The Vital Sense of Proportion: Transformation, Golden Section, and 1:2 Preference in Acheulean Bifaces

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ABSTRACT

The manufacture of all complex artifacts depends upon the maker's ability to control individual variables and their interactions. All such artifacts are multivariate in nature, and often they can be made at different sizes—in consequence it is vital for the maker to possess a sense of the proportions involved, in order to make the necessary transformation. This ability is keenly developed in modern humans, and also is apparent in Acheulean bifaces. There it has been noted particularly in highly controlled Breadth/Length relationships, although it also features in other dimensions. Several authors have commented on the recurrence of the proportion 0.61/1 (Golden Section) in the bifaces. Its presence is evaluated here in the context of various biface assemblages from Africa and Europe. Many of them have mean B/L values of 0.61. But some of them are quite clearly not made to Golden Section (e.g,. the Spanish assemblage of San Isidro, where the mean is 0.53). A case is set forward here that the ratio of 0.50 (1:2) is preferred for long bifaces. Thus any innate preference for the 0.61 ratio, or any other, appears to be a relatively weak one that can be overridden. Early artifacts demonstrate remarkable early human abilities to control dimensions, and also to impose allometric adjustments, but despite the frequent recurrence of the Golden Section value, it is far from universal. The results imply that the very acute modern human sense of proportion has a history in earlier *Homo* going back more than one million years. It seems likely that ranges of preference for particular proportions existed in earlier *Homo,* somewhat comparable to those observable in modern humans.

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Why should the sense of proportion be important? The argument starts roughly like this. Animals need to perceive the world in which they live, so that they can behave. Often behaving is just moving, but the act of gaining food can be a complex set of operations, involving external manipulations, such as twisting or breaking plant or animal parts. Then a higher order of manipulation altogether is to make things, imposing oneself on the external world through construction. The things can be made only through the appropriate actions, however prescribed. These are the projection of instructions from the brain into activity in the external world. In that three-dimensional world all but the very simplest artifacts are multivariable or multivariate constructions. They have to be made 'out there' at some particular size, and that is achieved only if the contributing variables are all scaled appropriately —*in proportion*. This paper aims to examine evidence for that sense of proportion in the early archaeological record, and to see how definitely it is imposed.

The ability to make external constructions can be seen as a very significant threshold in the evolution of brains and minds. Some of the manufactures are made by birds and insects, but the regular construction of complex objects 'out there' is limited to humans. As humans we find such action sequences sufficiently easy in concept that often we do not analyze their requirements (but see, for example, Hoc 1988).

Take the analogy of building a space station. You cannot just build it. All the components have to be shipped up in a particular way, so that the installation can be put together. In a way the same is true for all artifacts. A set of instructions in the head (perhaps you can *imagine* all the requirements for a fine hand-axe) cannot simply be floated out into the external world as the object. The ideas have to be broken down, deconstructed, for successful assembly 'out there'.

The sense of proportion is one of the basic requirements, fundamental to the analysis of visual information in

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the world. In the first instance in the evolution of animals it was part of the process of visual perception. For many millions of years animals have had the capability to assess an object at different distances, recognizing that it is the same thing through interpreting the scale change (from its behavior, a dog shows that it knows another dog is a dog, far or near). Hence Caelli (1981), for example, stresses the importance of geometric understanding in visual perception. The newer human ability to make external projection of constructs for assembly in the outside world at any particular required scale can be seen as a sort of inversion or reverse-engineering of this very old basic capability. Specifically, it can lead to the ability to make geometric transformations, itself essential among the innovations that permit refined material culture and all higher skills

The author first noticed issues of proportion in analyzing sets of Acheulean hand-axes from the site of Kilombe in Kenya. Kilombe stands out even now for its vast numbers of hand-axes, and the fact that they occur on a single surface, allowing many inter-comparisons (Bishop 1978; Gowlett 1978, 1982, 1984, 1992, 1993, 1995, 2005, 2006). The first thing Kilombe seemed to show was that early humans had a geometric sense of proportion. From there you could extend to saying that they were able to make geometric transformations and that we were seeing here precursor abilities of later expressions of mathematical abilities. Transformations are both a crucial factor and a unifying point in the (eventual) practice of mathematics and art (Gowlett 1982, 1984).

Accepting these points (as I still do), it became evident that there were many additional aspects to work out, and others to think about introduced by other researchers (e.g., Crompton and Gowlett 1993; Gamble and Marshall 2001; Kohn and Mithen 1999; Lycett and von Cramon-Taubadel 2008; Machin 2009; Machin et al. 2007; McNabb et al. 2004; McPherron 2000, 2006; Nowell et al. 2003; Pope et al. 2006; Vaughan 2001; Wynn 1995, 2002; Wynn and Tierson 1990). Other major contributions to studying Acheulean biface morphology were and are also relevant (Callow 1976, 1994; Isaac 1977; Jones 1994; Roe 1976, 2001). Making a tool is not a simple process of invoking a perfect ideal design in the head, and then making a perfect external product. In the real world there are numbers of practical factors capable of influencing a process during its realization.

So perhaps there was not just one step of choosing a proportion—why indeed should early toolmakers have opted for one particular proportion? Different proportions might well be suited for different tasks, or materials, and could easily become embedded in different cultures. There could also be chance factors in operation.

The "trouble" is that one particular proportion has caught our modern eye, and this is the ratio of Golden Section. It can be expressed as 0.61: 1, or inversely as around 1:1.64. It is a ratio used in classical architecture, and it underlies the European A series of paper, such that a sheet of A4 happily folds into two of A5, all maintaining the same proportion. Golden Section frequently catches the imagination and has been studied by many authors from many perspectives (e.g., Arnheim 1955; Benjafield 1976; Benjafield and Davis 1978; Boselie 1984; Fensom 1981; Fischler 1981; Godkewitsch 1974; McManus 1980; Plug 1980; Stone and Collins 1965).

This ratio was strikingly evident in the mean of Breadth/Length in the hand-axes from Kilombe (Gowlett 1982; Figures 1 and 2). It appears also in the bifaces from Nadaouiyeh in Syria (Le Tensorer 2006), and subsequently, notably, features as the mean of the series of more than 400 bifaces from Boxgrove (Pope et al. 2006). Quite independently all these authors have been struck by the finding, but also somewhat puzzled by it. Le Tensorer (2006), for example, notes that later bifaces from Nadaouiyeh are less refined, and do not respect the ratio. Pope et al. (2006) go on to demonstrate the presence of Golden Section in many other biface series, and highlight the semiotic potential of hand-axes, noting the effect that their pattern of discard might have in marking out significance in a landscape. Here they echo White (1962) who talked of artifacts 'symboling' through passing on their 'bestowed' meaning. The importance of the bifaces in development of an aesthetic sense has been noted various times (e.g., Schmidt 1936; Oakley 1981; Gowlett 1982; Mithen 2003; Pope et al. 2006; Le Tensorer 2006), and recent work in neurosciences gives hope that some of the specific mechanisms of such a sense can be elucidated (Cela-Conde et al. 2004).

From all this work it is tempting to say that there is something aesthetically special about the presence of the ratio, and that this was in the minds of the Acheulean toolmakers. Early on I became unconvinced by this explanation for at least three reasons, all empirical. The first came from studying two further assemblages, from Kariandusi, at about the same time (Figure 3). These belong to the same time range as Kilombe, and are only 80km away (Gowlett 1980; Crompton and Gowlett 1994). The raw materials contrast strongly—beautiful obsidian bifaces make up nearly the whole set from the Upper Site, originally studied by Louis Leakey. Those from the Lower Site, on the opposite side of the Kariandusi River gorge, are all made from a local trachyte lava. They may be slightly younger, but both sets are dated to ca. 1.0 Ma (Evernden and Curtis 1965; Gowlett 1980; Deino et al. 2004; Trauth et al. 2005).

The ratios can be compared with Kilombe as follows:

		Length	Breadth/ Length	Thickness/ Breadth
Kilombe (all)	(N=394–400)	149 ±31	0.61 ±0.07	0.47 ±0.11
Kariandusi lava	(N=126–135)	164 ±23	0.58 ±0.07	0.52 ±0.11
Kariandusi obsidian	(N=60)	125 ±24	0.64 ±0.09	0.47 ±0.07

Plainly, these three assemblages taken one by one would not point anyone to say that means for B/L approximated closely to Golden Section. Certainly, there would be an equal case for saying that 0.50 was the target for thickness/breadth (but no one seems to comment on this).

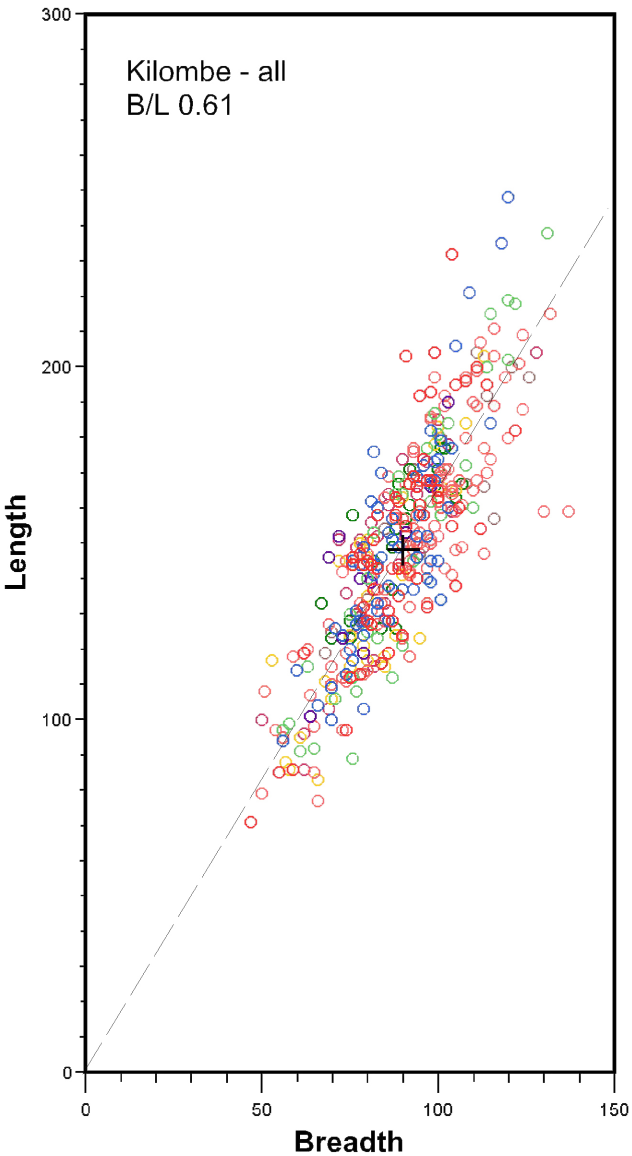

Figure 1. Kilombe: Breadth and Length plot of all Kilombe bifaces (as of 2008). All scatter plots are scaled in millimetres. In this and the following plots, the dotted line is the (isometric) ratio line, which always runs through the origin and through the centroid of the data.

Then too there was an issue of how much secondary working of the bifaces affected their shape. Harold Dibble's suggestion that bifaces acquired their shape fortuitously through core reduction is not entirely convincing (Dibble 1989), but his challenge to the idea of a fixed end-form was useful, as was that of Iain Davidson (2002). These stimulated a comparison at Kilombe between the least worked specimens—taken as ones which preserved cobble cortex on at least 50% of one face, and the most finely worked specimens, taken as those with more than 20 flake scars (and usually retaining little or no cortex). The result was interesting because it showed that the heavily trimmed specimens were not shorter, but were markedly narrower (Gowlett 1996). One inference is that the makers were not concerned to maintain the ratio of ca. 0.60 found in the primary flake blanks. It seemed likely that maintaining the length of the piece and its cutting edge was a greater consideration.

The third insight, or caveat, came from size-shape studies (allometry). Crompton and Gowlett (1993) were able to show that in a systematic way within each dataset small bifaces have a different shape from large bifaces (Figures 4 and 5). These allometric size-shape shifts were apparent in several ways, including thickness:breadth and of course breadth:length proportions. Normally in archaeology we express these relationships as ratios (T/B, or B/L), but such ratios offer a very primitive form of analysis, since they discard all size information, and hence any information about variation with size. In effect they assume the very thing that we want to know—whether or not the artifacts were made with the same proportions regardless of size (isometric variation). The authors concluded that the shifts observed were likely to have been functionally driven, and partly aimed at weight saving in the larger specimens. As each artifact is an individual solution of various and varying needs, which can be seen as 'imperatives' (Gowlett 2006), powerful factors may operate to override any initial ideal of proportion.

All these studies reinforced the importance of early hominins making *transformations*, and showed that these were complex—early toolmakers seemed able to handle the relationships between several variables in a successful way. They were coping with a heavy cognitive load, but sequencing of the manufacturing steps in a regularized routine (or script) probably served to reduce this load (Gowlett 2006). Equally, however, the observations and evidence seemed to write off high significance for any particular ratio—all the relationships seemed to be flexible.

RETURN OF THE GOLDEN SECTION

Now however, we could say that Golden Section has come back. In the work just mentioned it occurs in several major series of bifaces, often enough and in sufficient places that it calls for a new evaluation—with some special attention not just to the cases that fit but also to those that ***do not***.

The initial aim is to discriminate between two hypotheses:

- The first is that Golden Section (0.61:1) is the underlying 'grand proportion' found within and across Acheulean biface series—but liable to become obscured by other factors which can override it. It may harmonize in some way with the emergence of an aesthetic sense.
- The second expresses an idea that certain proportions may be preferred for functional or even cultural reasons, but that they are not invariable either locally or regionally. It postulates that in the very nature of the linear dimensions of bifaces (L, B, T, etc.), the occurrence of ratios of *smaller to large*r measurement is completely inevitable, that through the generally 'moderate' shape of artifacts, the majority of these will fall in the range 0.40 to

Figure 2. Kilombe biface illustrating the exact ratio of Golden Section (specimen L 128mm x B 79mm, photographed on site in 2010).

0.70, and that particular values have no special significance.

To give support to the first view, here is a further example of how Golden Section might operate. At Kariandusi, the obsidian bifaces are small, the lava bifaces are bigger, and they have different B/L proportions. But combine them in one series, and they seem to tell a different story (Figure 6). That is, the larger and smaller sizes seem to mesh together on a single allometric gradient, and—surprisingly enough—the mean comes out at ca. 0.61:

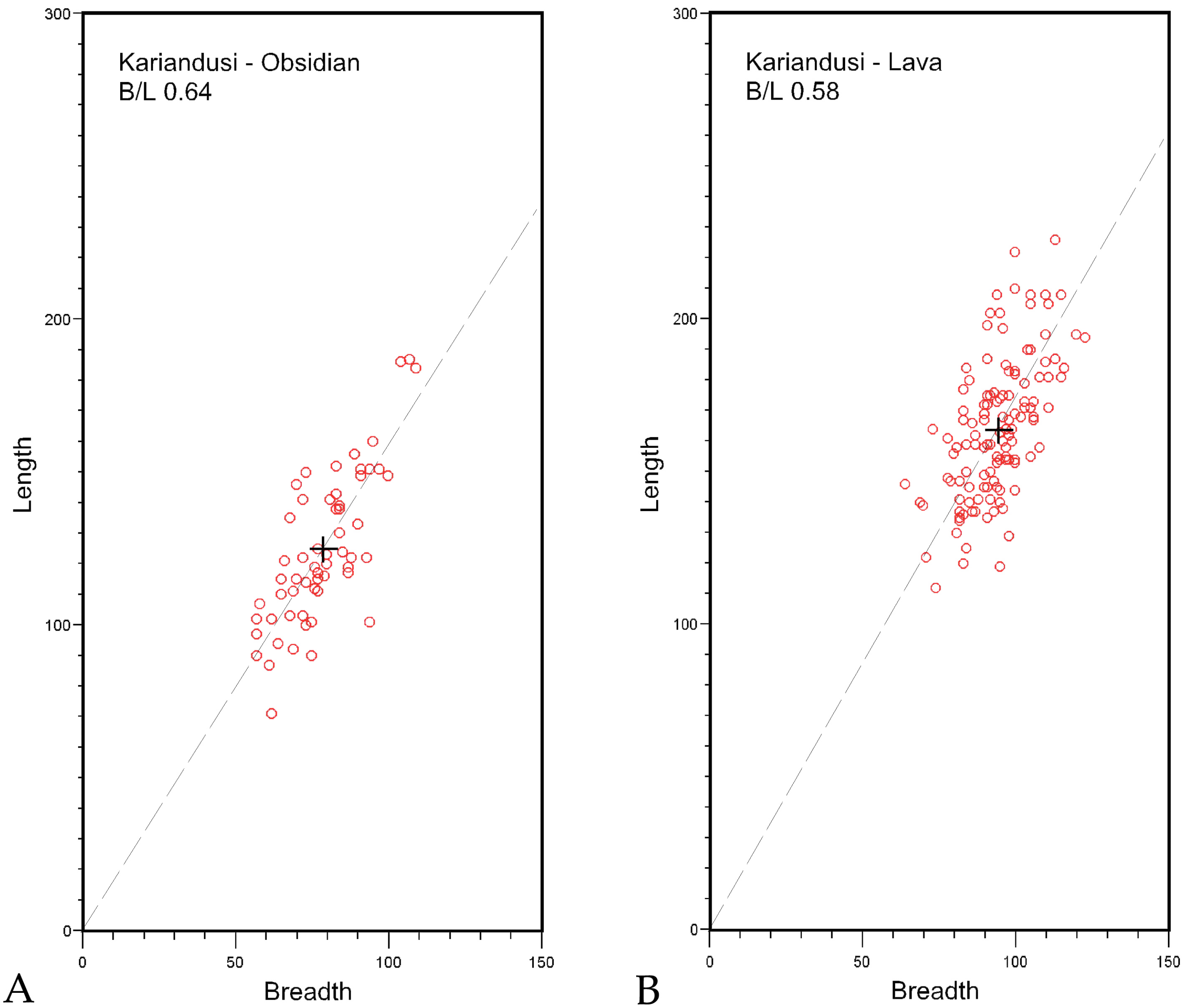

Figure 3. Kariandusi. a: Breadth and Length plot of obsidian bifaces from the Upper Site; b: the plot of lava (trachyte) bifaces from the Lower Site.

		Length	Breadth/ Length	Thickness/ Breadth
Kariandusi (all)	(N=186–195)	152±30	0.60±0.08	0.50 ±0.10

Possibly a similar gradient of B/L could apply at Nadaouiyeh, where it may be found (perhaps) that the later cruder bifaces are also smaller, and tending to be broader (a tendency for younger bifaces to become smaller in the Middle East was noted by Gilead [1970]).

Thus the Kariandusi samples which separately argued against any importance of Golden Section can be combined to suggest that there might indeed be a primary inclination in making bifaces to hit the B/L ratio of 0.61—as at Kilombe, Nadaouiyeh, and Boxgrove. The rule might be: ***0.61 tends to be preferred, and dominates at the mean of the series, but is not evident where some strong factor overrules its operation.***

One such strong factor could well be the need to achieve an appropriate weight in relation to the desired size and shape. The desired or appropriate weight can be achieved only by modifying the linear proportions, with effects that are especially clear in very large and very small specimens. The pressures to make some such shape-weight adjustment are powerful—if we double the length of a biface, then with geometric scaling, its weight rises 8 times. In practice shape adjustments are made which reduce this weight change, usually to a factor of ~5 times (Gowlett et al. 2001). This factor may even be able to account for the strong size-shape shifts seen in the linear dimensions at Kilombe and Kariandusi. We find very clearly in these series that the Breadth/Length ratio grades to 0.75 in the smallest bifaces, and down to 0.50 in the very longest specimens—a

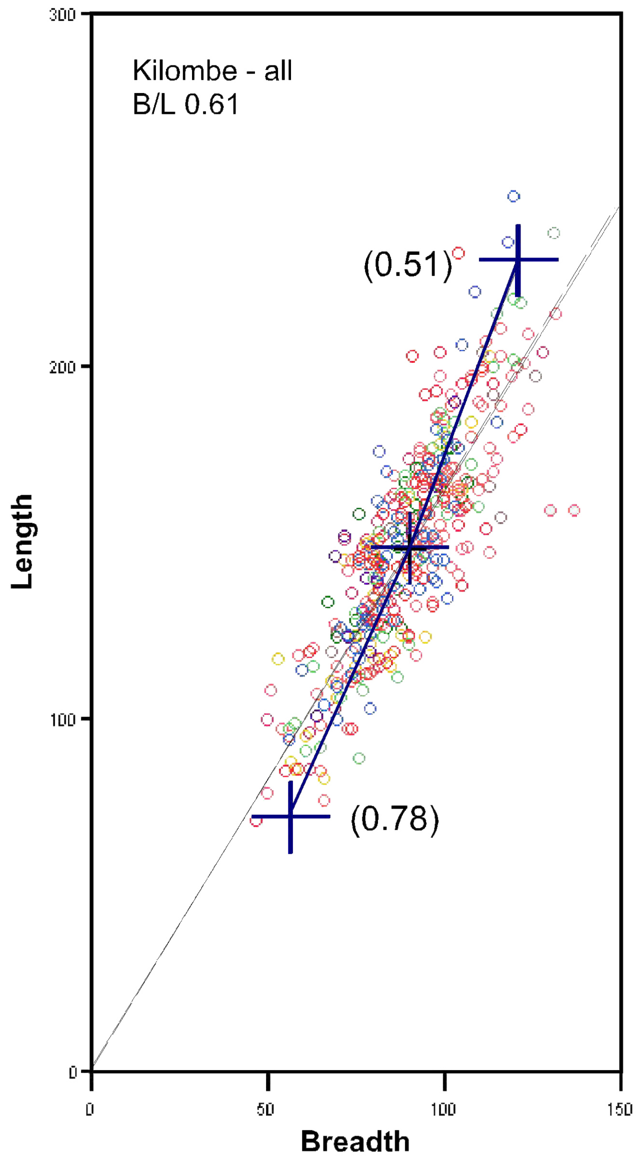

Figure 4. Kilombe—the Breadth/Length plot showing the marked trend of allometry. The central cross is the centroid for all the bifaces. The outlying crosses mark the centroids for all bifaces larger or smaller than the mean by 2 standard deviations or more (i.e., roughly speaking the 2.5% each of longest and smallest bifaces). The extent of the allometry is illustrated by the 'rotation' of the solid line from the dotted isometric ratio line, but is even more evident when the individual biface shapes are seen (see Figure 5).

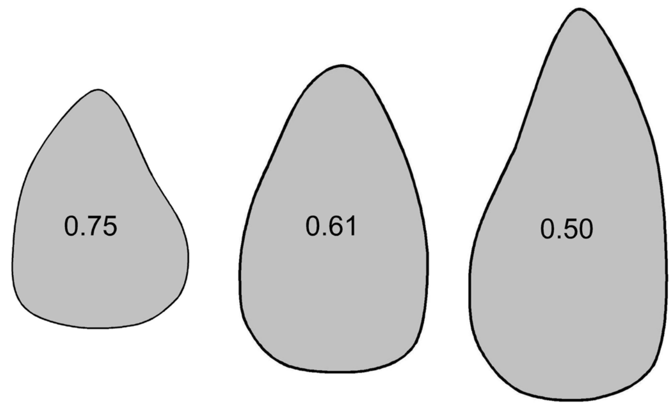

Figure 5. Kilombe—the typical shapes of bifaces at different points on the size scale: Small (B/L ca 0.75); Mean (B/L ca 0.61); Large (B/L ca 0.50).

big difference (see Figure 5). But it could still be that there is a preferred 0.61, overridden by the need (among other things) to have more relative mass in small bifaces, and less relative mass in large bifaces.

All this forms an attractive argument, and it would harmonize with an analysis given some time ago by McManus (1980). He showed that modern humans favor some rectangles to others in terms of shape. Their somewhat weak preference for a shape of circa 0.61:1 is chiefly expressed through disfavoring of more extreme proportions. In bifaces a similar weak preference might be overridden quite easily by functional imperatives, especially if failure to make

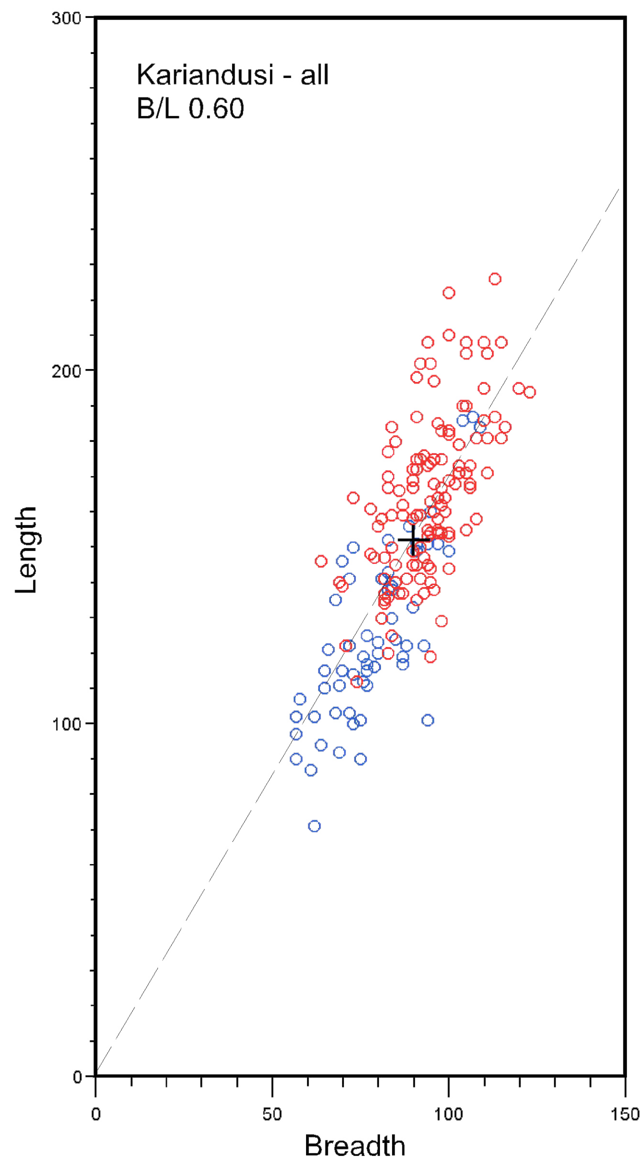

Figure 6. The Breadth/Length plot for all bifaces from Kariandusi, combining the obsidian and lava sets.

TABLE 1. SUMMARY OF KEY DATA, EXPRESSED AS MEANS AND STANDARD DEVIATIONS.*

Site	N	Length	Breadth	Thickness	B/L ratio	Correlation B & L
Kilombe	394	149±31	90±16	42±10	0.61±0.07	0.84
Kariandusi Upper Site (obsidian)	60	149±31	79±13	37±7	0.64±0.09	0.77
Kariandusi Lower Site (trachyte lava)	126	149±31	94±11	49±9	0.58±0.07	0.59
Kariandusi, all	186	152±30	90±14	45±10	0.60±0.08	0.77
San Isidro	45	149±31	80±13	47±9	0.55±0.07	0.83
Pinedo	58	149±31	70±12	43±13	0.61±0.09	0.81

*Correlation coefficients shown in the right hand column are not discussed in the text, and merely show that there is normally a very strong relationship between Length and Breadth.

the adjustments would lead to poor performance in extreme specimens (Gowlett 2005). Boselie (1984) argued that there are several other rectangles with 'hidden order,' some of them quite close to Golden Section (e.g., 1:1.5 and 1:1.41), perhaps helping to explain the idea that modern humans have a 'broad peak' in their preference.

But is there a single story in biface proportions? The account above would depend on biface sets of different physical size all conforming to the same trend line. This trend, seen in many African assemblages, would achieve the 0.61 proportion at about 150mm length. In conformation with the allometric shift, longer specimens would be narrower and a series dominated by shorter specimens would be broader.

Unfortunately, the trend is not a universal. It is not respected, for example, by Spanish bifaces from the later Middle Pleistocene. A series from San Isidro in central Spain shows distinctly narrower proportions (Table 1). The bifaces are very much the same in length as Kilombe (mean 148 vs 149mm), but the B/L proportion at San Isidro is just 0.55 (Figure 7a; Gowlett et al. in prep.). If we take a Kilombe biface and a San Isidro biface of similar length, they will have similar weight, but the San Isidro specimen will be about 10% narrower, and 10% thicker. Bifaces from Pinedo, also in central Spain, may show a variation of the same story. They certainly show the occurrence of the Golden Section ratio again, with a mean value for B/L of 0.61, but they are very much shorter (mean 118mm). A plot suggests that they fall on the same narrower trend line as San Isidro (Figure 7b), and indeed the longer specimens from Pinedo (the 10 that are 1 sd or more above the mean for L, i.e., 145mm or longer) have a mean B/L of 0.53.

Narrow bifaces such as seen at San Isidro may be an innovation of the later Middle Pleistocene. Current time-space mapping of the Acheulean is not close enough to trace their emergence. At San Isidro, one example measures 153 x 69 x 47mm, thus having an individual B/L of 0.45 (#SI-13). These may be among the first examples of "Micoquian" characteristics in Europe (Raposo and Santonja [1995] apply that label). Such triangular bifaces are named after La Micoque in France—but use of the label is not well agreed in practice (cf. Otte 2003), and in the main, authors relate it to more recent Middle Paleolithic 'Keilmesser' specimens (Bosinski 1967; Jöris 2006; Kozlowski 2003; Ruebens 2007). Similar-shaped bifaces occur at least sporadically in other regions, for example, along the Vaal in South Africa (personal observation). In each of these cases, the refined flaking and symmetric outline suggest that the elongated form was a deliberate design goal.

DISCUSSION

Accepting the general importance of proportion in technology and art, and its expression in the construction of Acheulean bifaces, it is still difficult for us to comprehend the factors which determine and limit particular proportions. How is proportion imposed? It would seem that it must be through the maker's overview. The maker is probably influenced by the raw material block immediately available, and the immediate needs of the task, the two operating within the influence of the local cultural tradition (what everybody does) and personal experience. As archaeologists, we see our trend lines but do we see the makers' view? They do not have any sight of the trend line. They merely make each biface in the most appropriate way, judged in terms of the need, the material, and the cultural rules.

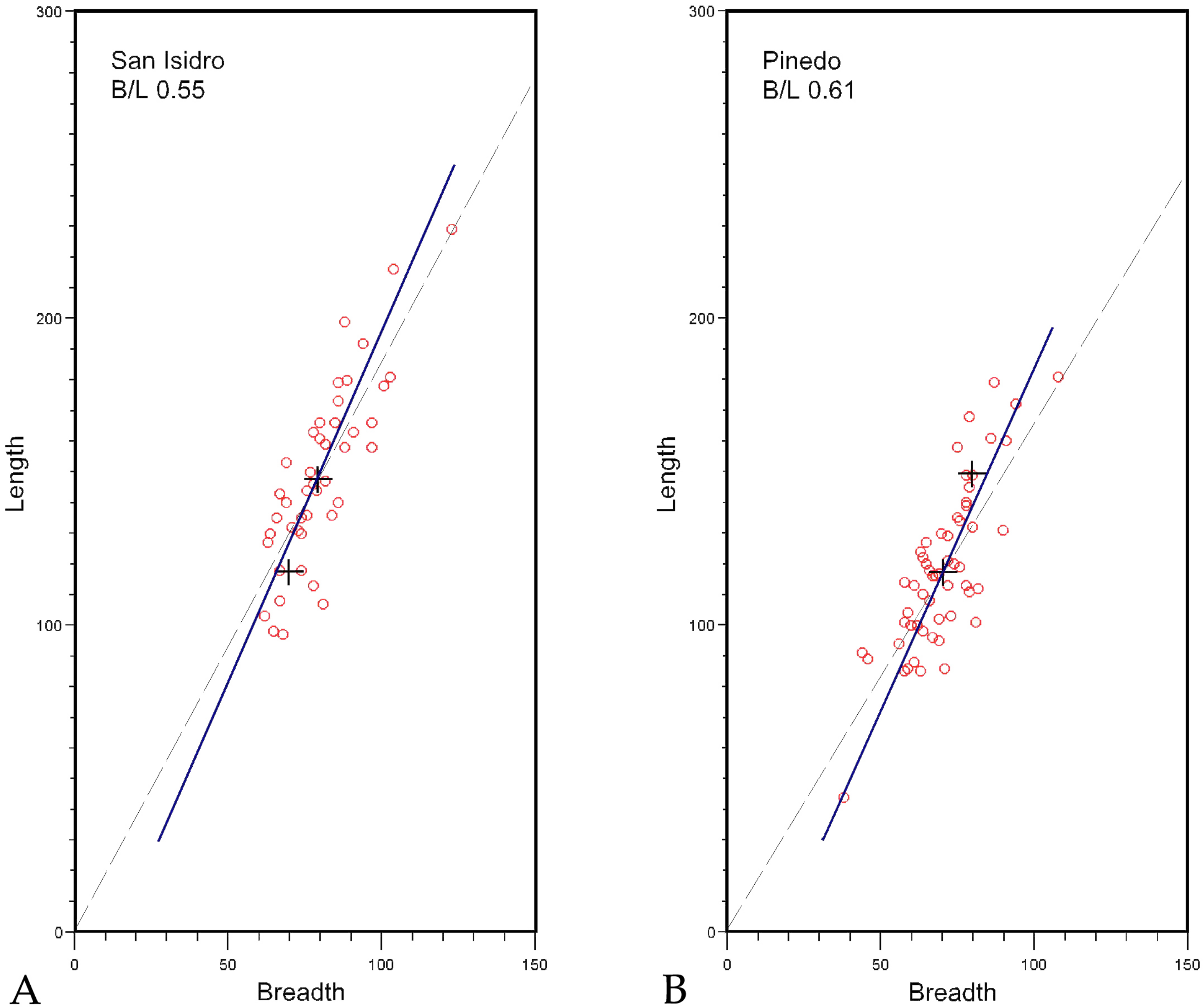

Figure 7. Breadth/Length plots of bifaces from two Spanish sites: (a) San Isidro; (b) Pinedo. To aid in comparison, the centroids for B and L are shown for both sites on both diagrams. In these diagrams the fitted straight lines are the Reduced Major Axis—in each dataset this passes through the centroid, and its slope is equal to the ratio between the standard deviations for B and L. See text for further explanation.

The clear presence of long-and-narrow specimens raises an issue—could there sometimes be a subgroup with a distinctive form, one that makes them stand out from the majority of bifaces in the same series? In that case, they would have their own B/L ratio. Normally we make interpretations from graphs that depict a single trend line (or from a ratio that expresses the mean of the set). Studies, including my own, commonly assume implicitly that the best way to represent group intention is to fit a line which runs through the center of the data (and through its centroids). The aim is to see through the haze of dots which represent individual variation, so as to recover the shared intent or ideal of the local style. But this position may not always hold. The long-and-narrow bifaces, for example, might represent a desirable extreme which most makers could not achieve. Quite possibly the narrowest specimens would have the most significance, because they are the most difficult to make. Stout (2002) shows that among the Langda in New Guinea only masters of stone knapping are able, and allowed, to make the very long and narrow specimens of adzes which others would not venture to make. In Acheulean bifaces, however, the B/L proportion tends to have a normal distribution, so hyper-narrow values of ca. 0.45 represent extremes rather than regular goals (and limits seem to be similar in various assemblages). The point to emphasize here is just that the mean is far from being the full story.

The central question raised in the hypotheses, was 'does the Golden Section ratio, 0.61, have some special status?' If we are to defend the idea of a general operation of Golden Section in breadth/length relations (Hypothesis 1), then we need to find it as a common occurrence, and also explain departures from it by general principles. We have seen that simple geometric ratios do not fully describe biface series, and that there are allometric shifts, such that longer specimens are relatively narrower than shorter specimens. In some cases, as at Kilombe or Boxgrove, the 0.61 value fits the center part of the series, and we can explain departures in the small and large specimens without too much difficulty. The consistency of the allometric departures suggests a firm rule, and the results of its operation are visible (as well as tangible).

In other cases, however, as at San Isidro, the series is clearly centered away from 0.61, with the mean at 0.55. We could try to "hang on" to an allometric explanation, by suggesting that 0.61 was the dominant proportion for short bifaces about 120mm long (as at Pinedo in the same region), and that San Isidro has its narrower mean proportion chiefly because the bifaces are long for the region. But the fact remains that the trend line for B/L is quite different in these two Spanish assemblages from that in all the African series, and such evidence argues strongly against a universal 0.61 ratio.

The narrow bifaces do raise one other possibility of general interpretation. If we examine the longest bifaces in each series, they are relatively the narrowest, in accordance with the allometric shift. Those bifaces that are more than 2 standard deviations above mean length turn out to have a B/L ratio closely approximating to 0.50/1 (alternatively, of course, 1:2). This is true for Kilombe, also for San Isidro, and indeed for larger combined datasets. The plots show not a separate design goal as discussed above, but that broader 'average' bifaces grade up to the long narrow specimens in a continuous series. As previously noted, the 0.50 value is also common in Thickness/Breadth relations in bifaces.

The Acheulean biface has been the focus of all this discussion, because it is the earliest artifact which shows the imposition of elaborate form, and because elements of that form are tantalizingly hard to explain. Those factors have led to a wide assumption of a plausible explanation—that the bifaces reflect a primitiveness or 'otherness' in the behavior of *Homo erectus*. The monotonous 'sameness' of the bifaces meets that view. It also is easy to assume that in the allometric adjustments we are dealing with some specific property of Acheulean bifaces, and that this again reflects some primitive aspect of the mind of *Homo erectus*. Yet many of the features found in bifaces also can be found in modern artifacts, if we look for them. A study of modern screwdrivers shows that as a broad set they replicate many of the variation features found in handaxes (Gowlett 2009). Like bifaces they are made through a size range with a factor of 3–4 (e.g., 8–24cm in bifaces, and similar in screwdrivers), even though this kind of variation is often ascribed to 'poor standardization' in *Homo erectus*. They also show a similar allometry, with short specimens being 'stubby', and long ones spindly (Figure 8). In screwdrivers, we can be fairly certain that most of such variability is functionally driven, and they serve as a reminder that the same may be largely true for Acheulean bifaces, including perhaps the Breadth/Length variation. Generally we think about proportion in isometric terms, but allometric adjustments such as have been discussed above are evidently a crucial factor to take into consideration, because they increase the range of proportions which are in play—at Kilombe ensuring that the range 0.50–0.75 is regularly found.

Figure 8. Modern screwdrivers are made in a similar extended size-range to Acheulean bifaces (varying in length by a factor of 3 or 4), and similarly exhibit an allometry, with small 'stubby' specimens and long 'spindly' ones.

CONCLUSIONS: WHICH HYPOTHESIS?

The paper starts from the point that linear proportion has a basic importance in the manufacture by humans of complex artifacts—without it no design can be implemented. Nearly all tool classes show some size variation, reflecting differences in tasks, or even differing body and hand sizes among the makers. The individual tool has to be made at *some* size, and the moment the first key decision has been made, the rest must follow—in proportion. The sense of proportion is thus essential to the idea of size-transformation. The data presented show that makers of the Acheulean had a complex and subtle grasp of the practicalities of making transformations, even in million-year-old industries (Figure 9). It would not be easy to say whether these were old abilities harnessed to new tasks, or whether their evolution actually allowed the practice of new technological abilities. The most important point is that some proportions are very highly controlled in Acheulean bifaces. This

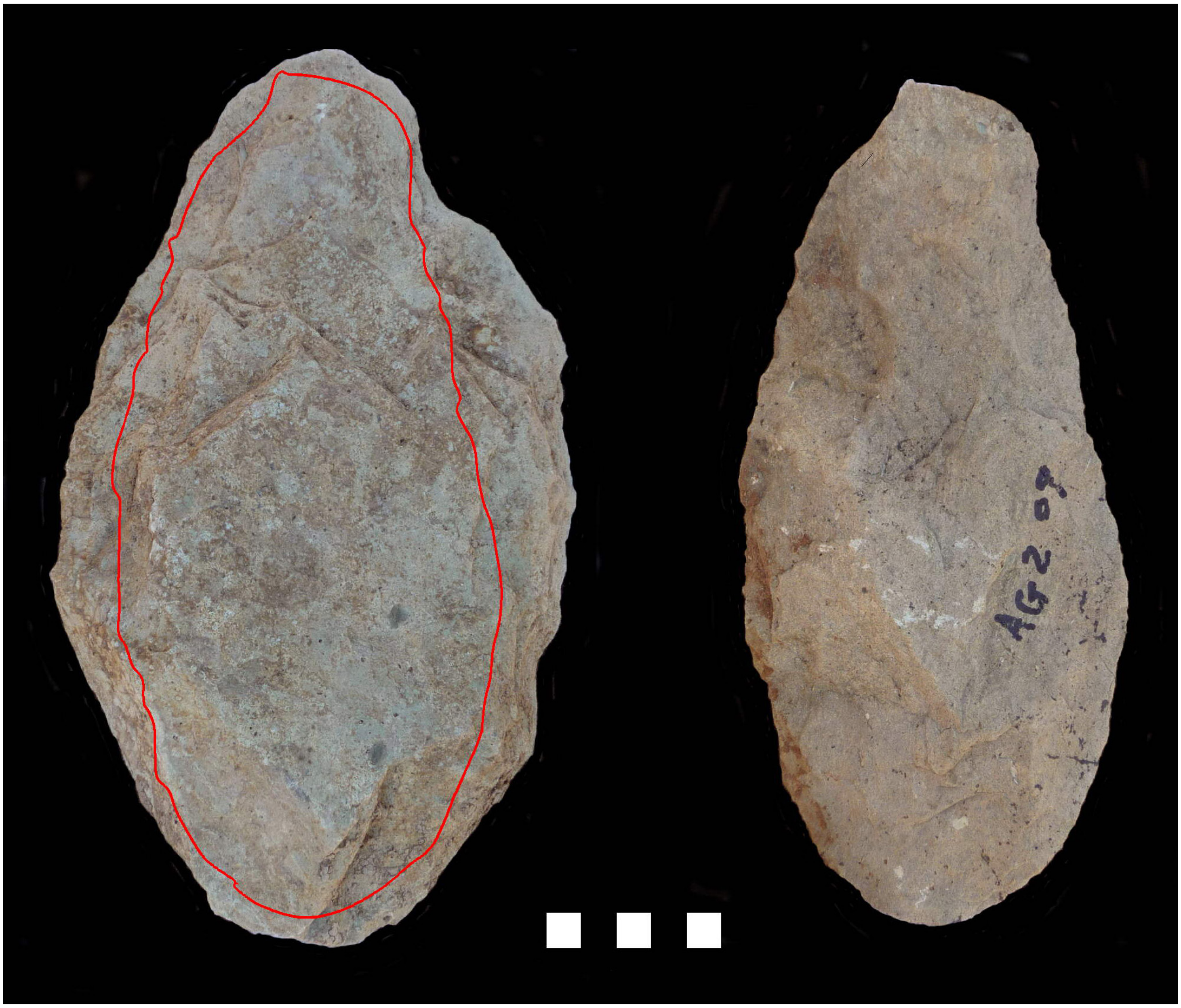

Figure 9. Very long Kilombe bifaces—the massive specimen is unique on the site and appears to be an unfinished piece. The huge flake, with B/L ratio 0.58, would probably have been reduced to the shape of the more typical long specimen also shown.

implies that the very acute modern human sense of proportion has a history in earlier *Homo* going back more than one million years. A good deal of precision and complexity also is implied in social transmission (cf. Gamble et al. 2011).

Next, neither of the two hypotheses originally outlined seems to provide a complete explanation for the particular pattern found in Breadth/Length in hand-axes. They were formulated with the assumption that there might be either a general preference for 0.61, sometimes overridden by various factors, OR there might prove to be no such preference, with the appearance of it being shaped by our own selective attention. The evidence suggests a more complex picture (Figure 10):

- that there was a general and very widespread tendency for hand-axes to be made with breadth/length proportions having a mean value of about 0.61, but also that this central tendency emerges from a swarm of other values;
- that the allometry factor has the consequence that far broader and far narrower bifaces were regularly made; and, in some biface sets, other proportions tending towards 0.50 were actively preferred so strongly that the 0.61 value scarcely occurs; and,
- that the value B/L 0.50 seems actively favored in long bifaces in all sets, as well as occurring commonly in Thickness/Breadth (T/B) relations.

In the face of all the variation, there can be no case for arguing a deep or hard-wired imposition of any particular proportion in artifacts, but the data strengthen the idea that there is some firmly established human disposition to like particular ratios of shape. It seems most likely as McManus (1980) has argued that this is a weak preference, existing partly as a disfavoring of extreme proportions. Very long term selection for technological success might favor such a 'sense,' but there is a proviso that quite different shapes might be preferred in wood and bone artifacts, often hyper-elongate.

Amid the variation, a fixed ratio, such as 0.61, or Golden Section, has a particular appeal. Yet we have seen that it does not occur in a fixed way, and a skeptic's view would

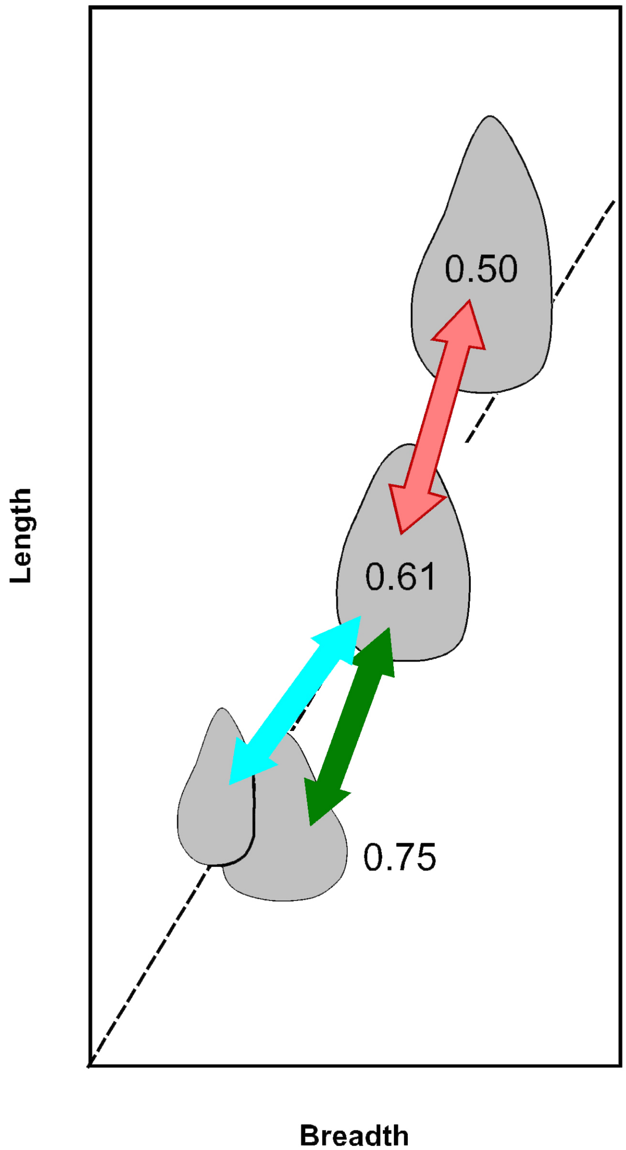

Figure 10. The shapes that they liked—a generalization of major preferences of B/L in the making of bifaces. As noted in the text, mean values approximating to 0.61 can occur at different lengths in different assemblages. The mean value of ca. 0.50 occurs at around 210–220mm in several assemblages. Small bifaces tend to be more varied in form; a similar phenomenon can be seen in the smallest modern screwdrivers which vary according to weight of the task (e.g., electrical screwdrivers are quite different from the stubby specimen shown in Figure 8).

be that we focus on this value for reasons of 'mystique,' imposing a spurious specialness on mundane occurrences. But the significance of the 0.61 value is not quite so easily dismissed. It is the mean for the large dataset used by Sharon (2007), as well as those used by Pope et al. (2006). It turns out to be the grand mean for the 20 varied biface assemblages in the author's database. It may happen to be the primary 'natural' ratio in stone flakes struck by simple techniques, and have been made desirable by long familiarity. Very probably, in stone artifacts extreme forms tend to be unworkable or unusable, so that middling forms (around 0.6) tend to recur—but it is still notable that these datasets return the value 0.61, rather than say 0.60 or 0.62. Even so, throughout the Acheulean many of the finest bifaces do not conform to Golden Section by any stretch of the imagination. A case is presented here for a similar or equal emphasis on the value of 0.50 (1:2)—and the long bifaces which favor this ratio are themselves often regarded as somewhat special. The seamless gradient of proportion from 0.61 in shorter to 0.50 in longer bifaces may indeed be one of the most remarkable things about the Acheulean.

For modern and ancient humans it has been vital to possess a sense of proportion, and then essential to be able to vary those proportions according to need. Modern humans are both very sensitive to variation in proportion, and have wide variation in preferences (McManus and Cook 2007). It now seems likely that preference ranges for particular proportions were comparable in earlier *Homo* to those observable in modern humans.

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NOTE ON METHODS

The scatter plots were made using output from SPSS. The ratio lines necessarily pass through the origin of Length and Breadth and through the centroid of the data. The lines fitted in Figure 4, highlighting allometry, run from the overall centroid to the centroids for data at least 2 standard deviations from the mean for L and B (as described). This line is almost straight from end to end, suggesting that a straight line fit would be appropriate to the data. In Figure 7, the straight lines shown are the Reduced Major Axis (in each dataset this passes through the centroid, and its slope is given by the ratio between the standard deviations for B and L).

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