distinguishing between bast and yucca fibers and determining that yucca fibers composed the majority of the assemblage, I then examined the degree of yucca fiber maceration. It is difficult to categorize the degree of secondary fiber separation, but for the sake of this study, I applied an ordinal scale, grouping the yucca fiber cordage into categories of coarse, medium, and fine. In fibers of medium preparation, primary yucca fibers are only partially separated, and fibrils are visible at 40X magnification. In fine cordage, primary fibers are thoroughly macerated, perhaps better than 80 percent, and mostly fibrils are visible.

The extent to which prehistoric peoples macerated fibers correlates with the intended function of the cordage. Coarse and fine cordage differ in two ways: ease of manufacture and suppleness, two inversely proportional variables. Fortunately for the Basketmaker II people, coarse yucca fiber, when compared to other fiber materials, is a very strong product, and extracting mass quantities is relatively simple. The Boomerang Shelter cordage assemblage consists of 44 percent coarse yucca cordage. Coarse and medium fiber cordage are associated with the foundations of rabbit fur and turkey feather cordage, objects requiring a large amount of cordage and little suppleness. Fine cordage maintains a suppleness that rivals cotton, making it a suitable material for the manufacture of finer fabrics. The extra work required in further macerating the fibers made this fiber type slightly less common (26 percent). In between coarse and fine refinement, medium refined cordage occurs at 26 percent.

While yucca fiber refinement variability likely reflects cordage function, the relative percentage of each type (fine, medium, and coarse) at a given site may additionally dictate stylistic preferences. Minar (2000) shows that when concerned with the direction of twist, manufacturers of cordage almost invariably twist in the direction that they were taught. Accordingly, preindustrial ethnic groups show certain stylistic preferences with respect to twist direction. Where yucca fibers are used for cordage manufacture, the degree of fiber processing offers ethnic groups another variable to control. I suggest that the relative percentages of fine, medium, and coarse fibers at a given site can be useful in defining cultural preferences for cordage manufacture.

CORDAGE MORPHOLOGY

In addition to material types and species, other important morphological attributes of cordage include the orientation of the twist, the length, the diameter, and the mass. Such morphological characteristics provide important criteria for fiber industry analysis. Hoover's (1974) definition of cordage, all manner of twisted and braided fibers, does not include unrefined materials such as unprocessed leaves, vines, and withes. Such materials may serve a similar function to cordage, but do not require the same complexity of process in manufacture. The manufacture of prehistoric cordage is often highly consistent. Rohn (1971:114), impressed by Basketmaker II cordage manufacture, states, "The uniformity both in diameter and in degree, is so great in this twine, that we can assume the motor habits of manufacture were usually quite constant."

Twist Orientation

Plies make up the constituent parts of cordage (Figure 3). Each ply has an initial spin, which is described as "Z" or "S" (Minar 2000; Kent 1983). In cordage manufacture, the plies are twisted around each other so as to interlock. Twist is also described as "Z" or "S" and is almost always opposite the direction of the spin. Simple cordage requires two or more plies and one episode of twisting (Baker 1993). Complex cordage involves reversing two or more existing lengths of cordage around each other. Two or more strands of simple cordage make up the plies of a piece of complex cordage (Figure 3).

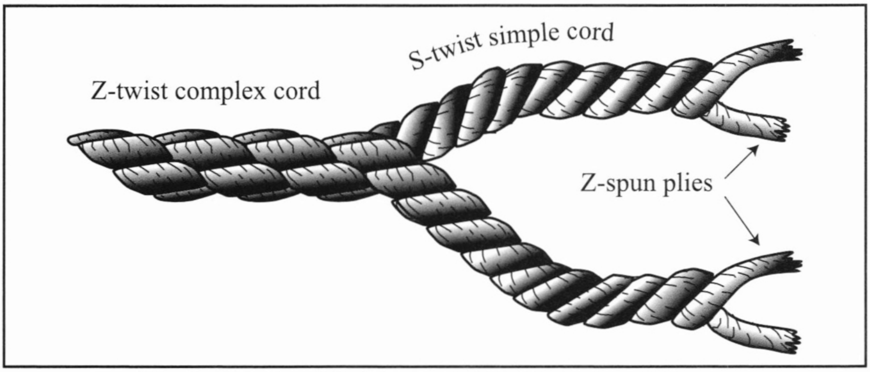

Figure 3. Illustration showing spin versus twist and simple versus complex cordage.

Of the 423 specimens in the Boomerang Shelter assemblage, 78 percent are S-spun, Z-twist, simple-plied types. Another 7 percent of the assemblage is complex cordage that has a final Z-ply for a combined 85 percent of the cordage artifacts with a final Z-twist. The rest of the assemblage consists of 11 percent simple S-twist cordage and 2 percent complex S-twist cordage. Hoover (1974) explains that two-ply cordage occurs universally and is ubiquitous because of ease of manufacture and strength. Manufacturing two-ply cordage requires less effort than manufacturing multi-ply or complex cord and proves stronger than single-ply cord.

Why, then, does Z-twist predominate in the Basketmaker II cordage assemblage? Minar (2000:85) suggests four possible explanations for twist direction including production method, fiber type, handedness, and the presence of ethnic groups in temporal and geographic space. Minar considers the former three possibilities to be unlikely causalities for twist direction and argues that twist direction is instead a learned motor skill related to a maker's social group. In an inter-site cordage analysis in the Midwest, Maslowski (1996) provides convincing evidence that twist direction is, in fact, culturally dictated.

The ratio of Z- to S-twist cordage at Boomerang Shelter is 85:13 (2 percent is unidentifiable). In support of the hypothesis that cultural preferences influence twist, it is interesting to note that Z-twist occurs significantly more than S-twist in both complex (78:11, Z:S) and simple cordage (7:2, Z:S). This suggests a cultural preference for Z-twist cordage. In order to produce complex Z-twist cordage, at least two lengths of simple S-twist cordage must first be manufactured. In other words, the people of Boomerang shelter did not simply ply readily available simple Z-twist cordage into complex cordage. Instead, they intentionally manufactured simple S-twist cordage so that the complex cordage would exhibit the preferred final Z-twist. One problem with this hypothesis, however, lies in the fact that considerable mixing of excavation levels due to looting has occurred. Boomerang Shelter consists almost entirely of a Basketmaker II component, but there is some evidence of an archaic component.

A similar analysis of Z:S ratios at surrounding sites might supply data to refine possible ethnic boundaries in the northern Southwest. Studies of cordage type distributions in other regions have shown that different ratios of Z:S cordage exist at different sites and at different times (see Maslowski 1996; Minar 2000; Petersen and Wolford 2000). Because there are only two main variations (Z or S) in cordage types, cordage cannot be considered a cultural determinant, but it can certainly add to our understanding and defining of cultural boundaries in time and space when considered in conjunction with other stylistic variables (such as degree of maceration) and other material remains. Cordage analysis is especially important for the Basketmaker II cultural period because fibers make up such a large portion of many Basketmaker II artifact assemblages and because ceramics, which are so heavily relied upon for ethnic markers at later Southwestern sites, are not available at Basketmaker II sites.

Tightness

Cordage also varies in the degree of "tightness" of the original twist, which is introduced during manufacture. The angle at which the twist occurs reveals the "tightness" of cordage. The degree of twist occurs between 0 and 90 degrees as a length of cordage is oriented parallel to a 0 degree plane. Because the angle of the twist in a single piece of cordage can vary greatly, I separated the twists into two broad categories: tight (greater than 30 to 60 degrees) and loose (greater than 60 to 90 degrees).

Stewart (1997) more accurately indexed the number of twists per centimeter with respect to diameter to indicate cordage tightness. However, for the purpose of my study I only found it necessary to measure the tightness by the angle of twist. Seventy-seven percent of the cordage displays a tight degree of twist, 18 percent displays a loose twist, and five percent of the cordage could not be discerned. This emphasis on tightness at Boomerang Shelter suggests that cordage represented an important technology and one in which the people were highly proficient.

Length

Cordage remnants at Boomerang Shelter tend to be less than 15 cm in length and range from 0.5 cm to 70 cm with a median value of 12 cm. The array of specimen length data exhibits a right-skew but is unimodal. Because the length of any given piece of cord measures less than that of the longest yucca leaves found at the site, one might conclude that the people at Boomerang Shelter did not splice most of their cordage to create longer lengths. However, my dissections of several pieces of cordage revealed joints where two lengths of fiber had been overlapped, indicating that splicing did indeed occur. The artifacts, then, clearly consist of fragments of used cordage that were either cut to a desirable length, broken, or subject to postdepositional processes.

Diameter

The distance between two imaginary parallel lines tangent to the outermost arc of the spiraling plies represents the diameter of cordage (Emery 1966). The right-skewed, unimodal distribution of the cordage diameter (Figure 4) suggests that, in general, the Basketmaker II people did not manufacture cordage to fit discrete diameter functional classes. However, when the specimens are compartmentalized into classes of fine, medium, and coarse cordage, some patterns do appear. Cordage specimens of fine and supple preparation have a narrow diameter spread, indicating that fine cordage likely served a specific function and that the people who made it carefully controlled the manufacturing process. Fine fiber cordage occurs in string bags and other woven textiles that require smaller diameter, supple cordage. The diameter of coarse cordage exhibits a greater range of variation. Thus, coarse cordage

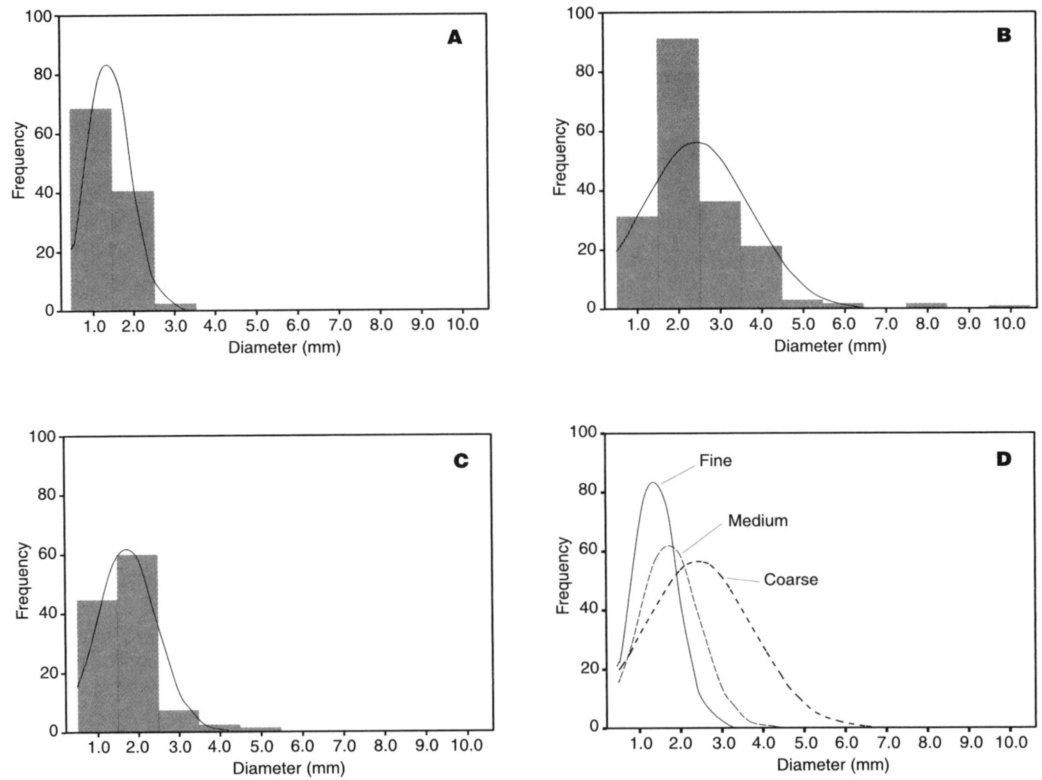

Figure 4. Graphs showing the frequencies of fine (A), medium (B), and coarse (C) cordage at Boomerang Shelter. Graph D superimposes the normal curves for each.

seems to have served less specific functions. Coarse cordage occurs as sandal straps and the foundation for fur and feather blankets, and likely served as lashings for any number of projects.

OTHER EVIDENCE OF CORDAGE MANUFACTURE

In addition to cordage, the yucca fiber industry assemblage also consists of such artifacts as quids, fiber bundles, and raw leaves. Although many raw yucca leaves occur at Boomerang Shelter, it is unclear whether the people intended these leaves for lashings, as a weaving material, or for further preparation for cordage. Accordingly, raw leaves have been omitted from this analysis.

The assemblage contains 17 hanks of yucca fibers showing primary and secondary stages of preparation. Thirteen hanks consist of primary coarse fibers and four hanks consist of fine or medium fibers. Although magnification at 40X is insufficient to reveal differences in yucca species, the length of the fiber hanks provide some insight to yucca species differentiation. The lengths of the fiber bundles range from 19 to 50 cm with a mean value of 39 cm. Two of the most common species of yucca on the Colorado Plateau are *Yucca baccata* and *Yucca angustissima*. *Y. baccata* grows on the high mesas at a considerable distance from Boomerang Shelter, whereas *Y. angustissima* grows locally. For the manufacture of cordage, the fibers of *Y. baccata* have an advantage over *Y. angustissima* in that the average length of the leaves is 90 cm compared to *Y. angustissima* which has an average length of 50 cm. Because the lengths of the archaeological fiber bundles are considerably less than 90 cm, I infer that the agriculturalists of Boomerang Shelter seldom obtained the long leaves of *Y. baccata* for their cordage industry.

Quids also provide a clue to Basketmaker II cordage manufacture. When I began my analysis of the quids, I hypothesized that most of them consisted of the fibers of the yucca genus. However, of the 131 g and 139 quids that I examined, only 18 percent by frequency and 29 percent by mass proved to be *Yucca* sp. Corn, rice grass, other unidentified monocots, and one occurrence of sinew constituted the rest of the quid assemblage. In their excavated state, the constituent fibers of quids are difficult to identify because they are "cemented" together and compacted. I was able to identify the types of the fibers by soaking a 50-percent sample of the quids in water for five minutes each and opening them up. After allowing the quids to dry, I observed the fibers at 5X–40X and referenced the comparative collection to discern the types of fibers.

Fiber length, singeing, and degree of fiber maceration distinguish three types of yucca quids: roasted quids, fiber quids, and pulping quids. Of the 24 yucca quids, 13 are roasted quids. When moistened and opened, roasted quids exhibit short primary fibers that have singed ends. The Basketmaker II people compacted such quids by chewing, as evidenced by dental indentations. These fibers are generally darker in color with a reddish hue. Although composed of yucca fibers, such quids do not represent a part of the Boomerang Shelter fiber industry in that they are probably related to cordage production. The short fibers may, instead, have come from roasted yucca hearts, and may represent a food item from which the pulp was extracted from the fibers by chewing.

Longer fibers comprise the next two types of yucca quids at Boomerang Shelter. The first type, fiber quids, consists of fibers compacted into a tight flat or oval shape. The fibers, when unraveled, lie parallel in a long bundle. In some instances, two discernable bundles of fibers, presumably representing two separate yucca leaves, were loosely plied before being chewed, probably to prevent tangling during the chewing process. These hard fiber quids make up only 25 percent of the yucca quid assemblage, however.

The second type of long yucca fiber quid, pulping quids, differs in that the fibers lie in no particular direction. After reconstituting such quids, I was unable to unravel the fibers in an orderly manner. The tangled mass of fibers of the pulping quids envelops very small, greenish flecks of brittle pulp. Pulping quids comprise 20.8 percent of the yucca quid assemblage.

AN EXPERIMENTAL MODEL FOR YUCCA FIBER PROCESSING

The second portion of this study explores the economics of Basketmaker II Anasazi fiber manufacture through experimentation. Hoover (1974:3) reasons, "Since fiber suitable for twisting was available everywhere, and ply cordage was everywhere known and was, on the whole, more desirable than braided cord, the presence of the latter clearly resulted from a trend toward using certain materials in the general economic life of a region along with the technique used to suit these materials." As the data in this paper indicate, yucca represented the choice raw fiber material of the prehistoric Basketmaker II peoples of the Colorado Plateau. Two-ply, Z-twist cordage suited the material with respect to the technology at hand, a technology that does not require a spindle and whorl.

I believe that *Yucca angustissima* makes up the primary material of the cordage assemblage. Compared to other local fibers, the leaves of *Y. angustissima* contain fibers of superior strength that the local people could have easily procured and prepared and that they could have manipulated into various degrees of refinement. Because of the wide availability of *Y. angustissima,* Basketmaker II people did not have to settle for lower grade materials such as juniper bark nor did they have to travel for higher grade materials such as *Y. baccata,* and thus the people of Boomerang Shelter expended relatively little energy on procuring fibers.

To process yucca, first the parenchyma (the nonspecific photosynthetic cells that surround the fibers and lie within them) must be removed. Scraping the parenchyma from the fresh leaves proves to be sticky and laborious work, requiring about 30 minutes per leaf (Osborne 1965). There are several ways to loosen the pulp before scraping the leaves, and considering the size of the cordage assemblage at

Boomerang Shelter, loosening the pulp before scraping was likely a priority of the rock shelter's inhabitants. This can be accomplished by retting, boiling, roasting, freezing, or wilting the leaves (Abril 1999; Hoover 1974; Osborne 1965).

Retting consists of soaking the leaves until the parenchyma begins to decay. Roasting the leaves entails burying the leaves in a heated pit. Wilting the leaves involves heating the leaves over hot coals. Freezing entails allowing the freshly cut leaves to sit through freeze/thaw cycles. With the exception of freezing, I experimented with each of these techniques, effectively breaking down the parenchyma without noticeably weakening the fibers within. In my opinion, only roasting, wilting, and freezing would have been practical to Basketmaker II Anasazi who lacked the ceramic technology required for long term boiling (an hour or more) and whose environment lacked a surplus of water, likely deterring the people from retting the leaves.

For several reasons, roasting the leaves in a shallow pit seems a highly probable method for the initial stage of yucca fiber extraction. Basketmaker II people probably roasted corn and other food items, such as yucca hearts and meats, in roasting features. Yucca leaves could have been easily added to such roasting pits. More importantly, roasting pits, if properly sealed, require little or no water except that contained within the plant itself. Pit roasting thus negates the need for water and ceramic technologies. Several ethnographic accounts of other societies in the Southwest describe the pit roasting of yucca or agave leaves to extract the fibers. Such accounts include A. F. Bandelier's 1882 account at Cochiti (in Robbins et al. 1916) and Campbell's 1994 account of a Southern Diegueño woman (Campbell 1999). In both instances, the preparers of the yucca or agave leaves dug a shallow pit in the ground and burned a fire until the ground became hot. The coals were then removed, the leaves added to the pit and covered with dirt, and another fire built on top. This type of heating was done for two or more hours, roasting the leaves until the pulp was soft and easily removed.

Removing the pulp from the fibers is stage one of fiber separation and entails extracting the hard fibers from the leaves. For my experiment (Figure 2), I scraped the leaves with three different tools, including a serrated deer rib, a beveled bighorn sheep horn, and a straight-edged scraper of local siltstone. The siltstone proved most efficient as an active tool for removing the pulp, whereas the horn and rib worked as passive tools, for scraping across the beveled edges. In 1919, Nusbaum, Kidder, and Guernsey (1922) excavated a beveled sheep horn and a serrated deer rib at Dupont Cave, a Basketmaker site in southern Utah. Lindsay et al. (1968) also recovered a sheep horn at San Dune Cave.

Next, I rubbed the dried fibers between my palms to increase the degree of separation and to remove excess flecks of parenchyma. These hanks of fibers resembled hard fibers from the archaeological assemblage. Twisting the fibers resulted in coarse cordage of primary fibers with some pulp interspersed among the fibers. The resulting coarse cordage, under magnification, appears similar to the coarse archaeological specimens. Preparation of the primary fibers also resulted in pulping quids as a byproduct. Like the pulping quids of Boomerang Shelter, the experimental quids consist of masses of tangled fibers enveloping greenish flecks of brittle parenchyma. The experimental quids have a higher percentage of parenchyma, which is more uniformly distributed throughout the quid. The archaeological specimens likely contained a similarly proportional amount of parenchyma, but, over time, retained only the most protected parenchyma at the center of the quid.

Having prepared a large quantity of primary *Y. angustissima* fiber, I experimented with second stage preparation of the fibers. Fifty-four percent of the archaeological yucca cordage at Boomerang Shelter displays maceration beyond stage one. I believe that separating out the fibrils is best achieved by chewing the fibers and disagree with Osborne (1965) who asserts that chewing played no part in the manufacturing process. In fact, in 1882 Bandelier (in Robbins et. al. 1916) observed people at Cochiti participating in "a communal enterprise" of chewing the pulp of freshly pit-roasted *Y. baccata* leaves to extract the fibers.

My experience with chewing the boiled and roasted leaves of *Y. angustissima* proved not to be entirely disagreeable to the taste, detrimental to my health, nor even inconvenient. On the contrary, the cooked leaves tasted like a green vegetable and seemed beneficial for several reasons. The ingested pulp may have nutritive and/or medicinal value (see Cheeke 2000 for a discussion of yucca saponins). In fact, an extract from *Yucca schidigera*, a species found in southern Arizona and northern Mexico, is harvested for use as a dietary additive for livestock and in humans may reduce the occurrences of protozoal diseases and enhance the immune system (Cheeke 2000).

Chewing the leaves to separate the secondary fibers requires a considerable amount of time, but does not require any degree of concentration. A person could accomplish any number of other tasks while masticating the yucca fibers. Moreover, I found the fibers to be quite abrasive in the mouth, especially during the early stages of mastication. It does not seem unreasonable, then, to assume that chewing the fibers could have acted as a means of maintaining oral hygiene for these early agriculturalists.

In my experiments, chewing 0.6 grams of the fibers for only one minute achieved secondary separation, resulting in fibers of medium refinement. After five minutes of chewing, the fibers began to turn a bright white color, achieving a degree of fineness resembling the fine yucca cordage of the archaeological assemblage. Color is the only difference between the experimental cordage and the archaeological cordage. In both instances, the cordage grades from a dark to a light hue as the fibers grade from fine to coarse. The archaeological fibers are brown and the experimental cordage is yellow; however, I assume that much of the color discrepancy results from postdepositional processes.

THE ECONOMICS OF FIBER PRODUCTION

Throughout the experimental portion of this research, I recorded several variables of the experimental process, including times of preparation and masses of materials, in order to develop some inferences about Boomerang Shelter site use and the labor costs of yucca fiber manufacture. Scraping the freshly cooked leaves was a relatively simple task. Using each of the bone, horn, and stone tools, I effectively removed the pulp from 60 leaves in 65, 78, and 90 minutes, respectively. Each of the tool materials mentioned would have been available to Basketmaker II people. Various lithics and large ungulate bones were excavated at Boomerang Shelter. Horn, from desert bighorn sheep, and beveled bone occurs in some Basketmaker II sites (see Nusbaum, Kidder, and Guernsey 1922; Kidder and Guernsey 1919; Lindsay et al. 1968) and may have been used for the purpose of scraping yucca leaves (Phil Geib personal communication 1999).

While preparing primary fibers with siltstone, I measured the masses of the different component parts of the experiment. The fresh leaves had a mass of 166 g. The dry fiber bundle and quids, after stage one of preparation, had a mass of 40 g and 35 g, respectively. When this ratio is compared to the archaeological collection of cordage and quids (124 g of archaeological yucca cordage and 11 g of pulping quids), the proportion of archaeological quids is significantly low. One reason for this may be that a considerable amount of quid mass is lost as the pulp falls from the quid fibers. However, the discrepancy is still too large to account for the difference and a more likely cause for the low proportion of archaeological pulping quids is that the inhabitants of Boomerang Shelter did not process yucca fibers in the rock shelter, or at least not in the area of the rock shelter that was excavated. Instead, the people at Boomerang Shelter may have roasted and scraped the leaves of the yucca plant outside the shelter where the archaeological waste materials would not have been preserved.

Another calculation of interest is an estimate of the amount of time and the number of yucca leaves necessary to create the large assemblage of cordage at Boomerang Shelter. If 40 g of dry experimental yucca fibers required 90 person-minutes to process with a stone scraper, then 124 g of yucca cordage represents 279 person-minutes of scraping and more than 184 fresh *Y. angustissima* leaves. This assumes that the inhabitants of Boomerang Shelter had a processing rate similar to mine. This calculation does not take into account the cordage that may be present in the unexcavated portion of the rock shelter or any of the fiber hanks or fiber quids.

The requirements for medium and fine cordage are even greater. My experiments show that at least one minute is required to transform 0.6 g of primary yucca fibers into medium cordage by chewing and at least five minutes into fine fibers. Thus, to produce 23 g of medium archaeological cordage, at least 23 minutes of chewing the fibers is necessary, whereas producing 22 g of fine fibers required at least 109 minutes of mastication. Taken together, the cordage assemblage excavated at Boomerang Shelter required at least 6.8 person-hours of fiber preparation. Much more time was required for gathering leaves and twisting the fibers. Although these calculations include only the cordage from the excavated portion of the site, they offer a least-time model for the manufacture of cordage at Boomerang Shelter, with projections being possible for the rest of the site.

CONCLUSIONS

The people of a region adapt to their environment in such a way as to use the materials at hand and to suit their technologies. For the Basketmaker II people of Boomerang Shelter, the environment provided the yucca plant as a primary source for cordage fibers. The technology at hand did not yet include spindles and whorls or cotton agriculture, nor did the Basketmaker II people practice a ceramic technology. This research indicates that the Basketmaker II people used a simple thigh rolling method or hand twisting method to make plied cordage mainly from the fibers of yucca leaves. It is difficult to determine how the people at Boomerang Shelter processed the fibers, but ethnographic accounts, environmental and cultural factors, and archaeological clues favor pit roasting as the Basketmaker II method of choice for processing yucca fibers.

Certain morphological characteristics of cordage follow the function of cordage. The relatively short lengths of cordage fragments at Boomerang Shelter suggest that the recovered specimens represent not a lack of splicing ability, but a function of cutting cordage to a usable length or of postdepositional processes. The diameter of cordage shows a direct correlation with the degree of maceration of the yucca. Finely macerated, thin diameter fragments of cordage were a highly specialized material used in the manufacture of woven textiles and were prepared by chewing. The coarser form of yucca filled a greater range of function and, accordingly, the range of the diameter is broader. The specialization of the cordage types, the uniformity of the diameter, and the tightness of the twist indicate that the people of Boomerang Shelter were highly proficient fiber manufacturers who designed different types of cordage to fit their particular needs.

Beyond practicality, the cordage of Boomerang Shelter also reflects a degree of stylistic preference for Z-twisted cordage, which I believe is due to ethnic preferences. This pattern may be useful in helping to define cultural boundaries when the cordage assemblages of other Basketmaker II sites are examined. In addition, preferences about the degree of mastication may also lend some clues to the identification of Basketmaker II ethnic groups.

From my experiments, I found that, in addition to the cordage at Boomerang Shelter, hanks of fibers and quids could add significantly to studies of fiber industries. The lengths of the fiber bundles provide a macroscopic clue to the dominant use of *Yucca angustissima*. Yucca fiber quids occur both as a byproduct of primary fiber preparation and as a stage of secondary fiber separation. The relative lack of pulping quids at Boomerang Shelter indicates that people of the rock shelter prepared the primary fibers outside of the site. My experiments with percentage mass of yucca fiber processing products also allow me to project labor costs, including the times needed for primary and secondary fiber preparation.

Despite the ephemeral nature of organic materials in archaeological sites, remnants of a once thriving fiber industry survive at the Boomerang Shelter of the Comb Ridge in southeastern Utah. The lack of fiber artifacts at most archaeological sites has resulted in a proportionate lack of information about fiber industries. Yet the associated materials of fiber industries, including raw materials, cordage, and processing tools, represent a significant portion of the material cultures of preceramic societies. In the rare instances where fibers survive the archaeological record, as in the dry rock shelters of the Colorado Plateau, intense analysis is necessary for understanding the identity and economics of the culture under question.

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