THE BONE TOOL MANUFACTURING CONTINUUM

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Summary

One of the difficulties in the analysis of bone tools is the necessity of quantifying and understanding variability within formal morphological types because typology is often defined by species and skeletal part despite similarities in use wear and, thus presumably in function. While some morphological types stick closely to a formal definition others are made in a cruder, more opportunistic fashion on a variety of skeletal elements. Thus, there is a manufacture quality continuum along which individual tools fall. Clusters of tools of a general type from a particular assemblage falling near the extremes of this continuum have been termed Class I (planned) and Class II (opportunistic). It is suggested here that better quality tools reflect the economic importance of the task they were used in to the society as a whole, whereas more crudely made tools reflect the personal needs of an individual person in certain task(s) or activities. Variables examined include species and skeletal part, percentage of surface covered by manufacture wear, percentage of surface covered by use wear and curation. Examples of such analyses include tools from the Swiss Neolithic lake dwelling site of Saint Blaise-Bains des Dames as well as a small bone tool assemblage from the Migration Period site of Endröd 170 on the Great Hungarian Plain.

Résumé

Le continuum dans la fabrication de l'outil en os.

L'une des difficultés de l'analyse des outils en os réside dans la nécessité de quantifier et de comprendre la variabilité à l'intérieur de types morphologiques formels, car la typologie est souvent définie par l'espèce et la partie anatomique en dépit des similitudes dans les traces d'usure, et donc probablement dans la fonction. Alors que certains types morphologiques correspondent bien à une définition formelle, d'autres sont basés de façon plus grossière et opportuniste sur une variété d'éléments squelettiques. Il existe ainsi un continuum dans la qualité de la fabrication dans lequel s'insèrent les outils individuels. Les groupes d'outils de type général provenant d'un assemblage particulier s'insérant près des extrêmes de ce continuum ont été appelés Classe I (planifiés) et Classe II (opportunistes). Nous suggérons ici que des outils de meilleure qualité reflètent l'importance économique, pour toute la société, de la tâche pour laquelle ils ont été utilisés, tandis que des outils plus grossiers reflètent les besoins personnels d'un individu pour certaines tâches ou activités. Les variables examinées comprennent l'espèce et la partie anatomique, le pourcentage de la surface portant des traces de fabrication, le pourcentage de surface portant des traces d'utilisation et de réparation. Des exemples de telles analyses proviennent du site d'habitats lacustres du Néolithique suisse de Saint Blaise-Bains des Dames ainsi que d'un petit assemblage d'outils osseux de la période des grandes migrations du site d'Endröd 170, dans la grande plaine hongroise.

Zusammenfassung

Das Kontinuum der Knochengeräteherstellung.

Eine der Schwierigkeiten bei der Analyse von Knochenartefakten besteht darin, sie unabhängig bestimmter morphologischer Typen anzusprechen. Unterscheidungen werden häufig anhand von Tierart und Skeletteil vorgenommen, obwohl die Gebrauchsspuren auf gleichartige Funktionen hinweisen. Einige Typen stehen den formaldefinierten Formen sehr nahe, andere werden eher flüchtig aus verschiedensten Skeletteilen produziert. Diese beiden Kategorien stellen die Endpunkte des Knochenbearbeitungskontinuums dar. Das eine Ende besteht aus den sorgfältig, geplant gefertigten Geräten der Klasse I. Die Werkzeuge der Klasse II stehen für eine ganz andere, spontane Herstellung und Nutzung. Es wird angenommen, daß die sorgfältig gefertigten Geräte für Arbeiten verwendet wurden, die für die Gesellschaft von größerer Bedeutung waren, während die auf einfachere Weise gefertigten Exemplare der Befriedigung momentaner und persönlicher Ansprüche dienten.

Die aufgenommenen Parameter beinhalten Tierart, Skeletteil, Bearbeitungs- und Gebrauchsspuren (in Prozent der Oberfläche) sowie sekundäre Bearbeitungsspuren. Als Ausgangsbasis dienten die Knochengeräte einer neolithischen Ufersiedlung in der Schweiz (St. Blaise, Bains des Dames) und einer völkerwanderungszeitlichen Siedlung (Endröd 170).

Key Words

Bone tools, Manufacturing continuum, Planned tools, Opportunistic tools, Neolithic, Sarmatian.

Mots clés

Outils en os, Continuum de fabrication, Outils planifiés, Outils opportunistes, Néolithique, Sarmatien.

Schlüsselworte

Knochengeräte, Bearbeitungskontinuum, Geplante Geräte, Spontan produzierte Geräte, Neolithikum, Sarmatische Epoche.

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One of the intrinsic general problems with typologies is that they are basically static representations of fluid situations. Nowhere is this more true than in the case of bone tools where types are based on a hierarchical ordering of various combinations of species (size), skeletal part, form and function based on use wear. Thus, a bevelled edged tool made on a cattle rib is generally treated as a different tool type from one made on a cattle metapodial diaphysis despite the fact that the size range is the same and the use wear seems to be similar. While such typologies are indispensable tools for expressing bone technology, they beg the question of the meaning of quality of manufacturing and the degree of exploitation of individual tools. The fact remains that within individual tool types at a given site there may be great variation in the consistency of species/skeletal part selected as well as the effort that is put into their manufacture. This paper will present a methodology for expressing this variability in quality in a more objective fashion, along with a discussion of its meaning in a socio/economic context. Finally, examples from two very different bone tool assemblages will be presented.

The manufacturing continuum

At one end of the manufacturing continuum are the carefully planned tools. Such tools represent a manufacturing tradition which may be typical of the site as a whole at a certain time or even typical of a group of sites over a wider area. These tools are consistently made from the bones of certain species and on particular skeletal parts. They are usually produced using a multi-stage manufacturing schedule. Manufacturing wear of various kinds usually covers at least three quarters of the surface of the bone. Finally, such planned tools are often curated, that is reworked. This is probably because on the one hand, more effort has gone into their manufacture and on the other hand individual tools may have become "favorites".

At the other end are the tools which have been variously called *ad hoc* (Schibler, 1981), expedient (Johnson, 1982) and opportunistic. There is an extensive literature on such tools from early human sites concerned with distinguishing primitive tools from refuse bones (Bonnichsen, 1979; Johnson, 1985, 1989: 438). In these cases the problem of distinguishing flaking and deliberate fracturing from natural breakage presents real problems to researchers. However, the situation in later prehistoric bone tool assemblages is quite different since there is no question that these are indeed crude variants of more elaborate types. Manufacture wear may take the form of slight abrasion or carving with flint tools and the use wear usually takes the form of localized polish. These latter specimens are made on pieces of refuse bone from a broad range of species and skeletal part. After carcasses were divided, chopped up for cooking and the diaphyses broken to extract marrow, bones that broke serendipitiously were picked up and either used as they were or only slightly modified before use. Such tools may be quite heavily used but they are almost never reworked.

In between may be found those tools which have been made from a variety of selected skeletal parts and which have been modified to a greater or lesser extent. Some assemblages will be primarily characterized by this grey area of manufacturing quality where the particular tool merely shows a tendency toward one end or the other of the manufacturing continuum. In assemblages of sufficient size, however, such tools may display clustering which illuminates prehistoric attitudes toward certain crafts and activities (Choyke and Bartosiewicz, 1994).

The variables examined for each tool in order to establish its location along the manufacturing continuum include:

1. the species and skeletal part selection;
2. percentage of surface covered by manufacture wear; scored on an increasing ordinal scale of 0-5 with '0' representing no manufacture wear and '5' representing total modification of the tool's surface;
3. percentage of surface covered by use and handling wear; scored on an increasing ordinal scale of 0-5 with '0' representing no use/handling wear and '5' representing total coverage of the tool's surface;
4. curation; scored on a presence or absence basis.

The osteological method

The addition of osteological variables as an integral part of bone tool studies is a relatively recent development. Until the 1980's, such bone tool research as there was concentrated on pure stylistic form most often at the back of faunal reports. At that time, a number of reports appeared by archaeozoologists which considered the nature of raw material selection (Poplin, 1967; Schibler, 1980: 12 "*Verwertung*" or "*Vergleichsfaktor*"; Campana, 1980; Choyke, 1983; Olsen, 1984; Clason, 1991; Becker, 1993: 139). Choices made by the ancient craftsperson included considerations both biological and cultural.

Selection of raw material is dependent, among other things, on the contribution of different animal species to the refuse bone assemblage (Bartosiewicz and Choyke, 1994). The bones of such species were most likely to be on hand after food processing for making tools, especially opportunistic utensils. Thus, where a tool was needed only casually for a particular task there seems to have been a general tendency to pick up, modify and use bones which broke in an appropriate manner.

Species selection is most significant in terms of general size categories so that red deer and cattle bone may often be interchangeable with each other. Most tools made from large species are *de facto* of different types than tools made from smaller species such as sheep/goat or roe deer. Sex of the animal is important only in terms of red deer/roe deer antler, horse canines and pig tusks which come exclusively in from male animals. Age has a more general importance. It may be assumed that where many tools are made from the bones of immature animals, not the ideal bones for manufacturing, it strongly suggests an element of less targeted raw material selection since the bone derives from the refuse of food processing. Also, in addition to these biological parameters, there are those of individual size, robusticity and the natural form of the skeletal part (first discussed by Semenov, 1964). Certain bones such as ruminant ulnae produce a natural point after separation from the radius. Ribs and the proximal diaphysis segments of ruminant long bones lend themselves to the manufacturing of bevelled edge tools such as scrapers. Some bones such as ruminant metapodials with their straight diaphyses tend to fracture along their longitudinal axis which allows them to be easily modified into points (Sadek-Kooros, 1975: 143).

However, traditions of what species and skeletal parts are best for producing certain planned household tools, for example tools used in tool kits in specialized crafts, may also be very strong and conservative. The result is that raw material selection in these tool type categories become skewed toward certain preferred species and skeletal parts. This can be clearly seen at the Swiss lake dwelling site of Saint Blaise-Bains des Dames, to be discussed in detail later, where a clear preference is shown for the bones of red deer in the planned tool categories (Choyke and Bartosiewicz, in press). Changes in the choice of raw materials for particular tool types may often vary little over many years, even in the face of changes in the availability of species.

Manufacture wear

There has been a great deal of experimental and empirical work done on distinguishing different types of manufacturing wear which can be found on bone tools. Wear which can be identified includes cutting and scraping with flint, abrasion with materials such as sandstone, and perforation with a variety of materials as well as flaking. Much tool manufacturing is multi-stage with the exception of the extreme opportunistic end of the manufacturing continuum. After being cleaned and possibly soaked, a process which leaves no visible trace, the bone can either be used immediately or further modified (Campana, 1980: 82). Tools such as metapodial based awls or needles require that the diaphysis be reduced in width. Experiments (Newcomer, 1977: 294; Yesner and Bonnichsen, 1979: 305-306; Murray, 1979: 27) have shown that flint was usually used to cut a groove along the septum transversum of metapodia and then percussion was used to create a controlled break. This technique was used to create lengths of bone or antler. There are some examples where the size of the bone tool was formed entirely through grinding (Russell, pers. comm.). After, the initial break, the rough edges could be smoothed by further longitudinal scraping with flint which leaves a high polish and bunched wavy lines visible under relatively low magnification (Olsen, 1988: 343) otherwise the point or bevelled edge was made by grinding away the unwanted parts of the bone (Campana, 1980: 83, 89; Olsen, 1988: 354).

Various experiments in perforation techniques have also been carried out. These show that a small depression was often carved out first and then a blade, probably attached to some kind of a bow drill was used (Olsen, 1984). However, the author has also sucessfully produced holes in bone implements using a elderberry stalk and sand with water. The most elaborate tools, for example handles or needle holders, may often have all traces of the previous manufacturing obscured by final finishing of the surface. Olsen (1984) cites ethnographic examples of polishing with leather and fine silt which predictably results in fine striations, visible under magnification, running around the tool. Such a tool, made from selected raw materials and manufactured in several stages would be at the extreme, planned tool end of the manufacturing continuum and score '5' in manufacturing wear.

Use/handling wear and the exploitation index

Use wear may take a number of forms sometimes difficult to distinguish from handling wear and often open to questions of functional interpretation (Newcomer *et al.*, 1986: 203-204). Types of use wear include localized polish or even a rippling glossy surface, battering, chipping of edges, longitudinal striations at and over bevelled edges. Handling polish begins at the butt end of tools not inserted in handles and is considered to extend, more-or-less, half way up the tool's length. This handling polish may be of varying extent and intensity. Obviously, a heavily used tool, covered with a polish which all but obscures the marks of manufacture would be given a score of '5'. Both planned and opportunistic tools may receive a high score for heavy use. Planned (Class I) tools, however, tend to be made consistently on the same skeletal parts and were used more intensively.

The exploitation index was developed as a measure of how efficiently the tool was used relative to the amount of work which went into its manufacture (Choyke and Bartosiewicz, in press). In a much simplified way, the intensity of manufacturing may be regarded as input while the intensity of use wear may represent output. The proportion between these two entities was expressed as an index:

Exploitation index = use intensity/manufacturing intensity - 1

When this value is '0', the labor expended on manufacture was returned by full use. Values below 0 indicate the tool was not fully exploited. Positive exploitation indices show that the tool was used more than would be expected on the basis of the amount of effort put into its manufacture. This variable is particularly important because sometimes it is the only way of placing more simply made tools along the manufacturing quality continuum and judging the economic or social value of the task in which they were used. Thus, if a tool is consistently made on a particular skeletal part and only lightly modified (scoring only a 2 or 3 on the manufacture wear scale) but was heavily used it will have a high exploitation index. These two scores together place it more in the planned tool category and suggests that the activity in which the tool was used had economic importance throughout the Prehistoric community. The low score on the manufacturing scale suggests that the roughness of the work required frequent replacement making elaborate manufacture not worthwhile especially since curation was not possible because of size requirements. An example of such tools would be the rib points which make up the Neolithic linen combs found on Swiss lake dwelling sites (for example, Schibler, 1981: 38-39, 1987: 169) an implement type which is easily recognizable even when not found tied together in bunches.

Curation behavior

Reworking or curation behavior has been defined as the conservation of tools by craftspeople through constant repair as first described for Numamiut hunters (Binford, 1978: 242). Bone tools, and especially pins and awls often become dull or are easily broken at the tips during use. Such tools are likely to be repaired when:

1. they are made from special materials which are harder to acquire;
2. the labor expenditure involved in their manufacture is high and
3. they have become "favorites" despite having been opportunistically made.

Planned tools, especially types such as small ruminant metapodia awls, are more likely to have been curated, often several times during their working life. In the case of this type of tool, reworking results in small "pencil stub-like" utensils. Another confusing aspect of curation is that such planned points are sometimes transformed at the end of their working life into bevelled edged tools which should by rights be counted as a seperate tool falling more into the Class II range of the manufacturing continuum.

The manufacturing continuum at Saint Blaise-Bains des Dames and Endröd 170

The site of Saint Blaise-Bains des Dames, a lake dwelling settlement located on the northwestern shore of Lake Neuchâtel, Switzerland (fig. 1) was excavated between 1986 and 1988 by members of the Archaeological Service of the Canton of Neuchâtel. A total of 3843 bones and tooth tools, ornaments and worked scraps of bone were recovered. The site primarily represents late phases of the Neolithic in western Switzerland. The brief Horgen period occupation at the bottom of the archaeological sequence (3160 - 3100 BC) is considered to mark the end of the Middle Neolithic and the following Lüscherz component (2700 - 2670 BC) the Middle of the Late Neolithic in the region. The final, major occupation (2550 - 2510 BC) is that of then Auvernier culture which appears at the end of Neolithic period and is contemporary with the Corded Ware culture of eastern Switzerland. The majority of the finds from the Auvernier period come from the four sedimentological blocks into which it was divided and which represent the last building phase at the settlement. The complex stratigraphy from the site as a whole was synthesized into a total of eight sedimentological blocks. Blocks B and D unambiguously correspond to the Horgen and Lüscherz periods, Block C being transitional between them. Between them they contain only 2% of the worked bone and tooth material. Blocks E, F, G, and H represent the Auvenier occupation. Block H, however, at the top of the Auvenier sequence yielded a mixed material disturbed by the activities of the lake.

The large number of worked specimens permits the assemblage to be divided into typological sub-samples

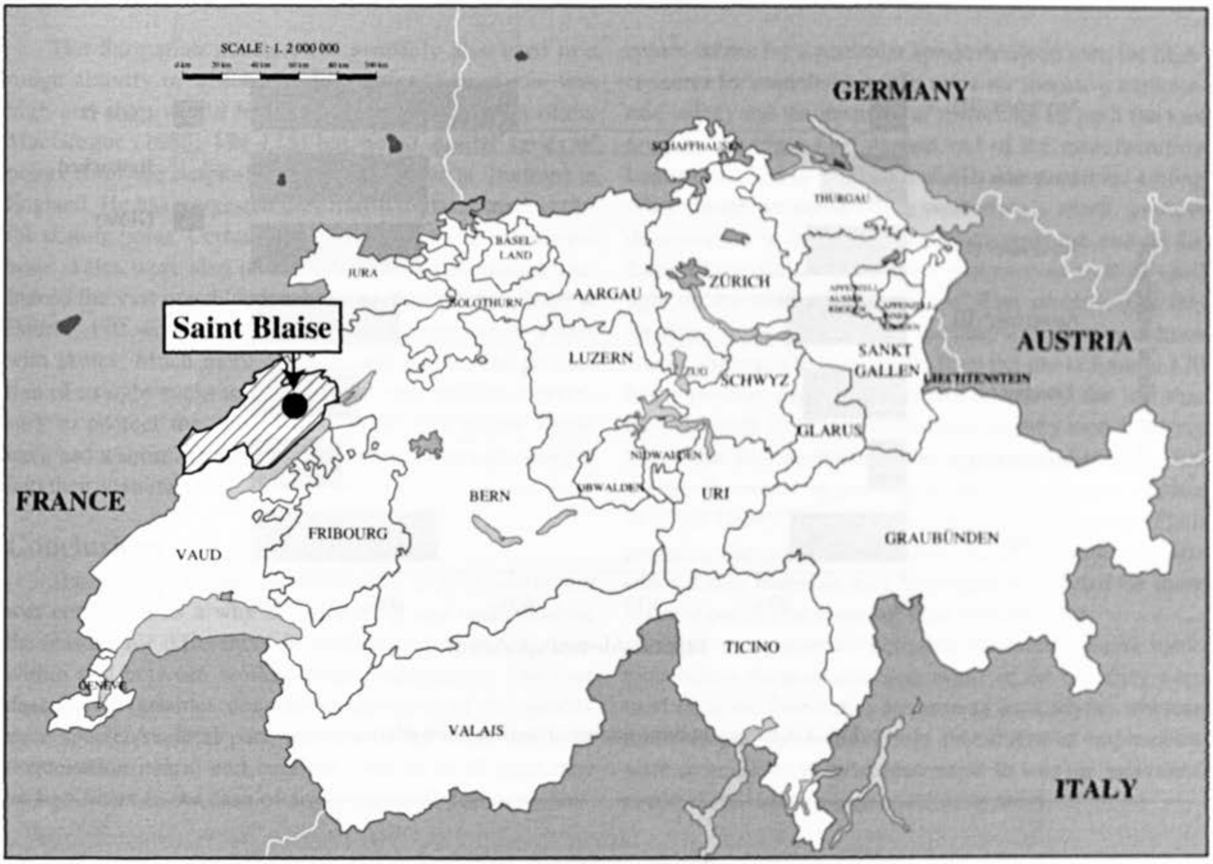

Fig. 1: The location of the Saint Blaise-Bains des Dames excavations in western Switzerland (Canton Neuchâtel).

where the tools are identifiable to species and skeletal part, which are still of sufficient size to provide a reliable picture of bone tool use at this site. For example, caprine bones are made into a somewhat greater variety of tools and the raw material is less standardized compared to those tools made on the bones of roe deer. Thus, more caprine bones are made into tools which fall into the middle of the manufacturing continuum. Roe deer bones, however, seem to be concentrated on the metapodia which were almost exclusively turned into carefully worked planned awls of high quality falling into Class I range. Fewer red deer metapodium based tools were available for study but the same tendency seems to hold true for them in comparison with tools made from cattle bone.

Class II tools cross-cut various categories of tool types. Diagnostic changes in the relative frequency of Class II bone implements may be diagnostic of the general status of bone manufacturing at this site. Certain *ad hoc* chisels which, by definition, fall into the extreme end of the Class II category, and most tools with bevelled edges are characterized by the greater skeletal part variability expected of Class II tools. Small and medium size points as well as rib points (but not linen comb points) are the categories of pointed types most often produced in an opportunistic fashion. The percentual contribution of such Class II tools displays a small but steady increase throughout the chronological sequence, although it never reaches 10 percent. When one considers the earlier Cortaillod material from nearby Twann (Schibler, 1981), the general impression is that there is a higher incidence of bone artifacts which fall into the Class I or planned range on the manufacturing continuum (for example highly worked axes, spatulae, retouchers, and knives). On the other hand, such differences in overall quality of tools between the two sites and periods may simply reflect horizontal distributions of craft specialization areas in the settlements. More specialized bone tools would be likely found in households or working areas devoted, for example, to hide processing.

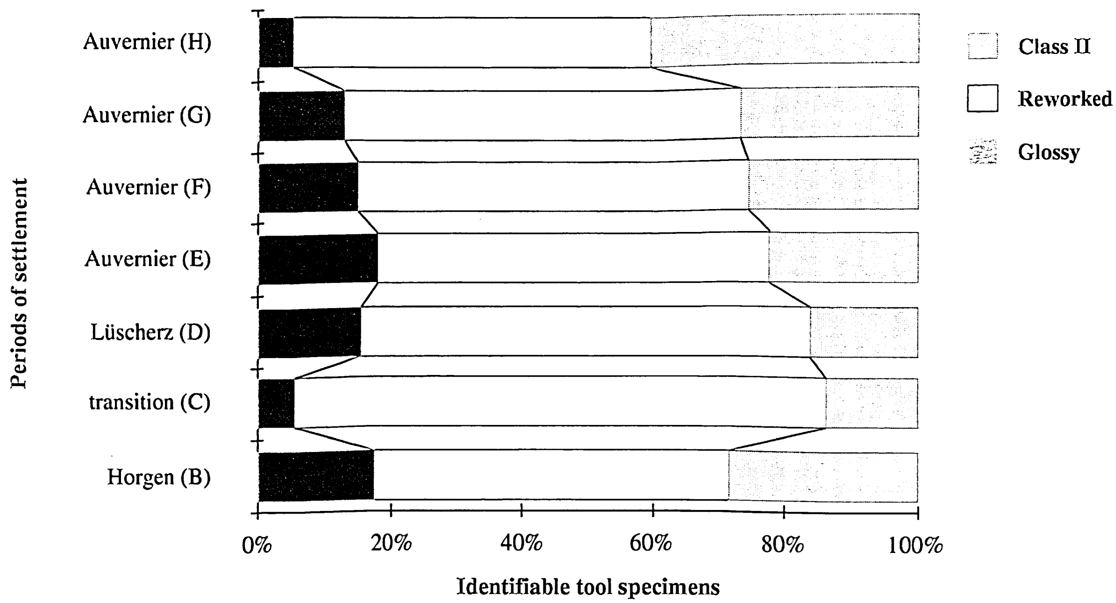

Fig. 2: Changes in three quality criteria at Saint Blaise.

As mentioned previously, point tips are most frequently reworked at this site. There is an inverse relationship apparent between increases in the numbers of Class II tools through time and the number of tools which display signs of curation behavior. Figure 2 thus shows that after the earliest Horgen occupation, there is a small but steady deterioration in the quality of manufacture at this settlement in the last years of its existence. It is tempting to suggest that as the occupation came to an end and the settlement slowly fell into disuse, hide and fiber processing was carried out on less of a communal and regular basis. Perhaps in the end people repaired existing goods individually and only produced new things more sporadically.

Examples of another way of utilizing the concept of manufacturing continuum in the analysis of worked bone come from the Migration Period, Sarmatian site of Endröd 170 (Békés county) in southeastern Hungary. This AD 2rd-3rd century settlement lays near the floodplain of the Körös river in the so-called Barbaricum east of the Roman province of Pannonia. Its inhabitants were pastoral people of steppe origin who occasionally used worked bone in mundane activities in spite of the availability of metal instruments by that time.

Among the twenty odd pieces of worked bone from this site were five large points made from the diaphyses of various cattle long bones. Not only was there no consistency in the skeletal part selected but the points were based on spiral fractures produced when the diaphyses were broken to extract the marrow. These 'natural' points were then minimally ground to produce a more even tip and the opposing end hollowed out. All but one of these tools displayed battering wear running parallel to the axis at the tip suggesting the tool was used with a thrusting motion on hard material. Because the effort put into their manufacture was low but the use wear heavy, they had a positive exploitation index. The fifth tool, morphologically identical to the others displayed a high glossey rippled surface at the tip and handling polish at the epiphyseal end missing on the others. It was probably used in leather-working. While these tools are all clearly opportunistically produced utensils, their high exploitation places them more toward the middle of the manufacturing continuum although still on the Class II side. This is the same general range as the Swiss linen combs which were placed more toward the Class I tool end of the continuum because, unlike the Endröd 170 points, they were consistently manufactured on ruminant ribs.

The Sarmatian points were probably also used in a rough activity in which the destruction/discard rate was high and they would have to have been replaced often. MacGregor (1985: 174-175) has noted similar series of points from the Anglo-Scandinavian levels at Thetford in England. He has suggested they may have been used as tips for skating poles. Certainly, fragments of horse metacarpal bone skates were also recovered from this Sarmatian site. Indeed the vast marshlands which surrounded the village at Endröd 170 would have been ideally traversed in winter with skates. Much more effort would go into the production of straight sticks to propel the skaters making it necessary to protect the ends. These protective points would have had a short life so that not much work or time was put into their manufacture.

Conclusions

The concept of the manufacturing quality continuum was conceived as a way of comparing and understanding the reasons for differences in stylistic quality in tool types within and between worked bone assemblages. The four descriptive variables considered measures of this quality were species/skeletal part, manufacturing wear, use wear (exploitation index) and curation. One or all of these may be significant in the case of any given tool. The more preference shown for a particular species/skeletal part, the higher scores for manufacture than use wear (negative exploitation index) and the presence of reworking all push the tool towards the Class I or planned end of the manufacturing continuum. Using these criteria it was possible, among other things, to demonstrate concretely a small, gradual deterioration in bone tool quality towards the end of the Saint Blaise-Bains des Dames sequence as well as shed light on the relative importance of fiber processing at this Neolithic settlement. As was the case with the Swiss linen combs, the massive bone points from the site of Endröd 170 had a positive exploitation index. In spite of the fact that they are made from a variety of only slightly modified long bones that they must have been regarded as disposable but useful. However, in contrast to the linen combs, skating over the frozen marshlands of the Great Hungarian Plain probably did not have the same socio/economic significance. Other materials may have been substituted for these massive points also reducing their relative value.

Thus it is suggested here that consistently better made tools reflect the economic importance of the task they were used in to the Prehistoric community as a whole, whereas more simple, opportunistically manufactured implements were more likely to have been made to suit the individual needs of the moment such as repair or sport.

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