

## 5. Ethnoarchaeology of Marrow Cracking: Implications for the Recognition of Prehistoric Subsistence Organization

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*Abstract:* Hunter/gatherer subsistence varies in organizational strategy, both intraculturally and interculturally, which should be manifest in patterning of faunal remains. Certain resources may be entirely consumed upon acquisition, before other resources are sought. Other resources may be acquired in sufficient quantity for mass processing and deferred consumption through storage. This contrast in consumption practices can be exhibited in the treatment of bones from which marrow is extracted, contrasting (1) marrow cracking that is incidental to eating the meat off the bones with (2) that which is systematic mass processing outside of the context of cooking and consuming meat.

Three samples of faunal materials from two ethnohistorically known Nunamiut Eskimo sites are used to develop recognition criteria. One sample is drawn from a bone dump associated with mass marrow processing; the other two are drawn from kitchen middens that were accumulated as results of direct consumption activities. The samples were analyzed and contrasted for attributes that should be monitorable in archaeological assemblages. Significant differences between mass processing and consumption were noted in element representation, fragment size, and variation in fragment size. These criteria can be employed to distinguish between residues resulting from different processing techniques and can lead to the identification of prehistoric subsistence strategies in archaeological contexts.

### Introduction

What, after unretouched lithic debitage, could be more ubiquitous and underutilized in the archaeological record of prehistoric hunter/gatherers than long bone shaft splinters? They represent a largely untapped source of

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information for the zooarchaeologist. What do we do with them? What can we learn from them about the behavior of prehistoric humans? The purpose of this paper is to suggest one potential analytical goal derived from the examination of these fragments from the archaeological record.

Faunal analysis is a growing field of investigation, covering a wide range of questions, approaches, techniques, and analytical goals (Chaplin 1971; Klein and Cruz-Uribe 1984). Issues range from the identification and differentiation of species (e.g., Brown and Gustafson 1979; Gilbert 1980; Lawrence 1951; Olsen 1964; Schmidt 1972) to animal population dynamics, paleoecological or paleoenvironmental issues (e.g. Grayson 1984), or to the critical taphonomic issues of archaeological site formation processes (e.g. Burgett 1990; Lyman 1987; Noe-Nygaard 1977). While they are very important for understanding the contexts of human adaptation and interpretation of bone accumulations, another important focus concerns a more anthropological aspect of archaeology, that is, interpretation of faunal assemblages in terms of human behavior. Other studies have examined butchering techniques (e.g. White 1952, 1953, 1954, 1955; Yellen 1977), often focusing on body part segmentation and representation. Few have dealt specifically with bone splinters *per se*. Fracture patterns on bones have been used to search for or identify tools (e.g., Dart 1957; Frison 1970, 1974, 1978; Kehoe 1967; Sadek-Kooros, 1972). Other researchers have more directly addressed the problems of butchering through examination of bone splinters and shaft fragments. Binford (1978) and Bunn and Kroll (1986) have struggled with the proportional representation of shaft fragments and articular ends, while Todd and Rapson (1988) have carried this problem further to investigate spatial patterning within archaeological sites.

Our ability to make interpretations about the organization of subsistence strategies in the archaeological record depends of necessity on inference. The inferences are all too frequently based on conventions for interpretation, tacit agreements among archaeologists as to how to read the patterning in the faunal assemblages to understand lifeways of prehistoric hunters and gatherers. Recent ethnoarchaeological work (e.g., Lupo 1990) has shown us that we often jump to conclusions without sound bridges linking bones in the ground to behavior on the ground. The research described here was undertaken to provide a bridging argument between material remains that might be found in archaeological sites and an understanding of the organization of human behavior responsible for their creation and deposition. This is the methodology and the purpose of ethnoarchaeology: linking statics with dynamics. What are the characteristics observable in static material remains that can inform on the nature of dynamic behaviors in the past, behaviors that may have relevance to some theoretical model of human organization?

One of the most useful heuristic devices for the study of hunter-gatherers has been Binford's distinction between foraging and logistical collecting (1980), which suggests a basic characterization of the organization of subsistence pursuits. It has been approached by means of studies of residential mobility (Kelly 1983), site structure (Simek 1987), and faunal assemblages (Enloe 1993; Enloe and David 1989). This study of long bone shaft fragments is intended to find ways to discriminate from the archaeological record between

behaviors resulting from subsistence organization of foragers and behaviors resulting from that of logistical collectors. In the former, a signal characteristic is that of immediate consumption of resources upon their acquisition. If food packages are too large to be immediately consumed by their acquirers, food sharing is likely to take place (Kaplan and Hill 1985). In contrast, the subsistence organization of logistical collectors is directed toward the acquisition of storable food resources. That activity most often occurs in highly seasonal environments, where there is both a restriction or limitation in acquisition of food during certain times of the year (e.g., winter) and an aggregated food resource with limited time for acquisition (e.g., migrating caribou). The logistical collection of such a resource yields a considerable quantity of meat and marrow at one time. Economies of scale dictate an efficient processing of such resources, that is, some sort of systematic butchering and processing for storage. The contrast between foraging and logistical collecting has been suggested as characterizing the transition from the Middle and Upper Paleolithic (Binford 1980, 1982a, 1982b; Mellars 1989; Simek 1987). The ability to recognize that difference in subsistence organization would aid us tremendously in study of the evolution of human adaptive patterns and culture.

When the dichotomy is applied to the kinds of processes that are responsible for the creation of bone splinters, it can be reduced to a question of the context of marrow processing. Marrow is a particularly important food resource for people whose diets are largely derived from faunal resources (Speth 1983; Speth and Spielmann 1983). Other than postdepositional or non-human agents (Binford 1981, 1984; Bonnicksen and Will 1980; Brain 1981; Haynes 1983; Meyers et al. 1980), the activity of marrow processing is the best explanation for the fact that bones found in archaeological sites are usually broken (Binford and Bertram 1977; David 1972; Delpech and Rigaud 1974; Martin 1910; Street 1990; Zierhut 1967). How does the extraction of marrow reflect on the difference between foraging and logistical collecting? One possibility is to derive expectations about the characteristics of remains that would pertain to immediate consumption of sequentially acquired food versus those that would result from mass processing of a single input and subsequent withdrawal from storage for consumption. In the former case, meat would be minimally processed, that is, carcasses would be disarticulated just enough for transport and distribution to consumers. Further processing might go no further than reduction of package sizes for cooking. Meat would be cooked on the bones and eaten, and the bones would be cracked by each consumer to obtain the marrow immediately thereafter. In the logistical case, meat would be filleted, removed from the bones in order to be dried and stored, and the bones would be mass processed at one time to obtain the marrow (Binford 1978). As far as the marrow is concerned, it is a matter of individual breakage of the bones immediately after meat consumption or collective processing of bones entirely aside from meat consumption.

Therefore, if the goal is to distinguish the difference between intentional mass processing for marrow and extraction of marrow incidental to meat consumption, the necessary data to be examined are the durable residues from both procedures, that is, bone splinters. This archaeological resource is

often overlooked because it is difficult to deal with and the conventional rewards are frequently meager. Bone splinters rarely yield information applicable to such conventional goals as determining past environmental conditions from species representation or counting minimum numbers of individuals; who knows how many splinters come from a single bone? That obviously depends on how many times the bone is broken, and to what ends. The goals here are to examine some attributes that can be observed in archaeological samples and to relate them to subsistence organization behavior known through ethnoarchaeological research.

## Data Base

Observations were made on assemblages of caribou (*Rangifer tarandus*) bone splinters, which had been recovered from ethnographically known situations among the Nunamiut Eskimos of the Brooks Range in the interior of Alaska by Lewis R. Binford (1978:428-447, 1983:176-184). Two samples came from distinct activity areas at a site known as Palangana's House. This winter residence was occupied in the late nineteenth century. Stone tools figure significantly in the processing of faunal materials from the site. Sample P1 ( $N = 181$ ) consists of material from debris associated with mass processing for marrow. The bones had not been previously cooked or processed, except for dismemberment and removal of meat (if there had been any). A large number of bones were broken open at one time, and the raw marrow was removed. Sample P2 ( $N = 624$ ) consists of material from a domestic cooking dump, that is, debris resulting from consumption of meals. Usually, joints of meat were cooked in a stew pot. After the meat was eaten, the bone were cracked open and the marrow was eaten. The dump, therefore, was the product of an accumulation of repeated consumption events. The third sample comes from a site known as the Bear site. This winter house was occupied in 1948. Steel tools were used during the occupation. Sample B3 ( $N = 528$ ) consists of materials from a kitchen midden similar to that of P2. These samples were derived from restricted areas (1 m<sup>2</sup>), in order to avoid mixing of the contents with debris from other activities. They do not represent the range of activities that might have been carried out at either site but were selected to highlight the differences between mass processing of marrow and marrow cracking incidental to meat consumption at meals.

## Analysis

A model for differentiating between breakage during mass processing of raw marrow and breakage for immediate consumption can be proposed. In the first case, elements present should primarily reflect their high marrow utility (Binford 1978). When a large quantity of the same elements are processed at the same time, there should be a standardized procedure for breaking them, that is, the points of impact should be in the same anatomical

locations on each bone. One might expect that this activity would result in relatively few impact cones per element and relatively long fragments, reflecting maximum efficiency in breakage (Binford 1978:155, Table 4.6). In the second case, element representation should reflect high meat utility. Since the bones would be broken incidental to meat consumption, they would be broken one at a time by various consumers. Thus, one would not expect that any standardized pattern of breakage would be evident. Impact fractures would be more variably located and more numerous, and fragments would be relatively short.

In order to test those expectations, observations were made on each fragment for element, length, and number of impact cones. Table 5-1 presents the element representation of the three samples.

It must be noted that not all fragments could be identified as to skeletal element. That is a very common problem in dealing with bone splinters. The unidentified fragments most likely come from the shafts of the major upper long bones, that is, humerus, radius, femur, and tibia. Recognizability is a critical criterion here. The major landmarks on the bones are mostly located at the articular ends, and there are long spans of what are essentially tubes between them. Various fragmentation processes result in the formation of bone splinters separated from their articular ends; those fragments were put into a category labeled *Unspecified*.

The metacarpal and metatarsal are much more recognizable than the upper limb bones owing to the deep groove and crests on their posterior surfaces, so a larger percentage of them could be correctly identified. The anterior surface presents another problem, however. The metatarsal is very distinctive and easily recognized, but the anterior portion of the metacarpal shaft is much less distinctive. Therefore, anterior metacarpal fragments lacking any portions of the posterior surface could have been placed in the unspecified category. Posterior portions of either of those elements lacking proximal, distal, or cranial portions had to be placed into the unidentified metapodial category. The final category (total metapodials) combines all of the fragments of metacarpals, metatarsals, and unidentified metapodials.

### *Element Representation*

The first test of the expectations deals with element representation in each assemblage (see Table 5-1). Strong preference for marrow-bearing elements in assemblage composition is argued to reflect mass-processing events, whereas no preference or preference for meat-bearing elements is argued for consumption incidental to meat consumption. Figure 5-1 displays the relative percentages of each element for all three cases. It is clear from this figure that assemblages P2 and B3 are almost identical to one another, while assemblage P1 appears radically different. All three track very closely through the upper limb elements. Where they diverge is in the unspecified and metapodial categories, with relative differences of at least 36% and 43%, respectively. If, as I suspect, the unspecified fragments really do come from the upper limb bones, then what we are seeing is a divergence between

Table 5-1. Bone Splinters from Three Nunamiut Samples

Element	P1 Mass Processing		P2 Meat Midden		B3 Meat Midden	
	NISP	%	NISP	%	NISP	%
Humerus	8	4	267	11	50	9
Radius	18	10	81	13	52	10
Metacarpal	2	1	5	1	7	1
Femur	11	6	63	10	55	10
Tibia	24	13	52	8	70	13
Metatarsal	37	20	43	7	23	4
Phalanges	0	0	1	0	0	0
Unidentified metapodial	62	34	34	5	25	5
Unspecified	19	10	278	46	246	47
Total metapodials*	101	56	82	13	55	10

\*Includes all metacarpals, metatarsals, and unidentified metapodials.

assemblages dominated by the meat-bearing elements and the assemblage dominated by marrow-bearing elements.

To clarify that difference, a second calculation was made of the relative percentages, disregarding the unspecified fragments (Table 5-2). Phalanges were omitted from consideration since there was only one identified in all three assemblages. Similarly, metacarpals, which constituted only 1% of each assemblage, were omitted. The percentages are graphically displayed in Figure 5-2, where the elements are ordered with the highest meat utility indices (Binford 1978:23) to the left and the highest marrow utility indices (Binford 1978:81) to the right. The lines for P2 and B3, the meat consumption residue assemblages, remain quite similar to one another in proportions of element representation. The line for assemblage P1, the marrow processing assemblage, lies substantially below the other two for the meat-bearing elements of the upper limbs but climbs sharply to the right of the graph. It crosses the lines for the other two at the tibia, which has significant values for both meat and marrow. In this figure the contrast demonstrates the differences in element representation between the assemblages biased toward meat-bearing elements and the one biased toward marrow-bearing elements. Here, both of the consumption debris assemblages, P2 and B3, exhibit relatively flat lines. Elements vary between 9% and 25% of the total assemblage. In contrast, the line for the marrow-processing assemblage exhibits a significant rise. It has relatively low values for meat-bearing elements but high values for important marrow-bearing elements. The contrast of this assemblage with the similarity of the other two suggests that significantly different things are

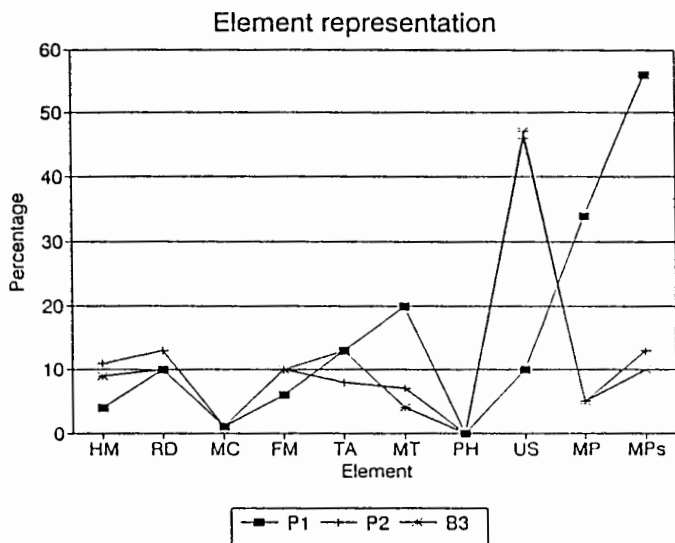


Figure 5-1. Relative representation of all elements.

happening in the two situations and that we will be able to see the difference in the material residues.

We can further test the differences to see if they are statistically different. First, the P2 and B3 assemblages were subjected to a chi-square analysis for the relative proportions of element representations, using the raw counts. Low frequency cells for metacarpal and phalanx were eliminated, so only the total metapodials were used to represent metacarpals, metatarsals, and unidentified metapodials. The resultant  $\chi^2 = 9.99$  is not significant at the .05 level, so we cannot reject the null hypothesis that the samples were drawn from the same population. This finding supports the similarity of their makeup, and we can therefore infer that they are likely to be derived from the same formation processes.

The same test was performed between P1 and P2, and between P1 and B3. In each of the tests the results are quite different from those of the first test, and they are very similar to one another. The  $\chi^2$  values are very high (257.01 and 244.29), particularly in contrast to that of the first test (9.99), and are highly significant at less than the 0.001 level. This strongly confirms that both times the samples being compared had been drawn from radically different populations and that P2 and B3 are similar in the order of magnitude of their differences from P1. These results support the idea that there is a significant difference in element representation between the sample drawn from intentional marrow processing and those drawn from meal residues.

Table 5-2. *Adjusted Relative Percentages of Identifiable Elements*

<i>Element</i>	<i>P1</i>	<i>P2</i>	<i>B3</i>
Humerus	5	19	18
Radiocubitus	11	23	18
Femur	7	18	20
Tibia	15	15	25
Metatarsal	23	12	8
Unidentified			
metapodial	38	10	9
Total			
metapodials	62	24	20

*Note:* Adjusted relative percentages disregard metacarpals, phalanges, and unspecified fragments.

### *Fragment Length*

The second aspect to be explored deals with the size of fragments. The three samples included only specimens from caribou so that problems of other taxa with different body sizes would not affect size relationships for the elements examined in this analysis. Additionally, evidence of carnivore gnawing was not present on bones from these samples. As previously stated, the samples were drawn from restricted locations to limit the processes that might have operated to modify the assemblages. On the Nunamiut sites, dogs were not allowed to roam freely and scavenge bones all about the camp. They were tethered in dog yards (Binford 1978:429, 431).

Table 5-3 summarizes average length and variance for each element in the samples. This relationship is displayed graphically in Figure 5-3. In general, the average lengths of element fragments are fairly similar between P2 and B3, while those of P1 are consistently greater. Average lengths of the meat-bearing elements of the upper limbs were fairly consistent, implying that in samples P2 and B3 bones were being subjected to the same treatment. Most of the differences that are apparent between P2 and B3 occur in the metapodials and metatarsals. It is the length of the unspecified fragments that plunges lowest below the mean for each case. For P2 and B3, those are the elements with the highest frequencies, which in itself pulls the mean down. Perhaps it is the very fact that these fragments are so short that they are unidentified.

Overall, the mean length of fragments for sample P1 is 143.26 mm, compared with 72.73 mm and 57.92 mm for samples P2 and B3. It can be seen in Figure 5-3 that the difference in length applies to all of the elements. The bones in sample P1 are clearly longer, but do they show less variation in length? The model for mass processing dictates that a standardized procedure of breakage should result in less overall variability in length than a fortuitous

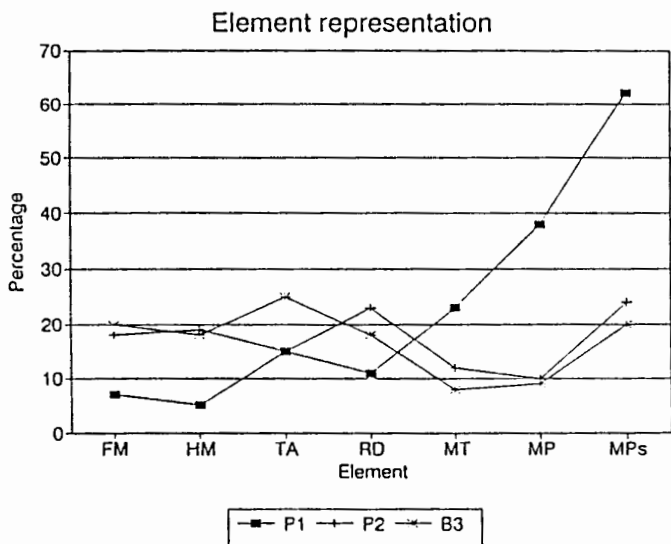


Figure 5-2. Relative representation of elements: meat utility to left, marrow utility to right.

or incidental breakage during meal consumption. Table 5-3 presents the standard deviations for the mean lengths for each element, but those are difficult to interpret. Since there are rather large differences in mean lengths between samples, raw standard deviation figures are not so informative. Rather, the coefficient of variation, which indicates the proportion of the mean represented by the standard deviation, can better inform us about the variation within and between samples. Overall, the coefficient of variation for sample P1 (0.430) is lower than that for either sample P2 or B3 (0.483 and 0.482). It is interesting that the latter two are so similar to one another. Let us further look at the variation between the lengths of meat-bearing elements as opposed to marrow-bearing elements. Again, in each case the coefficient of variation for sample P1 is lower (0.400 and 0.356) than that for sample P2 (0.460 and 0.536) or for sample B3 (0.484 and 0.417). The value for the high marrow utility elements of sample P1 is the lowest of these six. In summary, fragment lengths are both greater and less variable for the marrow-processing assemblage, confirming the expectations of the model.

### Impact Cones

The third aspect of the model deals with impact fractures, which are manifested in visible impact cones on the bone fragments. Not all frag-

Table 5-3. *Fragment Lengths*

<i>Element</i>	<i>Sample</i>	<i>Mean Length (mm)</i>	<i>Standard Deviation (mm)</i>	<i>Coefficient of Variation</i>
Overall	P1	143.26	61.55	0.430
	P2	72.73	40.15	0.483
	B3	57.92	27.97	0.482
Humerus	P1	103.39	25.04	0.242
	P2	50.20	27.67	0.551
	B3	66.08	19.82	0.230
Radius	P1	123.45	39.18	0.317
	P2	85.43	34.82	0.408
	B3	70.69	34.12	0.483
Metacarpal	P1	199.50	64.35	0.323
	P2	60.82	39.16	0.644
	B3	58.38	17.89	0.306
Femur	P1	108.62	23.16	0.213
	P2	71.85	28.79	0.401
	B3	70.26	27.25	0.388
Tibia	P1	132.32	44.87	0.339
	P2	86.98	30.32	0.349
	B3	76.62	30.49	0.398
Metatarsal	P1	151.07	63.99	0.424
	P2	119.45	65.46	0.548
	B3	71.65	25.29	0.353
Metapodial	P1	180.30	56.30	0.312
	P2	122.37	59.41	0.485
	B3	73.30	35.39	0.483
Unspecified	P1	70.67	37.38	0.529
	P2	59.08	24.48	0.414
	B3	42.62	17.01	0.399
Meat Bias	P1	109.53	43.90	0.400
	P2	66.02	30.37	0.460
	B3	56.45	27.35	0.484
Marrow Bias	P1	169.97	60.54	0.356
	P2	117.09	62.82	0.536
	B3	71.16	29.68	0.417

ments will show signs of impact cones. Spiral fracture intersections may define the limits of any particular fragment, even if they were originally caused by a single impact or multiple impacts that left impact cones on other fragments of the same bone. Data from the three samples are summarized in Table 5-4.

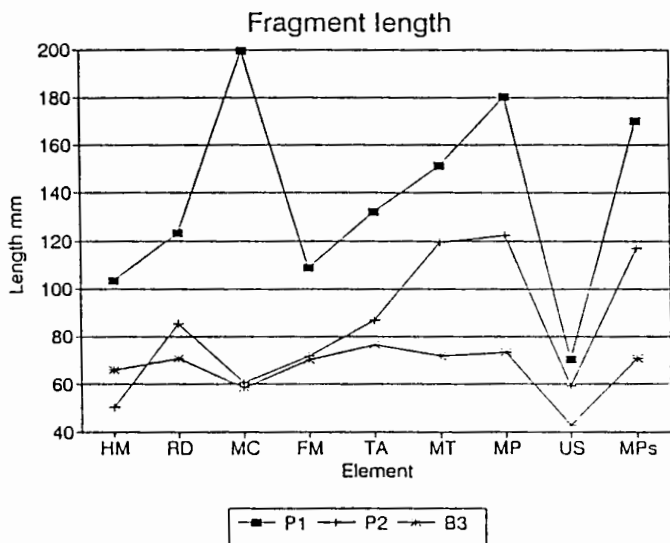


Figure 5-3. Average fragment length by element.

In general, there appear to be more cones per fragment in sample P1 (1.18) than in either P2 (0.82) or B3 (0.43). This is true for all elements. Again, P2 and B3 are quite similar to one another, while P1 appears slightly divergent. The standard deviations, however, are quite large, approaching or exceeding the mean in each case. The coefficients of variation emphasize the slightly smaller variability in sample P1 (0.991) and the similarity of the slightly greater variability of samples P2 and B3 (1.72 and 1.72). These differences are not statistically significant, and they are not diagnostic for our purposes, but they do hint at the differences in the formation processes of each of the samples. Examination of the average length per impact cone of fragments of the various elements does not reveal any pattern of distinction between the three samples. This index is quite variable in all three samples, ranging from 39.3 to 203.2 in P1, from 57.0 to 138.8 in P2, and from 51.1 to 233.0 in B3.

The presence of impact cones, by frequency or fragment length, does not appear to be a satisfactory diagnostic criterion for distinguishing marrow-processing remains from meal residues. Perhaps because the fragments resulting from the former activity are longer, they are likely to retain a greater number of impact points. It may also be that cooking has reduced the structural integrity of cortical tissue of the diaphyseal shafts, making them easier to break or easier to break into smaller pieces with fewer blows. No matter which situation pertains, it renders at least the kinds of observations made on

Table 5-4. *Summary of Impact Cones and Average Length*

	P1	P2	B3
NISP	181	624	528
Total Cones (N)	214	511	229
Average cones	1.18	0.82	0.43
Standard deviation	1.17	0.96	0.75
Variation coefficient	.991	1.72	1.72
Total length	25929.38	45385.06	30582.73
Average length	143.26	72.73	57.92
Standard deviation	61.55	40.15	27.97
Length/cone	121.2	88.8	133.5

these samples unusable as diagnostic criteria or signature characteristics for distinguishing between assemblages deriving from meal residues and those deriving from specialized marrow processing.

## Conclusions

This research has examined a few attributes of several samples of known derivation from ethnographic sources, in search of diagnostic criteria for recognizing characteristics of material remains that might indicate the processes responsible for their creation. In this case, it has been a search for criteria for discriminating between bones splinters that are the result of meat and incidental marrow consumption and those that are the result of intentional, specialized processing of raw bones for their marrow. There appear to be some significant differences in element representation, fragment length, and length variation between the two processes. Mass marrow-processing dump locations appear to contain more metapodial fragments relative to upper limb bone and unidentified element fragments than do immediate consumption middens. The fragments from mass-processing locations appear to be longer and to be of a more uniform length than those from consumption middens.

Given the small sample size of three assemblages of only a few hundred identified elements in each, the results cannot be considered conclusive or truly diagnostic. They may be more profitably viewed as a starting point for examining long bone shaft splinters under other controlled conditions. The problem of equifinality has not been sufficiently addressed. There may be other cultural or taphonomic factors that might yield similarly high proportions of metapodials of uniform length, for example. The primary importance of this research has been its contrastive nature on a single site. Two of the samples were drawn from different activity areas of the same site. Clearly, each activity does not define the overall subsistence strategy of the site's

occupants. The very fact, however, that mass marrow processing was present on the site indicates its importance in overall subsistence. The application of this type of analysis only to small samples of archaeological sites runs the very great risk of not discovering the appropriate activity areas. It should be applied to the analysis of different concentrations of debris or activities on sites that have already been excavated over large surfaces, as suggested by O'Connell (1987). When properly and cautiously applied, it is hoped that this ethnoarchaeological research will add to the means available to zooarchaeologists for learning about past organizations from the sparse documents of the archaeological record.

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