GETTING ROUND TO THE POINT: BIFACE TIP SHAPE IN THE BRITISH LOWER PALAEOLITHIC

J. McNabb[4] *& C. Rivett*

ABSTRACT

This paper describes a new methodology for looking at one aspect of large cutting tools/handaxes, their tips. It describes the application of the methodology at four British Lower Palaeolithic assemblages and concludes that tips may not have been a primary concern of the knapper in the initial making of a handaxe.

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INTRODUCTION AND BACKGROUND

In a recent interpretation of African large cutting tool (LCT) data (McNabb *et al.* 2004), one of us (JM) argued that African Acheulean handaxes and cleavers could be usefully characterised by a series of repetitive tip shapes. These distinctive tip morphologies were clearly present on the LCTs from the Cave of Hearths Acheulean site (Mason 1988), and were also present on other African Acheulean LCTs as represented by digital images of these tools from a selection of South African Middle Pleistocene sites in the Marshall *et al.* (2002) database. The methodology of McNabb *et al.* came under criticism from Machin & Mithen (2004). They concentrated their discussion on the analysis of symmetry (the remaining aspects of the technological analyses raised by the methodology did not attract critical comment). The gist of their criticism was that a non-metric methodology which established classes of artefacts solely on the basis of observational criteria was too subjective to be of any real value and thus its results would not be precisely replicable.

McNabb's response (2004) made a number of points, one of which is reiterated here. Analytical methodologies should be developed in response to particular research questions. They should be both appropriate to, and therefore conditioned by, the question posed. Machin and Mithen's call for greater precision in analysis was an honest and justified appeal for scientific rigour. As such it can not be faulted. But one of us (JM) remains committed to the concern that it is possible to over-analyse a data set generated by unnecessarily sophisticated data-gathering apparatus. Machin and Mithen could not believe that *Current Anthropology* would accept a simple observational methodology in an age where a millimetre seems a large and imprecise measurement.

We have no measure of how precise hominins felt they ought to be in manufacturing material culture, or by what yardstick they measured their results. It might seem redundant to state that *Homo erectus* in Africa and *Homo heidelbergensis* in Europe were not the same as modern *Homo sapiens*, but it is nevertheless true. Brain size and neural architecture were different,

[4] Centre for the Archaeology of Human Origins, University of Southampton, Avenue Campus, SO17 1BJ. Email contact: j.mcnabb@soton.ac.uk

and this will have had important repercussions on how and what earlier *Homo* accepted in terms of the rules that bound the making and use of material culture — in judging acceptability. Cognitive levels of comprehension of the actions of self and others were decidedly different to our own (Dunbar 2003, 2004). Ultimately, the original makers of this material culture passed judgement with their eyes, and it was this final filter that mapped socially generated acceptability onto finished form. Put another way, there was a finite limit set to an individual's judgment of his or her own work, and that limit was imposed by the physical limits of the structure of the eye itself working in concert with other cognitive, material, and cultural constraints. We should aim our methodological enquiries at the search for *this* level of precision. This is what is meant by making our analytical approaches relevant to the research questions we set ourselves.

To delve too deep, and add ever increasing layers of analytical minutiae is to produce pseudo-science. Over-measuring a thing just because we have the ability to measure it ever more precisely does not really help us to understand it in the way the maker originally intended it to be understood. On the other hand this does not negate the very appropriate call made by Machin and Mithen for rigour in analysis. What they sought was replicability (i.e. a rigorous methodology consistently applied that other workers can reproduce with the confident expectation of parity in results). All that is asked here is that such methodologies be applied that are appropriate to the scale at which the original research question is being asked.

We would like to ask two inter-related questions, the justifications for which are outlined in more detail below.

- What evidence is there for the consistent imposition of a particular tip shape in individual assemblages of British Middle Pleistocene handaxes?
- How great is the variability in tip form seen within individual assemblages?

To this end we have developed a methodology for looking at the tips of handaxes which does not include a measure of total handaxe outline form as is present in the seminal methodology of Derek Roe (1968, 1981), though it does borrow one of his measurements (B_1 — width at the tip measured at $^1/_5$ or 20% of the length down from the tip). The methodology primarily rests on observational criteria because this is what hominins would have used when they evaluated the suitability of their own work. We are of course assuming that hominin cognition in the Middle Pleistocene had reached a level that allowed them to make such value judgements based on purely visual stimuli.

As modern interpreters we look for visibly robust and repetitive patterns. Onto these primary observational categories are placed a series of further evaluative criteria intended to help the analyst in assigning an LCT to a particular category with a greater degree of confidence, thereby imposing a more rigorous approach to the question of replicability. Since the method deals with individual artefacts it lends itself to simple inter-assemblage and intra-assemblage statistical testing on the basis of frequency counts as well as ratios generated from continuous data.

At the heart of this method is the belief that tip form, divorced from overall LCT outline form, is a much understudied aspect of LCTs, and one that is not adequately catered for in the Roe methodology. Recent experimental studies (Mitchell 1996; Machin *et al*. 2007) make it only too clear that for those artefacts classed as ovates or cordiforms, it is the lateral edge that is the most important part of the LCT — literally the cutting edge. Yet at sites like Boxgrove

(Roberts & Parfitt 1999) and other ovate/cordiform dominated assemblages, tips were clearly important to the knappers. The presence of *tranchet* removals, often as multiple *tranchets*, makes this original focus evident, as does a variety of recurring tip forms within the basic ovate/cordiform shape category (Rivett n.d.).

THE METHODOLOGY

The methodology is designed to be applied to digital photographs of LCTs, though it can also be applied to actual artefacts. The primary data for this paper was taken from the images in the Marshall *et al*. (2002) database. While it is obviously best to work from the original artefacts this is not always possible. Observations and ratios developed from digital images can be generated by measuring the image itself, irrespective of its true dimensions as represented by any scales present on the images. This has the advantage of neutralising differences between photographers if using different image sets, and different printer size settings.

The width of the LCT at specific points down its length is measured. These are the width at 3% of the total length measured down from the tip (top most point of the biface; 3%L), the width at 10% of the length measured down from the tip (10%L), and again at 20% (20%L; Figure 1). This latter is the same as Roe's B_1 (breadth at tip) measurement.

The first filter to apply in interpreting a tip shape is ratio based. Here, the width at 20%L is divided by the total length of the handaxe. Three categories are defined (Figure 2). Those with a ratio at 20%L of =<0.29 are categorised as having long and narrow tip shapes. Further sub-division within this is possible, based on the shape of the convergence of the tip itself, but is not necessary for our purposes here.

A ratio of between 0.30 and 0.49 indicates a tip shape which is converging. A ratio of =>0.50 is a wide or diverging tip shape. Within these two latter groupings are at least eight possible tip shapes which are established by eye. In theory most of the tip shapes could occur on either the wide and convergent sub-groups. However, in practice some are probably impossible, such as a pointed tip on an LCT characterised as wide.

In the next step the eight tip shapes are established by visual inspection of the tip's outline shape. This involves identifying the presence, or absence, of corners defined here as distinct and clear breaks of slope/outline along the margin of the LCT in the vicinity of the tip (Figure 2). The analyst, by a process of elimination, decides which tip shape the artefact fits best. Two critical break-points are introduced at this stage. These are intended to supplement the process of visual inspection. They are the position of the corners in relation to the 3%L and 10%L lines. The corners, once identified, are placed in zones delimited by the location down from the tip of these two lines.

One refinement to the methodology became clear when applying preliminary analyses to the images from the site of Boxgrove in the Marshall *et al*. database (*op. cit.*). While some tips are visually very straight, others are only nearly so. They are perhaps better described as flattish. One of us (JM) thinks it likely that the knapper's intent was to make a tip shape that was more or less straight but for one reason or another it didn't quite turn out that way. What makes it probable that very straight and flattish tips are related is the fact that the corners are always high up on the tip, always close to the very tip itself. This is why the straight or flattish tip shapes have been grouped together and defined by the tip's corners lying above the 3%L line.

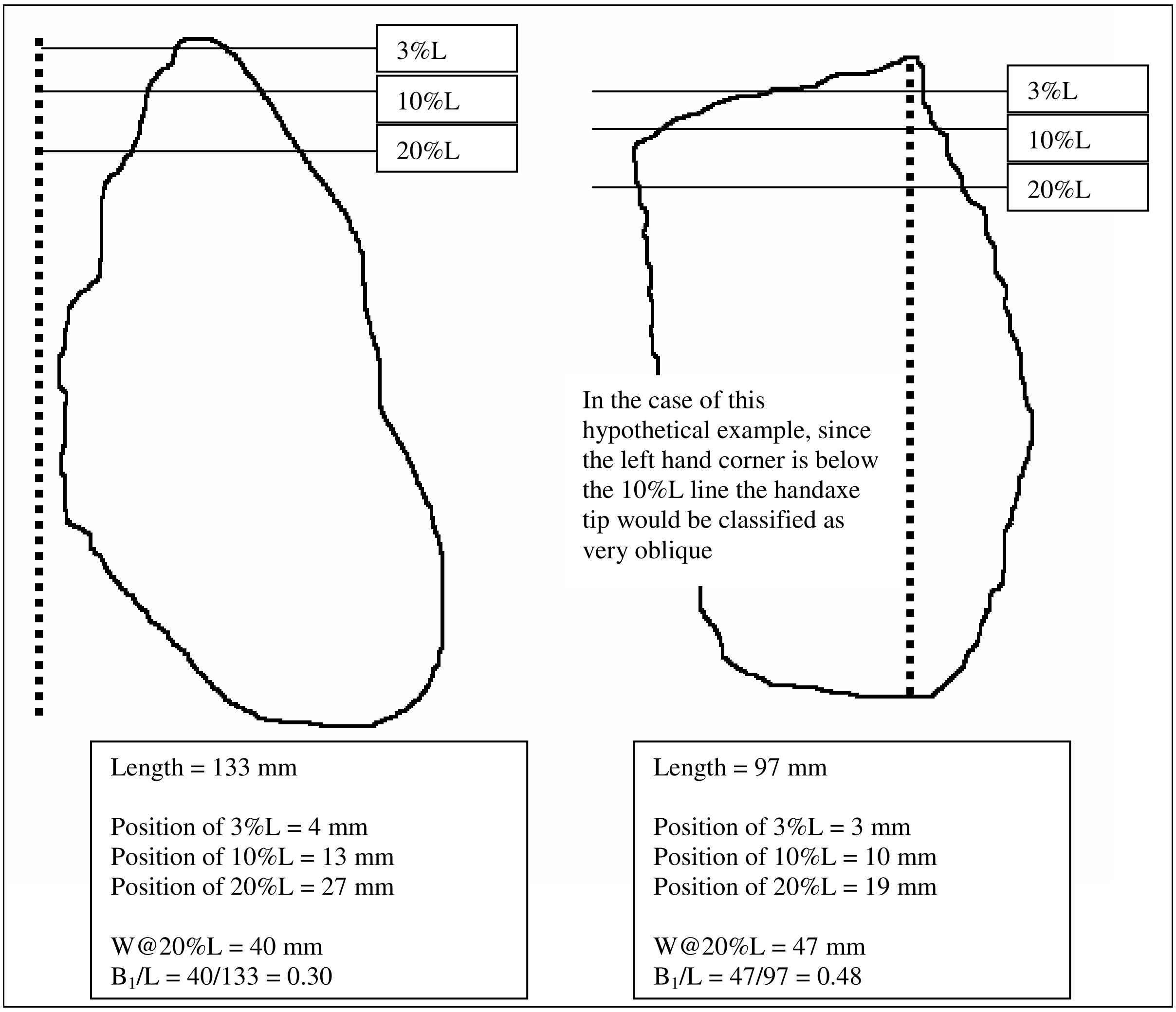


Figure 1: Schematic illustration of large cutting tool measurement scheme

In other cases the corners lay below the 3%L line, the actual tip being slightly more convex or more irregular in outline. By eye, however, it still looks like a flattish tip, usually because the tip area is wide relative to overall length. Inclusion in another shape category is inappropriate — they are not oblique or convex. The irregular-straight tip shape was therefore defined on the position of both corners lying below 3%L, but with the width of the tip at 3%L being at least 50% of the tip's width at 10%L. This is shown on Figure 2. When the straight or irregular-straight tips do not match these criteria, then the tip is characterised as being a generalised convergent tip.

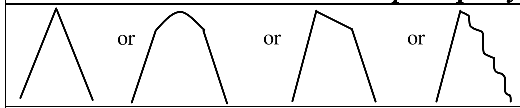
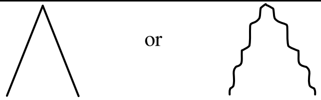
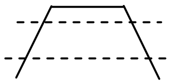
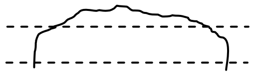
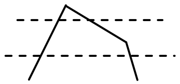
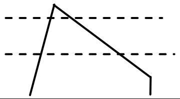
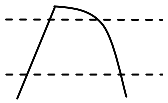
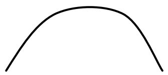
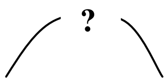
Tip shape by observation		***Description of tip shape***			***Tip width***
	Sides may be straight or irregular, but not convex. Sides may be similar or different. Actual tip shape may vary.	**Long and narrow**			**Long and narrow** W@20%L =< 0.29
	Tip is a clear point where two sides converge to form a visible apex.	**Pointed**			**Convergent** W@20%L is between 0.30 and 0.49
 W3% W10%	Both ‘corners’ above W3%. Width of tip itself must be => than 40% of W10%. If not = generalised convergent.	**Straight – flattish**	**Straight to flattish**	One or two ‘corners’ identified by clear break in slope.	
 W3% W10%	*An occasional variant*. One or both ‘corners’ below W3% line. Still straight if tip width at W3% is => than 50% of width at W10%.	**Irregular straight to flattish**			
 W3% W10%	One ‘corner’ above W3% line and one corner in between W3% and W10% lines.	**Slightly oblique to oblique**			
 W3% W10%	One ‘corner’ above W3% line and one corner below the W10% line.	**Very oblique**			**Wide** W@20%L =>0.50
 W3% W10%	One ‘corner’ only — above W3% line. Other margin is an unbroken convex margin which crosses the W3% and W10% lines.	**Convex oblique**			
	A broad sweeping convex tip with no clear break of slope between margins and tip.	**Convex**		No clear ‘corners’	
	Margins converge above the W10% or W3% lines. All the convergent tip forms that do not fit into the above categories.	**Generalised convergent**			

Figure 2: Metric and observational criteria for tip shape in British large cutting tool assemblages

THE SITES

The method was field tested on three British Lower Palaeolithic Acheulean/handaxe sites.

Boxgrove. The site of Boxgrove in Sussex is a well known MIS 13 locality (Roberts & Parfitt 1999). The handaxes from this site are from Unit 4c, which was interpreted as an open grassy plain fronting a chalk cliff with areas of cliff collapse and with flint nodules from a raised beach at the base of the cliff (Pope & Roberts 2005). The beach pebbles provided the source of raw material for the knappers. A distinct temporal constraint exists on this handaxe assemblage as the Unit 4c land surface may only have been open for a century at the most, and quite likely much less than that. Although the site was discovered after the publication of Roe's results (1968, 1981) the majority of the handaxes would refer to his ovate group (Rivett n.d.). The handaxes from this site from the Marshall *et al*. database, and used in this study, are mainly from Unit 4c, but all will date from late MIS 13 to early MIS 12. Furthermore, the high frequency of *tranchet* blows (78%) indicates a clear hominin focus on the tips of handaxes, and this is a consistent theme throughout the assemblage.

Corfe Mullen. This site is located on terrace 12 of the Dorset Stour near the village of the same name. The terrace is probably a deposit of the ancestral Solent (Bristow *et al*. 1991) rather than of the modern Stour. Handaxes come from three localities: the Ballast Hole Pit, Cogdean's Pit, and the Sleight Pit (Bury 1933; Green 1947; Calkin & Green 1949; see Roe 1981 for a summary). The pits are mapped by the British Geological Survey as all being in terrace 12. Westaway and colleagues (Westaway *et al*. 2006) have dated this terrace to MIS 12, and Roe (2001) has suggested the handaxes may be pre-Anglian (MIS 12) in age on morphological and technical grounds. Traditionally, the Ballast Hole handaxes have been written-off as having been recovered from the slope (bluff) of the terrace and therefore not in a secure context. (A careful reading of Calkin and Green's 1949 paper reveals the ambiguity in their discussion. The authors did not actually state that the Ballast Hole artefacts came from the bluff, merely that the handaxes were often associated with a deposit that is found in the terrace bluff zone in other nearby pits. Their map (figure 1) has the main concentration of artefacts, marked with a cross, well away from the edge of the bluff which is essentially the railway line.) Recent re-investigation at the site has revealed that relatively little of the quarrying was focused on the terrace's edge and that the vast majority of the handaxes seem to have come from bedded gravel well away from the area of the terrace bluff (McNabb & Hosfield *in prep*.). Cogdean's Pit has also been associated with problems. The upper part of its deposits are claimed to have been disturbed by later channelling. However the artefacts' discoverers markings show quite clearly that many came from near the base of the cliff and were from undisturbed stratified gravels. There are too few handaxes from the Sleight Pits to contribute to this discussion. Roe placed the Cogdean's Pit artefacts in his Group VII, ovates with less pointed, and more blunted, tips (Roe 1968). He (1981) also remarked on one of Calkin and Green's (*op. cit*.) ideas that at the Ballast Hole there were two assemblages: a crude pointed group of handaxes underlying a more refined ovate group. The Corfe sites were chosen because they offered the potential of analysing two or even three assemblages from a single terrace in close proximity to each other. They also provided a contrast with the Boxgrove ovates.

Cuxton. This is a site in the Stoke Gravel or Stoke terrace of the River Medway (Bridgland 2003). It was excavated by Tester (1965) in the 1960s and revealed an astonishing number of handaxes. Bridgland dates the site as equivalent to his Corbets Tey/Lynch Hill terrace of the Thames, which would make it late MIS 10, MIS 9, or early MIS 8. However, it must be noted that the site is some eight metres too low to be associated with this terrace (Bridgland invokes erosion of the upper part of the terrace to explain this), and it could equally be associated with the Binney Gravel of the next terrace down in the Medway sequence which spans late MIS 8, MIS 7, and early MIS 6. Roe placed the handaxes from this site in his Group I (Roe 1968), pointed handaxes with a few cleavers associated. The site was chosen because the frequency of pointed handaxes suggested a focus on tip shape. The lightly abraded material from the Tester excavation was selected from Marshall *et al.*'s database (*op. cit.*) because the similarity in condition suggested these handaxes could be considered as a single group, one that had not been subject to much transport by the river. Recent work at the site has reinforced the character of the assemblage as originally interpreted by Roe (Wenban-Smith 2006).

THE RESULTS

Results of statistical tests are not presented in the text so as not to break up the discussion. Specific relevant results are noted in brackets and given at the end of the paper. There were a number of other statistical tests/statistically supported observations carried out, but for reasons of space the results are not reported here. They are highlighted as such by the expression 'data not presented'.

A first measure of comparison between sites is the width of the tip at 20%L, which is the basis for the subdivision into long and narrow, convergent, or wide tips. These data are presented as cumulative percentages in Figure 3. The distribution curves clearly separate out the assemblages as being characterised by different patterns of tip width. Cuxton and the Ballast Hole at Corfe Mullen at first glance appear quite similar, and indeed a Kolmogorov-Smirnov two sample test finds no statistically significant difference between the two distributions (1). There are statistically significant differences between the remaining distributions as might be expected from the figure (data not presented). In part this must reflect the distinctive presence of long and narrow tip shapes at both Cuxton and Ballast Hole (Table 1). However, it is interesting that there are a range of convergent tip widths (20%L =>0.30) that fall in the narrower end of that group, yet have straight or oblique tip shapes despite being rather narrow. It would have taken little effort to transform these into pointed tips. This will be returned to below.

What the relatively smooth profiles of Cuxton and Boxgrove mean, beyond the obvious point that no particular concentration of tip widths is apparent (otherwise there would be clear steps in the distribution reflecting selected ranges of tip width), is not immediately clear. At the very least this might suggest that the assemblages are homogenous, reflecting the use of the full spectrum of width possibilities inherent within whatever blank choices were being made. But what of the more broken profiles of the Corfe assemblages? Steps are clearly present within these distributions, but observations of the data (data not presented) do not suggest that these are related to particular tip shapes. It is unlikely that the step in the Ballast Hole distribution relates to the more pointed cruder handaxes that Calkin and Green (*op. cit.*) believed characterised the lowest assemblage from the pit. Taking all the handaxes from below where the step begins (20%L=0.37; N=24), 41.7% are abraded, and the remainder only show slight abrasion following the condition data in the Marshall *et al.* database; and of the 24, all but three are patinated. There is no convincing correlation between patination and the more abraded handaxes, neither is there one between the more abraded handaxes and the long and narrow tip shapes.

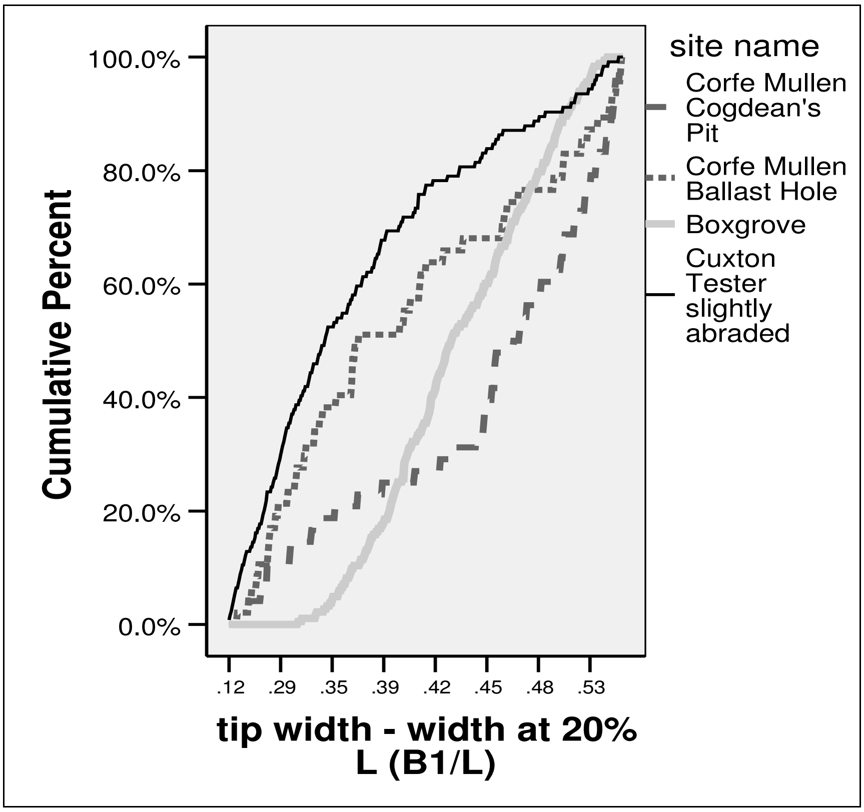


Figure 3: Cumulative percentage graph of large cutting tools from four British Acheulean sites based on tip width

For one of us (JM), the complete lack of long and narrow tip widths at Boxgrove, and minimal presence of pointed tips, evidently reflects a persistent behavioural pattern at this site. The narrowest tipped axes at the site begin in the convergent width range (in this case starting at a 20%L of 0.31), and although they are placed in the generalised convergent shape group (Figure 2), they are still very narrow. From here the distribution curve (Figure 3) sweeps up to the widest axe in the sample with a ratio of 0.57. Again, no correlation was noted between particular width ranges and specific tip shapes, and there appeared to be little inclination to fashion pointed tips, even on the already narrow ones. However, this is not the only possible interpretation of this point. One of us (CR) notes that with resharpening and reduction, what was a pointed tip may become a less pointed tip (as McPherron 1995 suggested), while retaining a narrowness of tip. Thus a tendency to discard bifaces late in their life may equally obscure an inclination to fashion points.

Moving on to the distribution of tip shapes across the four assemblages studied (Table 1), the data is summarised in Figure 4. The first point that comes across is that with the exception of Boxgrove, the full spectrum of tip shapes appears at all the sites. No one form could be said to *completely* dominate its assemblage (say to the extent of >60%). As expected at Cuxton the long and narrow tips represent the most frequent shape in the assemblage, but it’s important to note in this sample that the remaining shapes make up more than 60% of this sample. The general lack of pointed forms in the convergent group is intriguing. Inspection of the digital images suggests in many cases it would not be difficult to fashion a point on these bifaces, yet clearly this is not done, and it is perhaps particularly relevant that it is not done in those two assemblages which have a larger quota of long and narrow tip shapes. What might this mean? If we combine this point with the earlier observation that Cuxton shows an unbroken range of

Name of site	Long and narrow	Convergent or wide							
	Long and narrow	Pointed	Straight to flattish	Slightly oblique to oblique	Very oblique	Convex oblique	Generalised convergent	Convex tip	Difficult to classify
Corfe Mullen (Cogdean's Pit)	5 (10.4%)	1 (2.1%)	11 (22.9%)	9 (18.7%)	1 (2.1%)	9 (18.8%)	11 (22.9%)	1 (2.1%)	
Corfe Mullen (Ballast Hole Pit)	10 (21.3%)		7 (14.9%)	7 (14.9%)	5 (10.6%)	2 (4.3%)	11 (23.4%)	5 (10.6%)	
Boxgrove		2 (1.1%)	43 (24.2%)	37 (20.8%)	8 (4.5%)	27 (15.2%)	51 (28.7%)	10 (5.6%)	5
Cuxton	41 (33.6%)	2 (1.6%)	17 (13.9%)	25 (20.5%)	2 (1.6%)	6 (4.9%)	24 (19.7%)	5 (4.1%)	2
Boxgrove with tranchet on tip (% of assemblage = 78.1%)		2	34	31	6	21	37	9	3
Cogdean's Pit with tranchet on tip (% of assemblage = 41.7%)			7	3	1	6	3		

Table 1: Percentage occurrence of different tip shapes on large cutting tools at four British Acheulean sites. Percentages for Boxgrove and Cuxton do not include those pieces interpreted as difficult to classify.

tip widths, could we infer that the pointed element at the site was not as intentional as supposed? Perhaps it does reflect a range of raw material types, from narrower nodules to much wider ones, and the hominins were simply sampling across the complete range of availability. This is essentially the argument put forward by Mark White (1998).

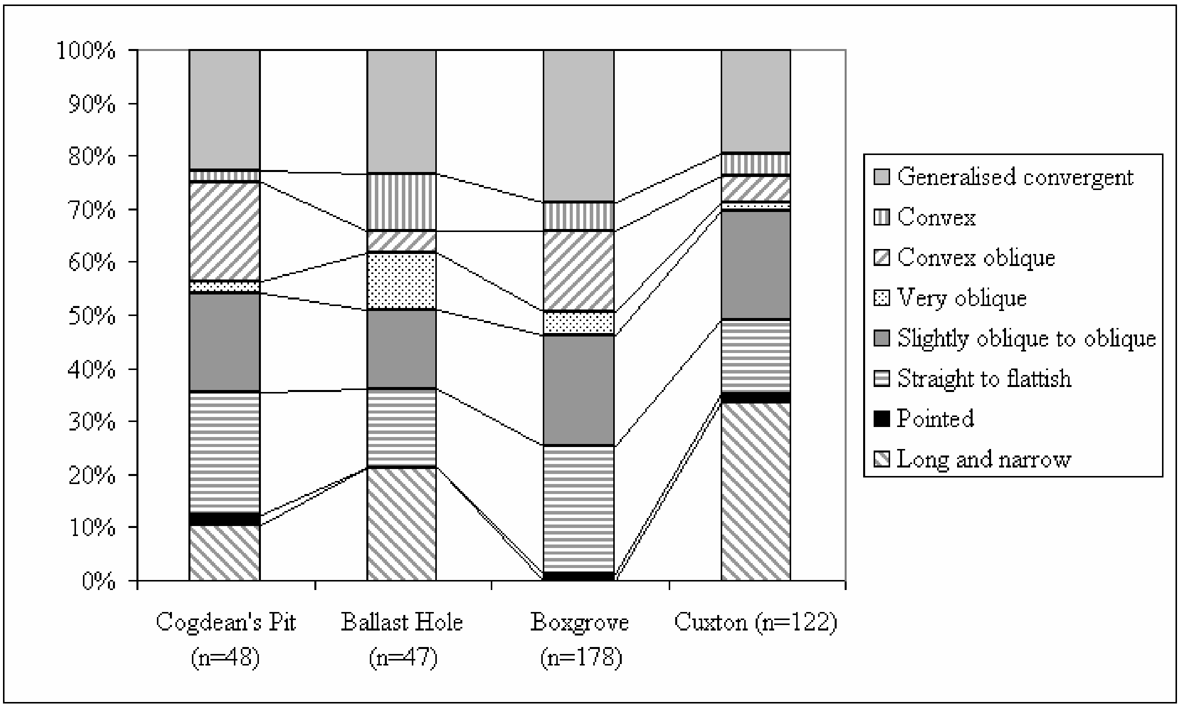


Figure 4: Stacked bar graph of percentage occurrence of different large cutting tool tip shapes from four British Acheulean sites

This argument can not be put forward for the two Corfe Mullen sites, which are geographically very close, in the same terrace and therefore of roughly the same age, and presumably offered access to the same raw material sources. The two distribution profiles in Figure 3 are significantly different from each other (2), yet the frequency of occurrence of the different tip shapes between the two sites (Table 1) is not significantly different (3). But what this means in hominin terms is difficult to discern. Despite a clear difference in tip widths, the same range of tip shapes occur in roughly the same proportions at each of the sites. Clearly there is no strong relationship between tip width and tip shape at Corfe Mullen.

Leaving aside the few pointed tips, what patterns are present within the remaining convergent and wide categories? The generalised convergent tips are the most common at each site, but not by much, and these are the tip shapes that show the least distinctiveness in terms of outline shape. Their frequency could perhaps be taken to imply that the hominins responsible for these assemblages had no specific requirement to consistently produce a particular shape, otherwise we would see one outline predominate. Significance testing shows none of the four assemblages are statistically similar to each other (data not presented) in terms of the frequency counts for the different tip shapes.

A simple way to test whether these differences may have been meaningful to hominins is by concentrating on the Boxgrove data. The high frequency of *tranchet* tips at the site (Table 1) clearly implies that the hominin knappers were very conscious of the tip as an important part of the axes they made. We also know that the Boxgrove assemblage from Unit 4c may have had a total lifespan of perhaps only a few decades. If a hominin social group had a specific requirement to produce particular tip shapes it would be here that it would be at its most archaeologically visible. If we concentrate only on those axes which have *tranchet* blows at Boxgrove, in other words those axes where we know the hominins definitely attended to the tips (Table 1), it is clear that the *tranchet*s are spread across the whole range of potential tip shapes. From these data it would seem that there are no grounds for suggesting that a strong preference existed for a particular tip shape at Boxgrove. For whatever reason they were produced, it is the presence of the *tranchet* itself that is more important to the Boxgrove knappers and users and not the production of a standardised tip outline. (A similar pattern appears to be present at other sites along the Goodwood–Slindon cliff-line, at Slindon and Lavant for example, though sample sizes here are small: Rivett n.d.) A similar spread on a smaller sample is seen on the Cogdean handaxes where *tranchet* tips form a more modest 40% of the whole assemblage.

CONCLUSIONS

Returning to the two interrelated research questions posed at the beginning of this paper, the sites and handaxe samples used in this analysis have demonstrated the following.

Firstly, in the four assemblages studied there is no evidence that any of them had a preferred tip shape. Secondly, the variability shown between the assemblages is marked and reinforces the first conclusion.

It must be admitted that this outcome came as a surprise. On of us (JM) expected that there would be distinct assemblage preferences for particular handaxe tip shapes, and that there would be a lot less variability than was seen in the data. How may we explain this pattern? Four reasons come to mind:

- Methodology wrong
- Sample size too small
- Sample integrity compromised
- Actual behavioural result

It is possible that the methodology was in this case too simplistic for the question posed, and that Machin and Mithen’s concerns were entirely justified. Yet the methodology is quite robust, easily falsifiable, and did reveal clear patterns in the data. A distinct possibility is that larger samples would reveal more robust patterns, at the same time as negating the influence of reason number 3 if this has had an effect on the samples chosen. Within time-averaged assemblages it is entirely plausible that different assemblages have become inextricably combined. Sadly in all too many cases it is impossible to tease the different samples apart.

Finally, the possibility must be admitted that this is a real behavioural pattern. On the one hand the different shapes may have had a discreet functional significance. Perhaps some were used for cutting and slicing, others for more robust chopping duties. It would not take a great leap of imagination to see re-sharpening as being a change from one tip shape to another, modifying a tip form to suit a specific job, then modifying it once again for a different task. Perhaps the different tips were associated with different aspects of the same task — carcass butchery and dismemberment. In such a scenario the similarity in the tip shapes at the different sites in the convergent and wide tip groups merely reflects a commonality in activities.

On the other hand, the tip shapes may not have been as significant as might be thought. The differences in shape may simply have reflected the nature of the blank (in terms of their width), the diversity in blank shapes available to the knappers, and ultimately the knapping of the lateral edges of the axe. Alternatively, *tranchet* removals may alter tip shape quite by accident. In such instances the difference in tip shape is more of a random drift across a spectrum of possibilities set up by the blank and the knapping itself. Put another way, BLANK TYPE + MARGINAL SHAPING = TIP SHAPE. In such a scenario this also calls into question the function of the *tranchet*; would this be tip regeneration, or more of an extension of the usefulness of the lateral margin onto the tip itself?

We have deliberately avoided offering a preferred interpretation as to which of the above reasons explains variation in tip shape. Larger samples and more sites would have to be included for a more definitive interpretation. Our aim has been to stimulate discussion on an area of handaxe studies that has not received as much attention as it deserves.

APPENDIX: STATISTICAL DETAILS

All statistical tests were carried out using SPSS v.15.

(1) Kolmogorov-Smirnov test for two independent samples.

Ballast Hole N=47, Cuxton N=124; K-S test statistic=1.115, biggest absolute difference 0.191; p=1.66. The null hypothesis of no statistically significant difference between the two distributions is accepted (reject at p=0.05).

(2) Kolmogorov-Smirnov test for two independent samples.

Ballast Hole N=47, Cogdean's Pit N=48; K-S test statistic=1.795, biggest absolute difference 0.368; p=0.003. The null hypothesis of no statistically significant difference between the two distributions is rejected (reject at p=0.05).

(3) Chi-square test of association.

Cogdean's Pit N=48, Ballast Hole N=47; X^2=3.230, d.f.=4; p=0.520. The null hypothesis of no statistically significant difference between the two distributions is accepted (reject at p=0.05). For this test the data was taken from Table 1. Long and narrow cells and the pointed cells were combined, very oblique and convex oblique cells were combined, and generalised convergent and convex tip cells were combined. This was done to remove the problem of low frequencies. The difficult-to-classify variable was omitted.

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