

Axe Age

Acheulian Tool-making from Quarry to Discard

Edited by Naama Goren-Inbar and Gonen Sharon

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What typology can tell us about Acheulian handaxe production

Shannon P. McPherron

Abstract

It was quite clear from the start, over a century and a half ago, that Acheulian handaxes come in different shapes and sizes, but early typologies designed to capture this variability had difficulties related to continuity in form between types. Thus, in the 1960s, Roe, Bordes and eventually others created objective, numerical approaches to quantifying and describing handaxe variability. The underlying reality, however, remains the same: handaxe forms grade into one another, handaxe assemblages are characterized by variability around a modal form, and assemblage-level modal forms grade into one another. One interpretation of this pattern is that types are capturing stages in a bifacial reduction technology, meaning that type frequencies are a function of raw materials and reduction intensity. The question then becomes to what extent and under what conditions did Acheulian bifacial technology vary? And can a typological or morphological approach continue to document and help explain significant behavioral variability?

Introduction

For almost as long as handaxes have been recognized as an important Lower Paleolithic stone tool type, we have been aware that this single class of objects encompasses a great variety of forms. In Europe, up until the 1950s, the description and creation of named varieties proceeded in a mostly ad hoc manner that resulted in a confusing array of terms, many of which described essentially the same type of handaxe. Then, in the 1960s, a number of different archaeologists produced standardized type lists for describing handaxe collections (Bordes, 1961; Roe, 1964; 1968; Wymer, 1968). Two of the more influential approaches, those of Bordes and Roe, were based on linear measurements combined with numerical limits to defined types.

Numerical approaches provided a solution to the problem faced by nearly everyone who has worked with a handaxe collection; namely, while one may have the overwhelming impression that certain shapes or types were the preferred ones, there nevertheless exists such a range of gradations in shape that it becomes at times impossible to say to which type a particular handaxe belongs (cf. Bordes, 1961: 71 or Wymer, 1968: 48). Numerical approaches to handaxe typology allowed objective summaries of the shape of handaxes in a particular assemblage and, therefore, more objective comparisons between assemblages. What these approaches did not immediately do, however, is

provide an explanation for the variability that they document and that has been apparent for over 150 years.

One possibility is that the statistical methods were not sophisticated enough to analyze the data effectively. Thus, in the 1970s easy access to statistical computing resulted in various high-powered, multivariate approaches to the data sets (Callow, 1976; 1986; Doran and Hodson, 1975; Rollefson, 1978). Since then others have tried similar approaches (Wynn and Tierson, 1990). These studies continue to reveal more about how handaxes vary in shape, a topic discussed below, than why.

Since the 1980s, some researchers have continued to look at the question of why handaxe shape varies (e.g., Crompton and Gowlett, 1993; Gowlett and Crompton, 1994; McPherron, 1994; 1995; 1999; 2000; White, 1995; 1998a). Two of these studies, White and McPherron, explicitly tackle the variability in western European handaxes documented by Bordes and particularly Roe. These studies share an emphasis on a consideration of large sample sizes, inter-assemblage comparisons and a focus on modal behavior. They disagree, however, on what it all means. White has shown that raw materials influence handaxe shape. McPherron has shown a relationship between size and shape that he argues shows the influence of raw materials and reduction intensity. White and others have rejected McPherron's model (cf. Ashton and White, 2001; 2003; Lamotte, 2001). On the other hand, Gowlett and Crompton, looking at African handaxes with an approach very similar to McPherron's, interpret inter-assemblage differences in the relationship between size and shape as reflective of functional constraints, mechanical/technological constraints (cf. Jones 1979; 1994) and perhaps stylistic preferences.

However, at the same time, there has also been a move away from typological studies, in part perhaps motivated by the failure of the typological approach to provide an explanation for the variability it documents. Starting particularly in the mid-1980s, approaches that emphasized the process of stone tool manufacture, with an emphasis on what are usually called technological rather than stylistic or functional attributes, rose in popularity. It is certainly true that often too much emphasis has been placed on final form rather than process, and handaxe studies are particularly open to this since they appear to be, at times carefully, shaped items (Davidson, 1991; Davidson and Noble, 1993). At the same time, it can be very difficult to reconstruct the process by which they were manufactured, in part because the byproducts of the manufacturing process are either fairly homogeneous (bifacial thinning flakes) or indistinct from alternative technologies and in part because the bifacial thinning process itself effectively removes traces of previous stages to the point where it can be difficult to determine even whether the artifact was made from a flake blank or nodule.

The approach taken here is to explicitly use typology to reconstruct process.

What this paper will do is first summarize what we know about how handaxe shape varies. This will be explored in two parts. First, data from two large studies of handaxe measures will be used to identify which aspects of shape show significant variability. Second, the paper will then look at what we can generally say about how these aspects of shape vary within and between assemblages. Once the variability is understood, some current explanations or models for this variability will be

discussed. These models seek to unite the process of bifacial reduction with an explanation for the variability in handaxe final form. Critical to this model is an understanding of discard behavior. It is discard that brings the process of bifacial reduction to an end and thereby structures the range of shapes present in the assemblage. Thus, if we can understand the factors underlying discard, we will better understand handaxe variability.

Quantifying variability in shape

For European assemblages, there are two principal measurement systems used to quantify handaxe shape (Bordes, 1961; Roe, 1964; 1968). These are summarized in Figure 1. The measurements, of course, record basic size information, but they are primarily intended to be converted into ratios to describe three aspects of shape: elongation, refinement (relative thickness) and edge shape. The formulas for these ratios are also given in Figure 1.

Where the two systems agree is in elongation and refinement. They take very different approaches, however, to edge shape. Bordes uses a formula that combines a ratio of the mid-width (width at the mid-point of length) and maximum width with a ratio that expresses where the maximum width is located relative to the total length. The main problem is that changes in the second ratio will affect how the first ratio is measured. If the location of the maximum width approaches the mid-point of the handaxe, then the mid-width will necessarily approach the maximum width. One can easily imagine a handaxe with a pointed tip in which, because the maximum width lies at the mid-point of the length,

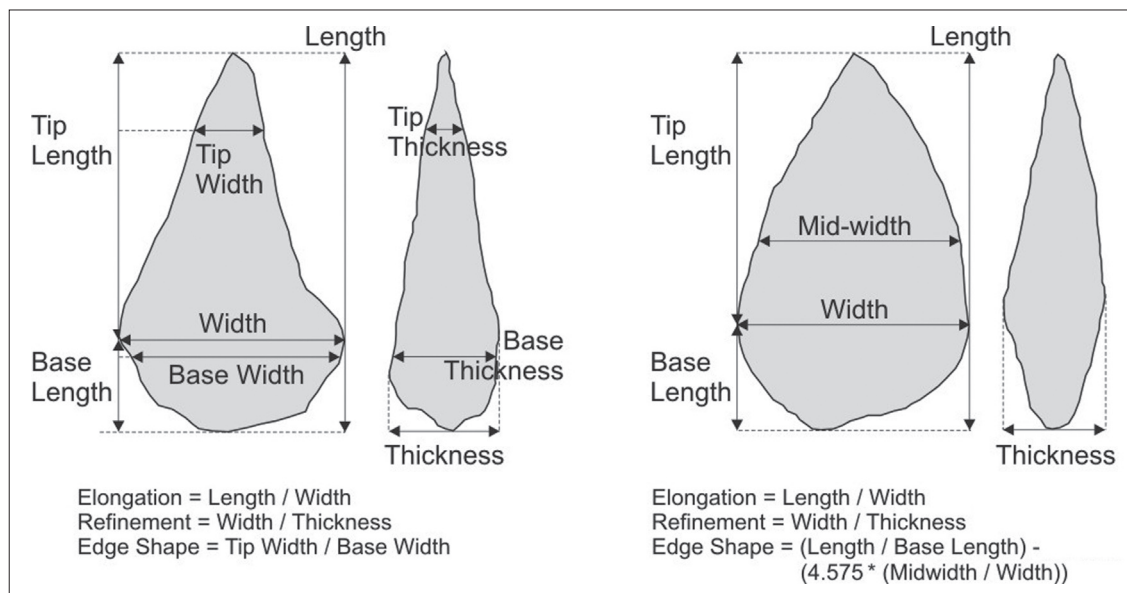


Figure 1: The measurement systems of Roe (left) and Bordes (right).

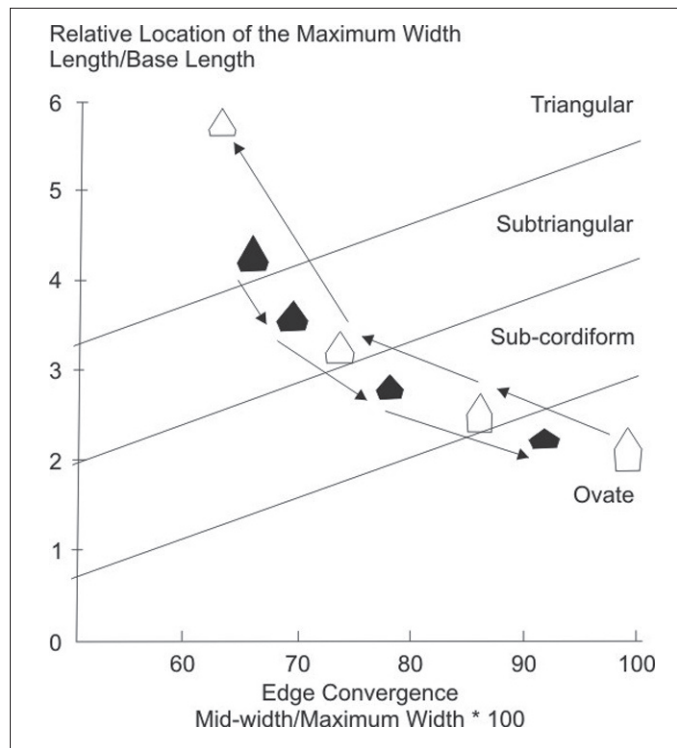


Figure 2: In Bordes' system of quantifying edge shape, changes in the relative size of the base or tip change where the mid-width is measured and, therefore, the edge shape type, though the edge shape remains constant.

the ratio of the mid-width to the maximum width will equal one and the handaxe will measure as an ovate according to Bordes (Figure 2). This is a fundamental flaw in the measurement system as regards edge shape. The fact that it nevertheless generally works with actual handaxe collections is only because handaxes with their maximum width at the mid-point also happen to look ovate.

Roe's approach also combines a ratio of width at two locations with a measure of where the maximum width is occurring on the handaxe. However, the key difference is that these two ratios are independent. Where the maximum width falls on the handaxe does not affect where the other width measurements are recorded. These are always recorded at 1/5 and 4/5 of the length. The interesting point, however, is that the ratio of widths, the ratio that most closely speaks to the edge shape, is essentially ignored in determining whether a handaxe assemblage is characterized by ovate or pointed handaxes. Instead, it is the location of the maximum width relative to the length that determines in which of Roe's tripartite diagrams the handaxe is placed and therefore whether it is ovate, pointed, or a cleaver. Again, this works because handaxes that plot on the ovate graph, those that have their maximum width at 35–55% of the length of the handaxe, happen to look ovate. The relationship between these ratios can be easily demonstrated using Roe's published data (Figure 3).

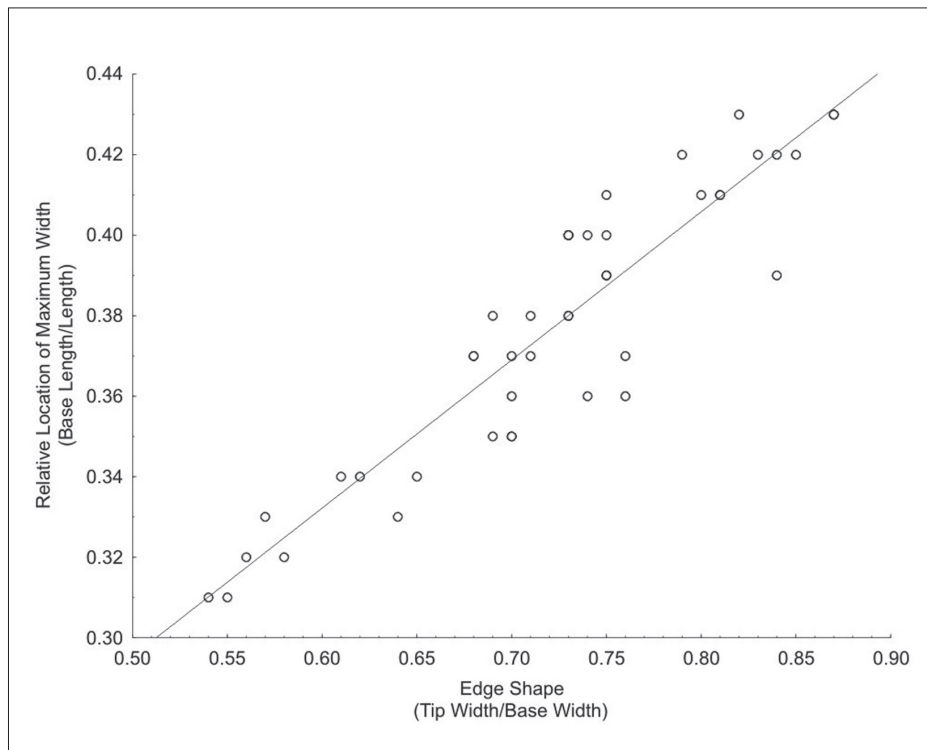


Figure 3: Plot showing relationship between Roe's edge shape ratio and the relative location of the maximum width. The data are assemblage averages drawn from Roe, 1968 and Callow, 1976.

Where shape varies

In creating their measurement and analysis systems, Roe and Bordes attempted to quantify the variability in shape that was, at the time, considered important and that was already being factored into existing typologies. What they did not do is test whether these aspects of shape, elongation, refinement and edge shape were the most important numerically. There are, however, two studies with large sample sizes that have attempted to address this topic.

The first of these, conducted by Callow (1976), included 69 Acheulian assemblages from northwest Europe with a total of 5500 handaxes. Callow ran a canonical variate analysis (CVA) of the log transformed values of both Roe and Bordes' measurements plus a few additional ones intended to provide more information on the tip.

Of these 11 measurements, the CVA isolated length, thickness, the length to the maximum thickness (tip length) and the thickness near the base (F-ratios of 50.8, 46.0, 40.5 and 40.1) as having greatest discriminating power in the data set (Callow, 1976: 8.16). Handaxe width had a discriminating power only slightly better than average. He interpreted these results as indicating the importance

of thick, globular bases versus thin bases in discriminating handaxe assemblages. In other words, refinement is an important factor in morphological variability. CVA combines variables in much the same way that a factor analysis produces factors. The first three variates, which together account for 75% of the total available discriminating power in the data set, are as follows:

CV1: Length and width versus width near the base

CV2: Length and width versus width near the tip, thickness and width near the base

CV3: Thickness near the tip, width near the base, width at the tip versus thickness near the base and width

The first two relate size as measured by length to the width of the base (CV1) and to the overall width and thickness (CV2). Callow interpreted the last variate as representing the profile of the handaxe, with lenticular profiles at one extreme and tapering profiles at the other.

To eliminate the effects of size on the analysis of shape, Callow divided each measure by the width and repeated the CVA on a reduced set of log transformed variables that included length, thickness, location of maximum width (tip length), width near the tip, width near the base and thickness near the tip. By dividing these measures by width, they become shape ratios. So, scaling length by width creates elongation. Likewise, thickness becomes refinement, and tip length describes the elongation of the tip. The results are as follows:

CV1: Thickness near the tip (tip refinement) versus length (elongation) and thickness (refinement)

CV2: Thickness near the tip (tip refinement) and thickness (refinement) versus length (elongation)

CV3: Thickness (refinement) versus length (elongation) and width near the tip

Together these three variates account for 84% of the total discriminating power of the six variables. With handaxe width standardized, effectively removing it from the analysis, elongation and refinement become the most important variables, accounting for 37.2 and 25.2% respectively of the total discriminating power. The elongation of the tip finished third with 21.1%. The next variable, the width near the tip, accounted for only 7.7%. Note that width near the tip divided by width is very nearly Roe's edge shape ratio and very similar to Bordes' edge shape ratio. In other words, Callow's multivariate study supports the traditional focus on elongation, refinement and tip shape, in that order, as the more important aspects of morphological variability in Acheulian handaxes. It also demonstrates that edge shape is, relatively speaking, much less important.

The problem with Callow's study is that it uses measurements that are already well suited to measuring these aspects of shape. Thus, the study was probably in part predisposed to come to this conclusion, though the internal ranking of these aspects of shape is still interesting. An alternative study, one that tries to side-step these issues and take a more all-encompassing view of edge shape in particular, was conducted by Wynn and Tierson (1990) on 1178 Acheulian handaxes from 17 sites in Africa, the Near East, India and England. They used a system of 22 radial measurements taken at specified intervals from the center of the handaxe outline to the edge. The center of the handaxe was taken as the mid-point of the long axis of the piece, with the long axis defined as the line running from the tip to the furthest point on the base. In cases where the tip was relatively flat, such as cleavers, the mid-point of the tip was used. Because the long axis seldom divided a handaxe into two identical halves, the narrow side was always

placed to the right (Wynn and Tierson, 1990: 74). The radial measurements were not taken at equal intervals. Instead, a higher concentration of measurements was taken near the tip and the base because previous work with the same technique indicated that more measurements near the tip are needed to distinguish cleavers and handaxes (though cleavers were not included in the published results).

I have reviewed their methodology in detail and commented on their interpretations of the results elsewhere (McPherron, 2000), but here it is useful to summarize again their results because, while I disagree with their overall interpretations, the results of the analysis are relevant to the discussion of how handaxe shape varies. They first conducted a PCA (Varimax orthogonal rotation). The results are not given in detail by Wynn and Tierson (1990: 75) because “the contribution of size to the first component was clearly seen”. The first component accounted for 83.1% of the variability in the data set, and the first two components together accounted for 89.6% of the variability in the data set. About these two components, Wynn and Tierson (1990: 76) state that “both components were related to size, since the component loadings over all variables were similar (for example, the lowest loading was still greater than 0.3)”.

Like Callow, they then restarted the analysis with size-corrected data, but unlike Callow they used length rather than width to standardize their measures. As a result, two of the twenty measurements are lost because they are coincident with length. Since all other measurements are then relative to length, width measurements become elongation ratios. In the PCA of the size-adjusted measures, the first four components account for 84.3% of the total variability. Wynn and Tierson interpret the first component, accounting for 54.3%, as representing shape differences on the left side of handaxes. In other words, in the absence of length, width or elongation becomes the most important factor. Note too that the left side probably ranked prior to the right side because of the above-mentioned procedure wherein the narrow side is placed to the right. The second component, accounting for only 15.6% of the variability, relates to differences in handaxe tips. It is more difficult to interpret what tip measures divided by length mean. It is tempting to attribute these measures to tip length, but since they are measured from the center of the handaxe and not from the point of maximum width or thickness, this is not exactly accurate, though it may represent the next closest proxy in the absence of length. What can be said is that tip measures co-vary and that they account for approximately 15% of variability. The third component, accounting for 9.0%, reflects differences in the lower right side of the handaxes, and the last component, accounting for 5.0%, reflects differences in the base of each handaxe.

In summary, the multivariate studies of both Wynn and Tierson and Callow provide quantitative support for the emphasis placed in handaxe typologies and in handaxe measures on capturing and explaining edge shape, elongation and refinement. If we can account for variability in these three aspects of shape, then we will have explained the largest part of morphological variability. This does not mean that the lower-ranking aspects of shape are not potentially behaviorally important or that there are no other aspects that we might want to study, but rather only that this is where we should start. Wynn and Tierson’s study is particularly interesting since it includes handaxes from several regions and since it is not based on the traditional measurement systems. Elongation seems to clearly rank first as the largest source of variability in handaxe shape. Callow’s study places refinement next.

Wynn and Tierson do not include this variable. The variables that reflect both Bordes' and Roe's approaches to edge shape also figure prominently in these results.

How shape varies

When we look at how these aspects of shape vary within and between assemblages, there are some clear patterns.

First, it is clear that assemblages are characterized by a modal shape. That is to say, the handaxes of an assemblage will tend to cluster around a particular shape and most other handaxes in the assemblage will grade into this modal shape. One way that this can be demonstrated is by putting back together the three graphs of Roe's tripartite system of representing assemblages (McPherron, 1995). The tripartite system gives the impression that there are three distinct edge shape types, ovates, pointed forms and cleavers, but when the three graphs are combined into one there is always a single cloud of points in which these three forms grade into one another. This does not disprove that there were several distinct shapes that the handaxe makers were trying to achieve, but there is no support for it either.

Second, the range of shapes or richness present in an assemblage is proportional to the size of the assemblage. This can be demonstrated using Callow's (1976) data set by graphing the number of types (richness) in an assemblage against log transformed sample size of the assemblage (Figure 4).

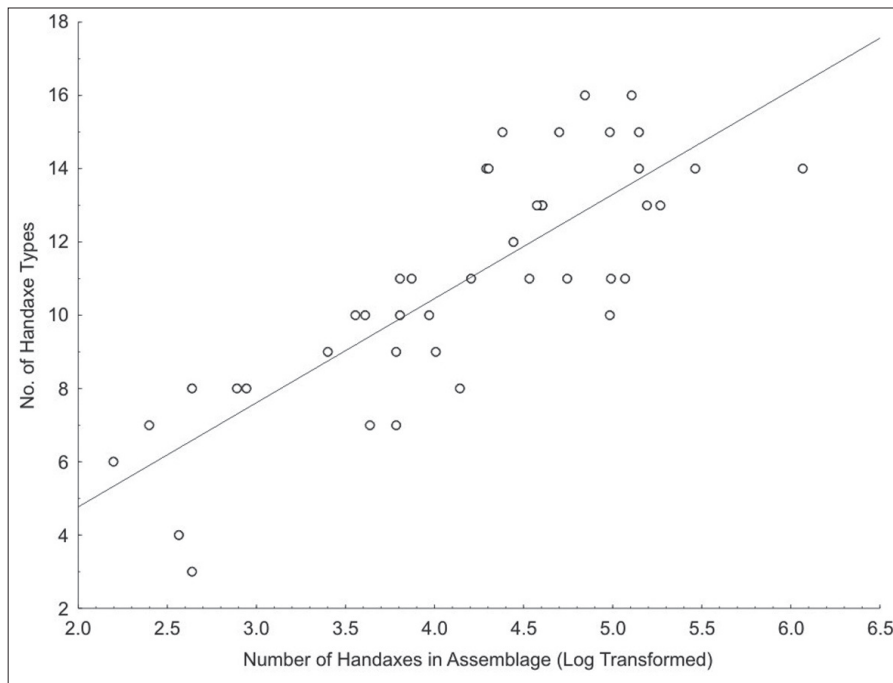


Figure 4: Assemblage richness against log transformed assemblage size using Callow's (1976) data set of Acheulian sites from western Europe.

If particular shapes were intended for particular activities, then we might expect to find task-specific sites with a reduced range of shapes despite large sample sizes. This is not the case.

Third, in the Roe data set there is a bimodal distribution in edge shape at the assemblage level. This was originally shown by Roe (1968) and has been supported by others using a variety of multivariate techniques (Callow, 1976; Doran and Hodson, 1975). Assemblages characterized by ovate forms are most common. There is a second peak on assemblages characterized by more pointed forms. If, however, you add additional assemblages, this pattern disappears (Figure 5). It is likely that the bimodal pattern in the Roe data set is a function of the relatively small sample size. This situation is reminiscent of the multimodal patterning that Bordes found in Mousterian flake-tool assemblages and that was later shown to be unimodal when the sample size increased (Dibble and Rolland, 1992).

Fourth, in addition, it is also clear that assemblages grade into one another just as individual handaxes grade into one another within an assemblage. This can be shown especially well by graphing the base length to length ratio used by Roe to separate pointed, ovate and cleaver forms (Figure 6). In other words, not only is it difficult to draw a line between one type and another, it is difficult to draw a line between one assemblage and another.

Fifth, elongation and edge shape are correlated both with the length of the handaxe and with the length of the tip, such that larger handaxes tend to be more elongated and more pointed as

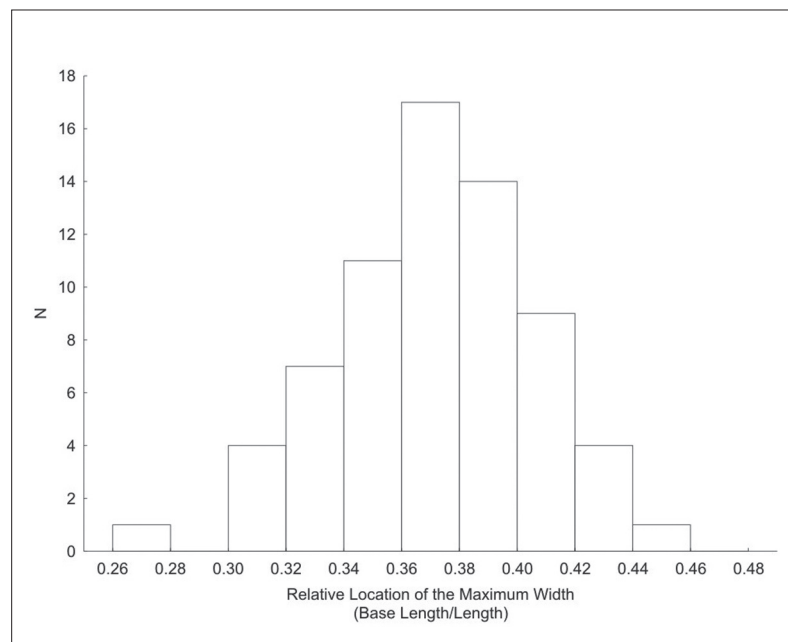


Figure 5: Base length to length (a proxy for edge shape) in Callow's (1976) expanded Acheulian data set from western Europe. When the data set is expanded in this way, the bimodal pattern in Roe's original, smaller data set is no longer apparent.

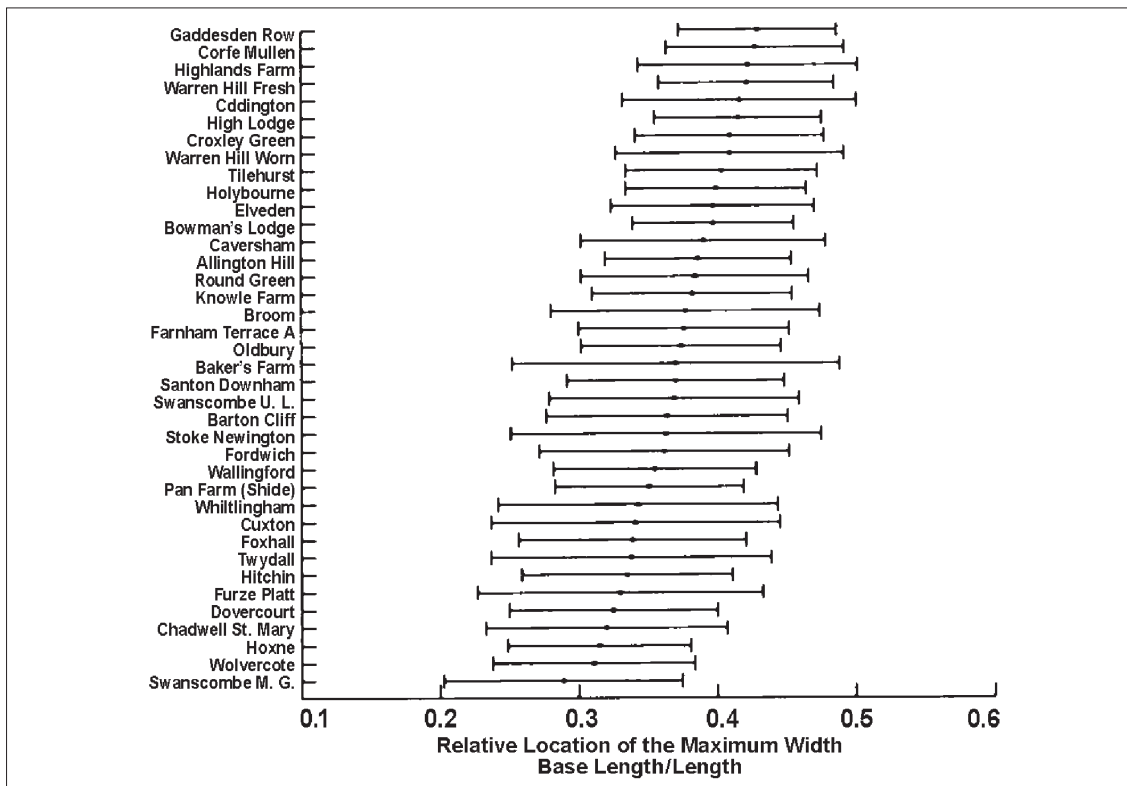


Figure 6: Relative location of the maximum width with error bars representing one standard deviation. Data are based on Roe, 1968.

quantified using either Bordes' or Roe's system of measurement (McPherron, 1994; 1995; 1999; 2000; 2003). This relationship is particularly strong with regard to elongation (McPherron, 2000) and is true whether you consider handaxes within an assemblage or whether you consider averages between assemblages. It also holds true throughout the Old World and throughout the Pleistocene. In the case of edge shape, this pattern holds true within assemblages (McPherron, 1994; 1999; 2003) and, though the data are a bit more difficult to obtain, it holds true between assemblages as well (McPherron, 1994; 1995). So, for instance, when we compare Roe's pointed assemblages with the ovate assemblages, the former have larger handaxes than the latter.

Sixth, to some extent, refinement is also related to measures of size (McPherron, 1994; 1995; 1999) and, therefore, to other aspects of shape both within and between assemblages. However, since refinement is typically calculated based on the maximum width and thickness, for handaxes that retain some cortex it tends to describe more the original blank than the bifacial technology (see also White, 1998a). In the northwestern European data set, pointed handaxes tend to be larger and to preserve a cortical base; they are, therefore, typically less refined than ovate handaxes, which tend to be smaller and worked entirely around their edge. There are also data to suggest that refinement

may be more affected by raw material variability than the other aspects of shape (Noll and Petraglia, 2003).

Seventh, the shape, size and quality of the raw material impact the reduction strategy (e.g., Jones, 1979; 1994; White, 1995; 1998a; Noll and Petraglia, 2003). In Roe's data set, there is a correlation between raw material type and shape (White, 1998a). When the material allowed a variety of forms, ovate shapes were more common and when the raw material was of low quality or when the shape constrained the production of an ovate form, pointed forms were more common.

Interpreting variability

The reason it is important to outline the above points is that if we understand clearly how the variation in shape, and importantly size, is structured, then some explanations become more likely than others. What I (1994; 1999; 2000; 2003) believe the preceding points illustrate is that, at least for the western European data set, the application of a shared and fairly narrowly defined bifacial reduction strategy resulted in a range of sizes and shapes that show consistent patterning within and between assemblages. The range of shapes and sizes shows no evidence for distinct types at the level of the assemblage or individual artifacts; however, variability within an assemblage is centered on a modal shape.

Given these patterns, stylistic and functional explanations seem unlikely. One could easily imagine a chronological trend in these data (Roe, 1968) with a gradual shift in time from one type to another. Despite initial suggestions that this might be the case, better chronologies showed this to be inaccurate (Roe, 1981). For instance, with the dating and publication of the Boxgrove (Roberts and Parfitt, 1999) and High Lodge (Ashton et al., 1992) assemblages, it is clear that highly refined forms exist alongside cruder forms from the earliest times. That said, with the greater time depth outside of Europe, there are some chronological trends (Bar-Yosef, 1994) that undoubtedly relate to evolving technical skill and perhaps manual dexterity and should be incorporated into explanatory models, though the low level of dating precision on most Acheulian finds makes this difficult to do presently.

As discussed in the introduction and above, White (1998a) argues that variability in southern Britain, particularly in edge shape, can be accounted for by raw materials. He makes the argument that in fact the preferred handaxe shape in the British Acheulian data set was the ovate and that pointed forms were a response to inferior raw materials. His model speaks less to elongation and refinement. White (1996) and Ashton and White (2001; 2003) have explicitly addressed my own intensity of reduction model and rejected it as playing a factor in determining handaxe shape.

What is unfortunate in the context of explaining variability is that they seem to see it as an either/or situation rather than considering the possibility that both factors may play a role. White (1996) in particular has suggested that because raw material plays a *greater* role in determining handaxe shape, reduction intensity plays no role. It is as if two doctors conducted two different studies, one to test the effects of poor diet on heart disease and the other to test the effects of poor exercise habits on heart disease, and then when both find a positive correlation one nevertheless argues that the

other is wrong because their correlation coefficient is not as large (cf. Ashton and White, 2001: 14; 2003: 114). And then, to make matters worse, the doctor who thinks the other is wrong constructs a test of the other that does not at all replicate the necessary observations.

Instead, what I think we have learned is that raw materials and intensity of reduction together account for a significant proportion of variability in handaxe shape. At the risk of proposing a study that could prove me wrong, I (McPherron, 2003) have suggested the following study. If raw materials predict shape and reduction intensity does not, then within a raw material type there should be no relationship between measures of intensity of reduction (tip length or overall length) and shape. If, on the other hand, there is a relationship between size and shape within the raw material types, then it would show that together these two factors can explain an even larger percentage of variability.

Not having good raw material data for the collections I have studied, I took a slightly different approach to the problem. I tried to control for or at least limit some of the variability in raw materials by looking at multiple assemblages within a single site, namely Tabun, Israel (McPherron, 2003). This is not to say that raw material was homogeneous at Tabun, but rather that the kinds of nodules (in terms of shape and size) available may have remained fairly constant through the sequence. What I found was a very good correlation between measures of size and measures of elongation and edge shape. I did not find a good correlation between size and refinement, which remains relatively constant. In addition, I found that measures of handaxe reduction correlated with the relative proportion of handaxes to scrapers. In assemblages that emphasize handaxes, the handaxes are smaller, less elongated and more rounded. In assemblages that emphasize scrapers, the handaxes are larger, more elongated and more pointed. In other words, at Tabun it is possible to link variability in retouched tools, handaxe size and handaxe shape. What is controlling this pattern, why handaxes or scrapers are favored level by level or why, for that matter, handaxes drop out altogether in the upper sequence, is unknown. Solving this problem may tell us something important about how these tools were used.

Discard behavior

In the perspective put forth here, the key factor that remains to be explained is discard behavior. Handaxes were, of course, made to be used, but what explains the success of the technology is that they were made to be *re-used* (Hayden, 1987; 1989). A handaxe, once made, was constantly reworked until it entered the archaeological record for the last time. As it was reworked, its size changed and with it its shape. Its final shape, the shape we study, is the one it happened to have when size factors made it unreasonable to continue with that particular handaxe. What constitutes “unreasonable” will, of course, be subject to any number of factors including raw material availability and mobility, but if we can explain what aspect of size limited further reworking, then again we may gain some insight into how handaxes were used.

In this light, there are some interesting patterns in the data. What I have found generally and

what is clear in the Tabun data set in particular is that while shape and size vary, measures related to the base and particularly to the width of the base remain fairly constant (Table 1). At Tabun, despite statistically significant changes in shape and many measures of size, the handaxes of seven levels entered the archaeological record with the same width, thickness and other measures of base shape. In addition, when you look at the amount of variability in length, width and thickness, with only one exception where it is equal to length, width is less variable than the others (Table 2).

This consistency in the base is what is driving most of the other patterns. What is happening is that the tips are reworked and reduced in length more than the width or thickness. The shape of the handaxe, particularly the edge shape and elongation, is a function of how much material was removed from the length. Refinement stays constant because width and thickness are constant.

One obvious explanation of this pattern is that the base is constrained by prehension and the length is determined by reduction intensity. In levels where handaxe related activities were intense, length was greatly reduced before the artifact was discarded. In other levels, handaxes were discarded earlier in their potential use-life.

Table 1: A comparison of measure of size between levels at Tabun. Only levels with a sample size >50 are included. Numbers are means and standard errors.

	Level 72	Level 75	Level 76	Level 79	Level 80	Level 83	Level 90	F	P
N	50	75	333	134	66	61	125		
Length	84.54 (2.26)	85.09 (1.85)	72.65 (0.88)	72.07 (1.38)	69.39 (1.97)	83.05 (2.05)	74.05 (1.43)	13.89	0.00
Mid-width	50.88 (1.48)	55.57 (1.21)	54.42 (0.57)	52.69 (0.91)	51.45 (1.29)	49.79 (1.34)	53.12 (0.94)	3.22	0.00
Mid-thickness	25.80 (1.01)	26.93 (0.82)	27.21 (0.39)	26.95 (0.62)	25.45 (0.88)	26.92 (0.91)	25.82 (0.64)	1.12	0.35
Max. width	56.66 (1.51)	59.56 (1.23)	57.27 (0.58)	56.41 (0.92)	55.09 (1.31)	57.13 (1.36)	56.48 (0.95)	1.24	0.29
Length to max. width	29.46 (1.35)	32.93 (1.10)	29.57 (0.52)	27.71 (0.82)	26.59 (1.17)	27.84 (1.22)	29.51 (0.85)	3.61	0.00
Max. thickness	28.56 (1.05)	28.95 (0.86)	28.64 (0.41)	28.68 (0.64)	26.26 (0.92)	28.82 (0.95)	27.28 (0.67)	1.54	0.16
Tip width	31.64 (1.34)	38.85 (1.09)	39.41 (0.52)	36.12 (0.82)	35.92 (1.17)	30.80 (1.21)	34.82 (0.85)	12.44	0.00
Tip thickness	13.82 (0.64)	13.96 (0.52)	15.43 (0.25)	14.97 (0.39)	13.94 (0.55)	14.67 (0.58)	14.10 (0.40)	2.83	0.01
Base width	48.58 (1.49)	50.76 (1.21)	50.13 (0.58)	49.54 (0.91)	47.44 (1.29)	51.67 (1.35)	49.49 (0.94)	1.18	0.31
Base thickness	26.38 (1.05)	26.99 (0.86)	26.36 (0.41)	26.47 (0.64)	24.85 (0.92)	27.30 (0.95)	25.78 (0.67)	0.82	0.55

Table 2: Coefficients of variation for Tabun levels with sample sizes >50.

Level	N	Length	Width	Thickness
72	50	0.18	0.17	0.26
75	75	0.24	0.21	0.34
76	333	0.21	0.17	0.22
79	134	0.19	0.17	0.24
80	66	0.19	0.17	0.22
83	61	0.27	0.23	0.35
90	125	0.21	0.21	0.31

There are indications of this pattern in other data sets. For instance, in a comparison of handaxes from the Olorgesailie location in Kenya and the Hunsgi-Baichbal location in India, Noll and Petraglia (2003: 38) show the exact same pattern of length, width and thickness. At eight of nine different sites, width shows the least variability of these measures. Also working on African handaxes, Gowlett and Crompton (1994: 36) found that measures of width at the base were “particularly negatively” allometric and generally behaved independently of other measures. What this means in this case is that with decreasing length, width decreased less quickly, and from the published tables it can be calculated that width is less variable than length or thickness.

What is more difficult to explain in the Tabun handaxes is why sometimes the reduction process resulted in the base being completely worked and why other times a cortical base was retained. Metrically, the main difference between these two groups is that handaxes with basal cortex tend to be thinner than those without (Table 3). What seems likely, though it remains to be shown, is that raw material, particularly the size and shape of the nodule, was controlling which path was taken. It may be that the handaxes with cortical bases were made on thinner, smaller plaques of flint that reached their reduction limit more quickly. A more detailed study of the placement (side and location) and type of cortex on the Tabun handaxes might help show how raw material and reduction intensity can account for a large portion of the variability in shape.

Discussion

So where does this leave us in terms of handaxe typology? One thing is clear from the data; we cannot compare final form between assemblages without considering the relationship between size and shape. Size is influenced at least by the form of the raw materials and the intensity with which they are reduced. Size might also have some functional/technological constraints (Gowlett and Crompton, 1994; Jones, 1979; 1994) and is likely limited at both extremes by prehension. It also seems clear that there is a relationship between the quality and availability of raw materials and the intensity with which they are reduced, which in turn affects shape.

Viewed in this light, the technologists are correct in emphasizing the process of stone

Table 3: A comparison of handaxe size measurements based on the amount of cortex preserved on the basal third of the artifact. Data are from Rollefson, 1978.

	0–50%	51–100%	F	P
Length	73.41	74.23	0.13	0.72
	(1.04)	(2.07)		
Base length	29.52	27.09	2.68	0.10
	(0.67)	(1.33)		
Max. width	57.01	57.72	0.21	0.65
	(0.71)	(1.42)		
Tip width	38.99	37.53	1.01	0.32
	(0.65)	(1.30)		
Mid-width	54.18	53.87	0.04	0.85
	(0.70)	(1.39)		
Base width	49.56	50.51	0.39	0.53
	(0.69)	(1.37)		
Tip thickness	14.76	13.62	2.84	0.09
	(0.31)	(0.61)		
Mid-thickness	27.30	24.81	6.06	0.01
	(0.45)	(0.91)		
Base thickness	26.25	25.21	0.97	0.33
	(0.47)	(0.94)		
Max. thickness	28.40	26.36	3.96	0.05
	(0.46)	(0.91)		

tool manufacture and not simply the final form. What has been overlooked in some instances, however, is that typological studies of final form can at times yield insights into the process of stone tool manufacture, and this certainly seems to be the case with handaxes. It seems, therefore, that we should continue to objectively quantify and report variation in handaxe shape in addition to conducting studies that more explicitly address technological aspects of handaxe production.

The approach presented here handles large data sets quite well and is in fact largely dependent on them. An alternative approach has been to study and describe in detail individual artifacts (e.g., Austin et al., 1999; Winton, 2004), preferably from recent excavations in good context where refit studies can be attempted. This descriptive, often non-quantitative approach tends to focus on variables that are considered indicative of decisions made by the flint-knapper in the course of manufacture, use and discard of the handaxe. Of particular interest are those points in the manufacturing process where decisions are made between apparently equal alternatives that are not constrained by raw materials or technology, because these decisions may tell us something of the desired form (White, 1998a) and its functional or perhaps even stylistic significance. Examples

include s-shaped profiles (White, 1998b; Ashton and White, 2001: 17), tranchet finishing and finishing retouch.

The problem comes in reconciling these two approaches: one that summarizes behavior on the regional or even continental scale as seen in hundreds or thousands of artifacts from multiple sites and one that seeks to describe small collections or even individual artifacts from one level at one site. The latter approach, when successful, can produce incredibly detailed results that bring to life the actions of an individual sometime in the past. The former approach, when successful, can be an incredibly powerful predictor or explainer of past behavior at somewhere between a large population and a species level scale. The key, of course, is that both approaches are correct and that one informs the other.

In this light, it is important too to emphasize that the findings of one do not necessarily invalidate the results of the other (see also discussion in Ashton and White, 2001: 17). Failure to appreciate this point has resulted in a number of debates within the field. So, for instance, a finding at a particular site that some large handaxes entered the archaeological record as ovate forms while some other small handaxes in the same deposit entered the record as pointed forms does not necessarily invalidate a model derived at the regional or continental scale that argues that handaxes tend to pass from larger pointed forms to smaller more rounded forms. What it does point out is that at that site something different was happening that needs to be explained, though perhaps it is idiosyncratic behavior that, by definition, cannot be explained. The point is that without models built on larger data sets, it is impossible to even recognize idiosyncratic or alternative behavior (for instance, Site Z in Gowlett and Compton, 1994).

What makes the formulation of these models possible is the standardization of handaxe measures. Whereas other stone tool types are infrequently reported with measurements, descriptions of handaxes assemblages are nearly always accompanied by at least length, width and thickness measurements (preferably with standard deviations) and often with Roe's measurements and/or diagrams as well. While Roe's measurements are a useful addition to length, width and thickness and while they provide a better summary of shape, the tripartite diagram is no longer particularly useful. The three-part structure gives a false impression of distinct types and the relationship between the two axes is now well established. Bordes' measurement system is used less frequently and given its peculiarities, some of which were discussed here, it is probably best to drop it. Alternative measurement systems, such as radial ones, may yet yield interesting results, but they should not supplant traditional measures as well. Finally, type lists, even if they are based on standardized measurement systems, appear to be of limited utility.

Significant steps have been taken towards an understanding of the factors that structure handaxe shape. An approach that takes into consideration the relationship between size, shape, reduction intensity and raw material variability is an effective starting point. Once these variables and their respective contributions are understood, then we can move to other, potentially more interesting aspects of what shape might be telling us (e.g., Wynn, 2002).

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