[Supplementary material]

Symmetry is its own reward: on the character and significance of Acheulean handaxe symmetry in the Middle Pleistocene

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OSM 1: Methods

Measurements:

1) Maximum Length (L)- the maximum distance from the butt to the tip parallel to the long axis of the handaxe.
2) Maximum Width (B) - the maximum distance between the lateral margins of the handaxe, measured perpendicular to the long axis.
3) Maximum Thickness (TH) - the maximum thickness of the handaxe, measured perpendicular to the long axis.
4) Butt length (L1) - the length of the butt, measured as the distance from the base of the handaxe to the point of maximum width.
5) B1 - the width of the tip, measured at a distance from the tip equal to one-fifth of the maximum length.
6) B2 - the width of the butt, measured at a distance from the butt equal to one-fifth of the maximum length.
7) Scar Count - the total number of negative removals >5mm in maximum dimensions
8) Cortex Percentage -the proportion of the original nodule surface or natural pre-manufacture surfaces remaining on a handaxe, estimated at 5% intervals

Indices:

1) Planform shape (L1/L) - calculated by dividing the butt length by the total length, yielding an index between 0 and 1. Lower values express lower positions of maximum width, i.e. handaxes with short butts and long tips, while higher values represent handaxes with longer butts and

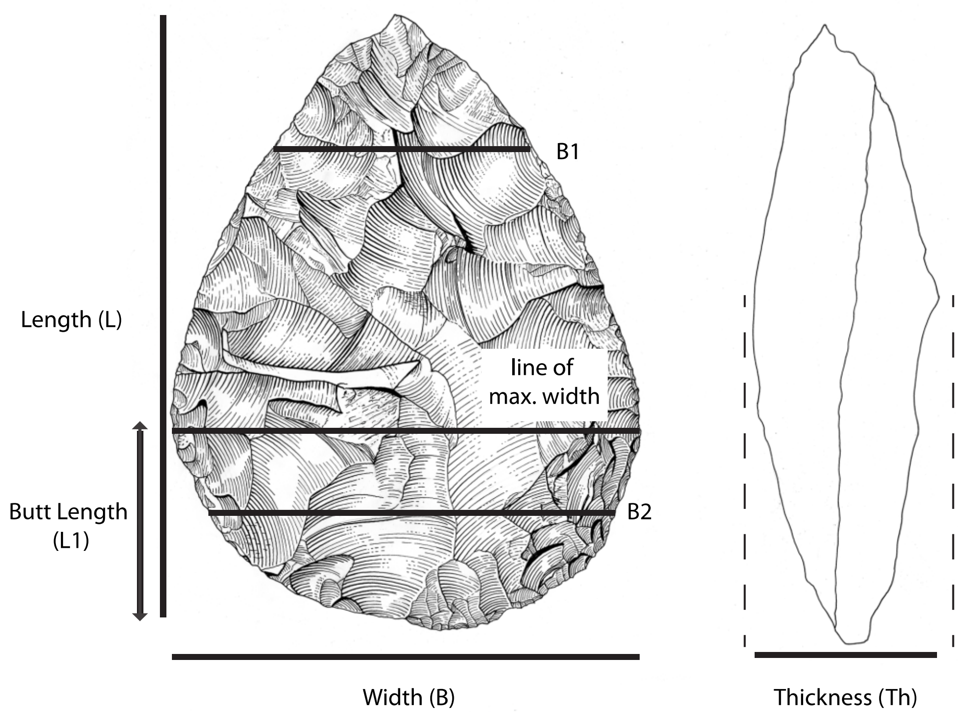
shorter tips. Roe arbitrarily divided this continuum into three main 'types'; i) points: L1/L ≤0.350; ii) ovates: L1 between 0.351 and 0.550; iii) cleavers: L1/L >0.550

2) Elongation (B/L) - expressing the relative length of a handaxe compared to its width, or in Roe's (1964) terms the 'broadness' or 'narrowness' of the piece.

3) Edge Shape (B1/B2) - expressing the relative pointedness or roundness of a handaxe

4) Refinement (B/Th) - expressing the relative thickness of a handaxe compared to its width.

5) Edge working - the ratio of the circumference of the entire handaxe over the worked circumference



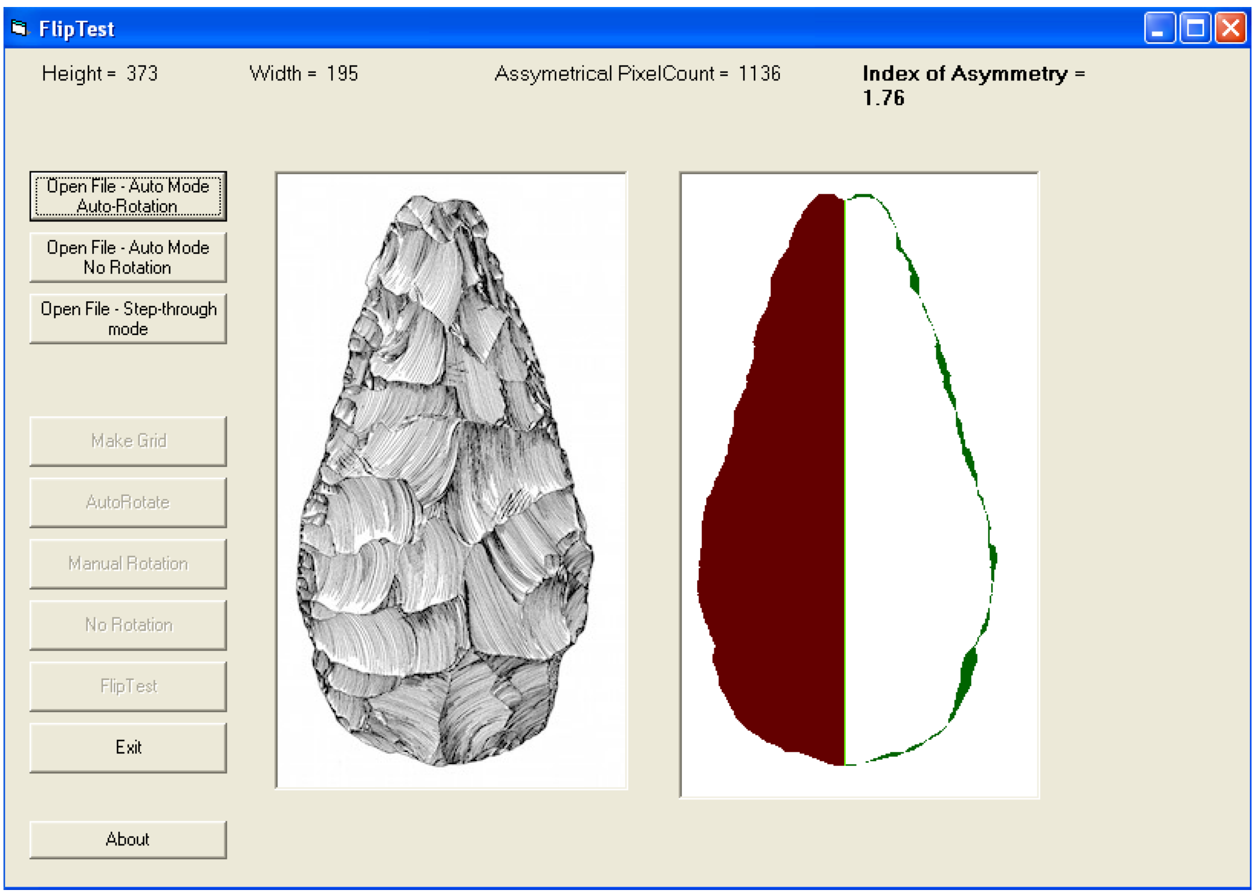
Categorical Observations:

1) Butt working - this was divided into four classes – i) Fully and finely worked ii) Fully but roughly worked iii) Partly worked, partly cortical iv) Unworked, cortical or natural

The Flip Test

The Flip Test is a freeware programme (http://www.fliptest.co.uk; Hardaker and Dunn 2005) that provides a graphical and numerical measure of bilateral symmetry by, as the name implies, 'flipping' a two-dimensional image of an artefact about its long axis and measuring the difference (in pixels) between the two sides. Images can be auto-rotated or manually rotated to attain the best reading of symmetry. The inputs to the programme were predominantly outline drawings produced in the 1990s by MJW, augmented by photographs lodged with the Archaeological Data Service by Marshall et al. (2002), photocopies of outline drawings given to MJW by Derek Roe and published line drawings.

Screenshot showing the Index of Asymmetry and graphical results for the Furze Platt Giant, found by Deffy Carter in 1919 and acquired by Llewellyn Treacher. This handaxe is not part of our sample, which was collected by A.D. Lacaille and is considered a more reliable representation of handaxes from the site.



Marshall, G.D., Gamble, C.G., Roe, D.A. & Dupplaw, D. 2002. Acheulean biface database.
http://archaeologydataservice.ac.uk/archives/view/bifaces/

OSM 2: Foxhall Road Red Gravel and Grey Clay Assemblages

Symmetry Classes, in percent

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Red Gravel, n=16	0	31.25	12.5	12.5	12.5	31.25
Grey Clay, n=17	0	35.3	29.4	5.9	11.8	17.6

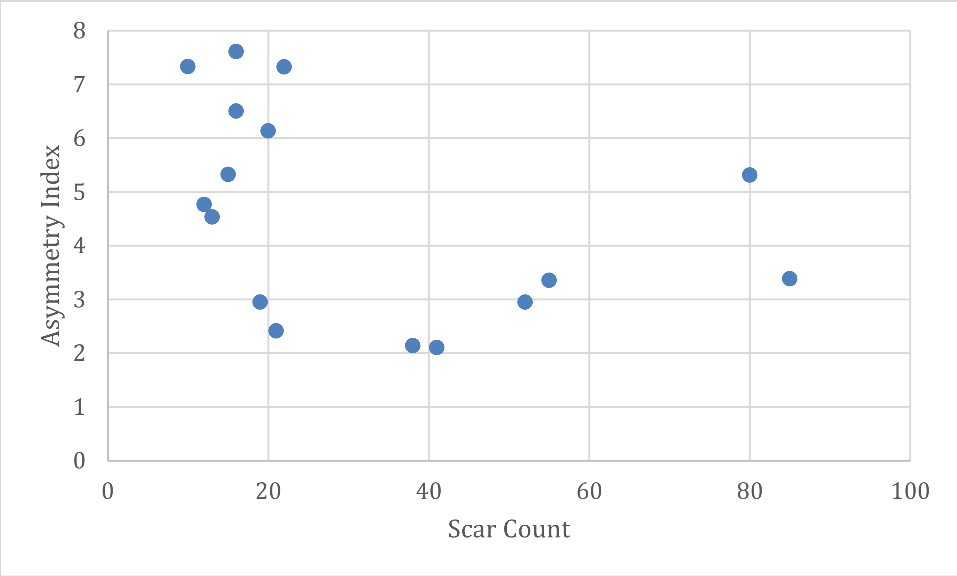
Correlation coefficients (r) for symmetry vs aspects of shape and reduction for Foxhall Road Red Gravel and Grey Clay assemblages. Bold red text indicates a statistically significant correlation. The Grey Clay assemblage, which can be assigned to Roe's Group VI conforms to the pattern seen in other ovate dominated groups. The Red Gravel, which belongs in Roe's Group II, shows the expected correlation between symmetry and edge working and symmetry and cortex, but no correlation between scar count and symmetry, contrary to other point-dominated sites.

Foxhall Road Layer	L/L1 (Shape)	B1/B2 (Edge Shape)	B/L (Elongation)	Th/W (Refine-mint)	Scar Count	Edge Working	Cortex %
Red Gravel N=16	0.218	0.047	0.161	0.359	**0.**401	**0.612**	**0.612**
Grey Clay N=17	0.485	0.059	0.210	**0.491**	**0.496**	0.396	**0.590**

Mean scar count, edge working and cortex percentage for Foxhall Road Red Gravel and Grey Clay assemblages (standard deviation in parenthesis)

Foxhall Road Layer	Average Scar Count	Mean edge working (% of edge worked)	Mean Cortex %
Red Gravel N=16	**22 (24.1)**	**74**	**27.5 (29.2)**
Grey Clay N=17	**44 (23)**	**82**	**13.5 (16.7)**

Asymmetry Index vs Scar Count at Foxhall Road, Red Gravel. The lack of correlation between scar count and symmetry is caused by the very low scar counts in most handaxes, which nonetheless show a range of symmetry values



OSM 3: Symmetry Data

Frequency of AI Values for all handaxe assemblages except Hoxne, in percent

	1 to 1.5	1.5 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12+
Furze Platt, n=107	0.0	13.1	15.0	26.2	16.8	10.3	8.4	4.7	3.7	0.9	0.9	0.0
Cuxton, n=152	0.0	7.9	18.4	20.4	19.7	11.2	6.6	4.6	4.6	2.0	1.3	3.3
Whitlingham n=130	0.0	29.2	24.6	15.4	14.6	6.9	4.6	0.8	1.5	0.8	0.8	0.8
Stoke Newington, n=70	0.0	12.9	25.7	18.6	14.3	14.3	2.9	5.7	0.0	0.0	2.9	2.9
Swans UMG, n=110	0.9	22.7	14.5	21.8	14.5	13.6	2.7	3.6	1.8	3.6	0.0	0.0
Dovercourt, n=110	1.8	28.2	30.9	17.3	10.9	3.6	3.6	0.9	0.0	1.8	0.0	0.9
Hitchin, n=63	3.2	30.2	27.0	9.5	14.3	7.9	4.8	1.6	0.0	0.0	0.0	1.6
Foxhall Road, n=57	0.0	28.1	22.8	17.5	14.0	5.3	7.0	1.8	1.8	0.0	0.0	1.8
Wolvercote, n=56	1.8	16.1	32.1	25.0	7.1	10.7	7.1	0.0	0.0	0.0	0.0	0.0
Fordwich, n=136	0.7	21.3	23.5	25.7	14.7	7.4	2.9	2.2	0.7	0.0	0.0	0.7
Elveden, n=64	3.1	53.1	17.2	14.1	9.4	0.0	3.1	0.0	0.0	0.0	0.0	0.0
Bowmans Lodge, n=29	3.4	44.8	27.6	6.9	3.4	6.9	0.0	3.4	0.0	0.0	3.4	0.0
Round Green, n =16	0	46.7	33.3	6.7	6.7	0.0	6.7	0.0	0.0	0.0	0.0	0.0
Wansunt, n=35	2.9	45.7	20.0	17.1	5.7	5.7	2.9	0.0	0.0	0.0	0.0	0.0
Swans Upper Loam, n=16	0.0	50.0	12.5	25.0	6.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0
Holybourne, n=19	0.0	21.1	52.6	15.8	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaddesden Row, n=45	2.2	35.6	26.7	15.6	11.1	6.7	0.0	0.0	2.2	0.0	0.0	0.0
High Lodge, n=66	0.0	57.6	16.7	10.6	4.5	6.1	3.0	1.5	0.0	0.0	0.0	0.0
Caddington, n=29	3.4	37.9	27.6	20.7	6.9	3.4	0.0	0.0	0.0	0.0	0.0	0.0
Boxgrove, n=78	9.0	43.6	28.2	11.5	5.1	2.6	0.0	0.0	0.0	0.0	0.0	0.0

Frequency of Handaxes in each Asymmetry Class, in percent (excludes Hoxne)

	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Furze Platt, n=107	0	13.1	15	26.2	16.8	28.9
Cuxton, n=152	0	7.9	18.4	20.4	19.7	33.6
Whitlingham n=130	0	29.2	24.6	15.4	14.6	16.2
Stoke Newington, n=70	0	12.9	25.7	18.6	14.3	28.7
Swans UMG, n=110	0.9	22.7	14.5	21.8	14.5	25.3
Dovercourt, n=110	1.8	28.2	30.9	17.3	10.9	10.8
Hitchin, n=63	3.2	30.2	27	9.5	14.3	15.9
Foxhall Road, n=57	0	28.1	22.8	17.5	14	17.7
Wolvercote, n=56	1.8	16.1	32.1	25	7.1	17.8
Fordwich, n=136	0.7	21.3	23.5	25.7	14.7	13.9
Elveden, n=64	3.1	53.1	17.2	14.1	9.4	3.1
Bowmans Lodge, n=29	3.4	44.8	27.6	6.9	3.4	13.7
Round Green, n =16	0	46.7	33.3	6.7	6.7	6.7
Wansunt, n=35	2.9	45.7	20	17.1	5.7	8.6
Swans Upper Loam, n=16	0	50	12.5	25	6.3	6.3
Holybourne, n=19	0	21.1	52.6	15.8	10.5	0
Gaddesden Row, n=45	2.2	35.6	26.7	15.6	11.1	8.9
High Lodge, n=66	0	57.6	16.7	10.6	4.5	10.6
Caddington, n=29	3.4	37.9	27.6	20.7	6.9	3.4
Boxgrove, n=78	9	43.6	28.2	11.5	5.1	2.6

Correlation coefficients (r) for handaxe symmetry against measures of shape and reduction intensity (left). Red bold typeface indicates a statistically significant relationship. Figures in square brackets are results once outliers are removed. The table also shows mean attribute values for key indicators of reduction intensity (right).

		Correlation coefficients (r) for symmetry and:							Mean attribute values (StDev)		
Site	Roe Group	L/L1 (Shape)	B1/B2 (Edge Shape)	B/L (Elongation)	Th/W (Refinement)	Scar Count	Cortex %	Edge Working	Scar Count	Edge Working Index	Cortex %
Cuxton	I	0.178	0.122	0.043	0.135	no data	**0.395**	**0.367**	no data	0.539	23.71 (15.4)
Furze Platt	I	0.127	0.114	0.046	0.165	**0.304**	**0.288**	**0.284**	35.2 (12.1)	0.646	13.4 (14.4)
Stoke Newington	I	0.134	0.138	0.164	0.137	**0.310**	0.005	0.126	36.6 (13.6)	0.669	18.8 (17.7)
Whitlingham	I	0.033	0.057	0.043	0.078	**0.352**	**0.382**	**0.217**	40.7 (20.3)	0.750	11.1 (11.4)
Dovercourt	II	0.052	0.178	0.061	0.124	0.132 **[0.258]**	**0.406**	**0.316**	42.9 (18.4)	0.763	11.8 (14.1)
Foxhall Road	II	0.064	0.165	0.146	**0.272**	**0.262**	**0.272**	**0.403**	31.0 (22.8)	0.811	17 (23.3)
Hitchin	II	0.091	0.023	0.126	**0.314**	**0.377**	**0.324**	**0.528**	50.5 (15.8)	0.796	8.6 (11.1))

Swanscombe UMG	II	0.076	**0.199**	0.011	0.130	**0.483**	**0.259**	**0.191**	22.8 (11.4)	0.660	13.7 (16.2)
Wolvercote	III	**0.363**	0.213	0.106	**0.298**	**0.360**	0.274	0.212	54.4 (20.9)	0.741	8.5 (12.2)
Fordwich	V	0.026	0.040	0.043	**0.231**	**0.382**	0.006	**0.277**	37.7 (15.8)	0.659	15.9 (15.7)
Bowmans Lodge	VI	0.050	0.009	0.082	0.014	**0.542**	**0.417** [0.144]	0.001	53.6 (16.9)	0.936	3.8 (8.1)
Elveden	VI	0.017	0.085	0.131	0.153	**0.421**	0.198	0.124	56.2 (20.3)	0.951	3.6 (7.5)
Round Green	VI	0.343	0.212	0.260	0.040	**0.700**	0.043	**0.323** [0.320]	51.6 20.4	0.811	11.3 (19.6)
Wansunt	VI	0.020	0.104	0.043	0.115	0.138 **[0.404]**	0.296	0.086	56.1 (12.2)	0.926	2.5 (3.1)
Boxgrove	VII	0.163	0.000	0.052	**0.399**	**0.265**	0.083	0.066	59.9 (16.1)	0.958	4.5 (4.8)
High Lodge	VII	0.047	0.068	0.023	**0.250**	0.162	0.205	0.141	59.2 (16.8)	0.941	4.5 (7.6)
Caddington	VII	0.282	0.100	0.157	0.318	**0.470**	0.150	0.283	47.3 (16.3)	0.874	14.3 (18.1)
Gaddesden Row	VII	0.050	0.031	0.069	0.216	**0.387**	0.162	[0.284]	50.3 (17.5)	0.880	13.3 (19.1)

OSM 4: Exceptions to the general patterns observed in OSM 3

Site	Variation from Expected Pattern	Probable Explanation (bold = conforms to the general pattern once the issue is resolved)
Wolvercote	L1/L shows significant correlation with symmetry	See OSM 7
Wolvercote	Cortex Percentages shows an insignificant correlation with symmetry	See OSM 7
Wolvercote	Refinement shows a significant correlation with symmetry	See OSM 7
Foxhall Road	Refinement shows a significant correlation with symmetry	See OSM 7
Hitchin	Refinement shows a significant correlation with symmetry	See OSM 7
Fordwich	Cortex percentage shows an insignificant correlation with symmetry	Use of pipe flint. Cortex retention is high across the assemblage & symmetry is imposed on minimally worked objects as much as well-worked ones.
Fordwich	Refinement shows a significant correlation with symmetry	**Symmetry outlier of 15.89**
Boxgrove	Refinement shows a significant correlation with symmetry	The distribution at Boxgrove shows a tight range of high refinement values, all falling within the range 0.25 to 0.55. Symmetry is much more variable, ranging from 1 to over 6, resulting in a stack-like distribution. Handaxes from Boxgrove are thus almost all highly refined, with variation in symmetry depending on how far the tranchet removal (84% of the assemblage) has affected the AI. See OSM 8
High Lodge	Refinement shows a significant correlation with symmetry	**Outlier with symmetry index >6 and refinement of 0.85.**
High Lodge	Scar count shows an insignificant correlation with symmetry	No obvious explanation **High instances of very high symmetry are possibly a result of collection bias**
Swanscombe	B1/B2	Extremely pointed handaxes at Swanscombe tend to be more symmetrical. We suspect this reflects greater attention to shaping the tip.
Dovercourt	Scar count shows an insignificant correlation with	**Symmetry outlier of 16.65**

	symmetry	
Wansunt	Scar Count shows a significant correlation with symmetry	**Symmetry outliers >6.5**
Round Green	Edge Working shows a significant correlation with symmetry	**Symmetry outlier of 7.8**
Gaddesden Row	Edge Working shows a significant correlation with symmetry	**Symmetry outlier of 9.8**
Stoke Newington	Edge Working shows an insignificant correlation with symmetry	Use of natural symmetry of pebble butts
Stoke Newington	Cortex percentage shows an insignificant correlation with symmetry	**Symmetry outlier >8**
Bowmans Lodge	Cortex percentage shows a significant correlation with symmetry	**Symmetry outlier >8**

OSM 5: Butt working and symmetry

To explore further the relationship between reduction intensity and symmetry we examined symmetry against butt working in Roe's Groups I, II, III and V, which contain assemblages with high frequencies of cortical butts and where raw material shape arguably had a greater effect on technological choices. Handaxes with unworked butts generally show higher levels of asymmetry than handaxes with fully worked butts, undoubtedly due to differential levels of artificial shaping at different points on the tool. This can be interpreted as showing either that symmetry automatically increases with reduction intensity, and was unintended, or that greater levels of reduction allowed humans deliberately to bring out greater levels of symmetry. The former explanation may partly explain tip symmetry, but not butt symmetry, which when worked, are crafted in arcs, triangles, or straight lines. At the point where the butt intercepts the margins, attention is required to maintain symmetry in both elements of the handaxe. In many cases—particularly at Dovercourt, Stoke Newington, Wolvercote and Whitlingham—symmetry has been achieved despite low levels of butt working by the advantageous use of natural symmetry, or by the use of limited amounts of working to mirror natural edges or other irregularities (Figure 5a). It seems inconceivable that this could be accidental in every instance, and the selection of symmetrical nodules and mirroring of natural surfaces support the notion that symmetry was desired and deliberately imposed.

Modal Asymmetry Class for handaxes from Roe's Groups I, II and III, divided by butt working levels. Key to Butt Classes: Class vi: fully and finely worked; Class iii: fully and roughly worked; Class ii: partly worked; Class i: unworked natural or pebble butt. See Table 2 for descriptive key to Asymmetry Classes.

	Butt Class i	**Butt Class ii**	**Butt Class iii**	**Butt Class vi**
Furze Platt	6	5	4	2
Whitlingham	3	3	2	2
Stoke N'ton	6	3	3	3
Swanscombe	6	4	2	2
Dovercourt	3	4	2	2
Hitchin	6	3	2	2
Foxhall Road	6	6	3	2
Wolvercote	3	4	3	2
Fordwich	4	4	2	2

OSM 6: **Symmetry at the tip or on worked sections only**

It seemed likely that measuring the symmetry of the tips alone might provide a more accurate impression of symmetry in partially worked handaxes, but this is problematic because there is no agreed definition of what constitutes the tip. It could be the top fifth (cf. Roe 1968), the top third (McNabb et al 2004) or everything above the point of maximum width (Roe 1968; Callow 1976), amongst others. Here we attempted to resolve this by measuring the symmetry of the worked segments only, using a sub-sample of handaxes in Butt Classes 1 and 2 from the Swanscombe UMG, a relatively large and well-excavated sample (Wymer 1968). This involved taking the original outline drawing and removing the unworked areas of the butt in Adobe Photoshop. However, in order for the resultant images to work with the Flip Test software, the object had to be closed by a line joining the two edges. If the object was not in proper vertical alignment, with the two edges in the most symmetrical plane, this straight line introduced additional asymmetry. For some handaxes this was impossible because no continuous edge existed, cortex or unworked edges being situated irregularly around the circumference of the tool. These were excluded from analysis. A total of 28 pieces were analysed from Butt Class 1 and 31 from Butt Class 2.

With these caveats in mind, symmetry nevertheless improved in 22/28 examples for handaxes in Butt Class 1 (mean difference = -2.36 AI), and in 21/31 cases for Butt Class 2 (mean difference = -1.6 AI), with 54% improving by at least 1 asymmetry class. However, in 16 cases (27%) symmetry decreased when only the worked portions were considered, meaning that the whole object was apparently more symmetrical than its parts. In these cases, hominins have utilised the natural shape of the original blank in attaining symmetry, sometimes deliberately mirroring unworked segments in their knapping. Thus, measuring the worked edges only does not provide a full picture and makes it no easier to decide between two equifinite explanations—accident or design—although the selection of symmetrical nodules and mirroring of natural surfaces both support the notion that hominins *were* mindful of symmetry. The variation of the method proposed by McNabb et al. (2018) while this paper was in press may be better suited for this type of analysis, although their arbitrary division of handaxes into thirds, regardless of form or manufacture, needs re-visiting.

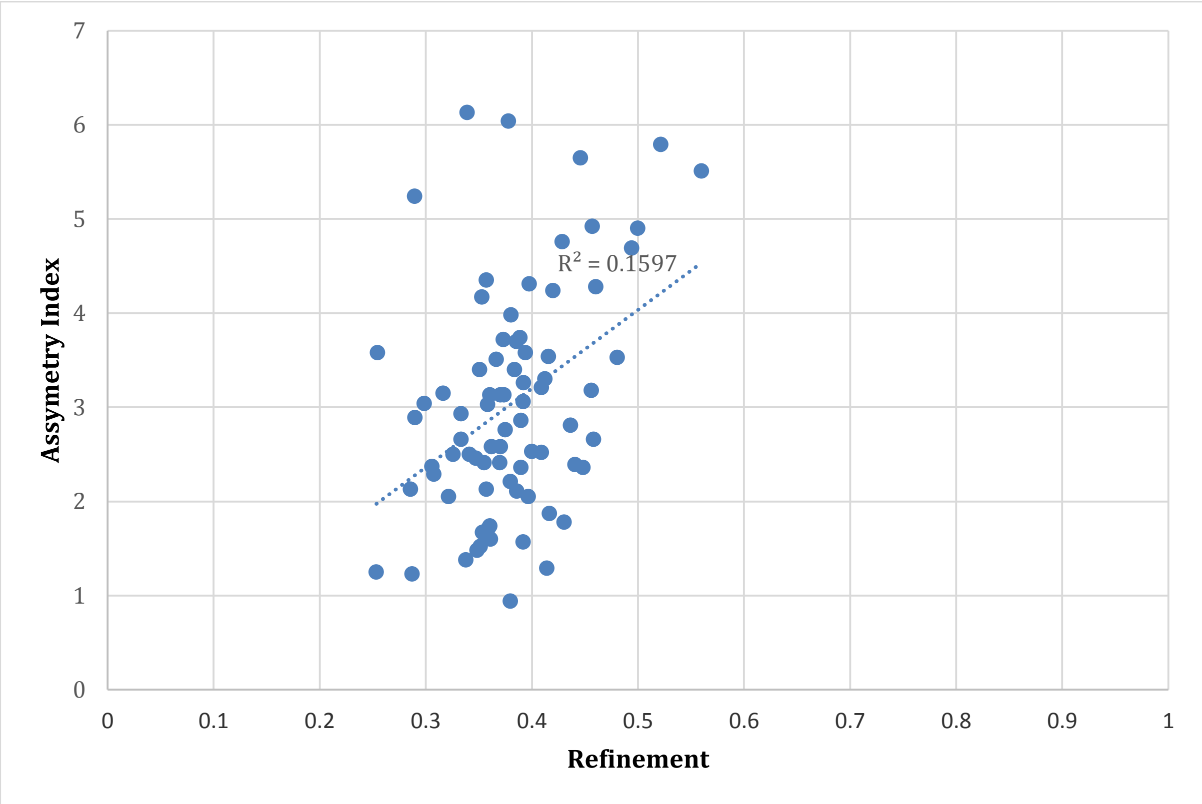
Reference:

McNabb, J., Cole, J. and Hoggard, C. 2018. From side to side: symmetry in handaxes in the British Lower and Middle Palaeolithic. *Journal of Archaeological Science: Reports* 17: 293-310. (doi:10.1016/j.jasrep.2017.11.008)

OSM 7: The character of the Foxhall Road, Wolvercote and Hitchin assemblages

These assemblages each contain two distinct elements made using different knapping strategies. At Hitchin and Foxhall Road, well-made ovates, many with a distinctive ‘twisted’ edge, occur within assemblages otherwise dominated by pointed handaxes. We suspect that the Hitchin sample, which came from Jeeves’ Pit or Folly Pit within the Hitchin Lake Beds (White 1998a), actually contains two discrete assemblages, a situation known to be true in the case of Foxhall Road. Similarly, at Wolvercote an otherwise unremarkable pointed assemblage contains a subset of fine plano-convex, slipper-shaped pieces. When the different types are taken individually, there no significant correlation between symmetry and refinement in the ovate subsets nor the plano-convex group, where symmetry is imposed regardless of relative thickness. Rather it is in the pointed elements at these sites that refinement and symmetry weakly correlate, probably reflecting the use of smaller cobble blanks showing varying levels of human modification. The same argument applies to Fordwich, where a large number of handaxes were manufactured on pipe or burrow flint that were naturally thick and difficult to work (White 1998a) - those which leant themselves to greater levels of working almost inevitably saw more bifacial thinning (and hence refinement) and imposition of shape. Wolvercote also deviates in having a very weak correlation between shape and symmetry, but no correlation between cortex percentage and symmetry. This can be explained by the flat flakes or plaquettes used in the production of the fine plano-convex set, which allowed symmetry to be imposed to the edges while patches of cortex remained on the faces. In this group imposing symmetry came was a more pressing consideration than refinement and cortex removal.

OSM 8: Regression for asymmetry index vs refinement at Boxgrove. Most Boxgrove handaxes are highly refined, with a Refinement (Th/B) index <0.50, but symmetry varies considerably, between 1 and >6. The pattern probably reflects the high frequency of tranchet removals at Boxgrove, which might have a detrimental impact on symmetry without affecting refinement.



OSM 9: Illustration Biases

Symmetry data were collected from four major text books on the British Palaeolithic from the last five decades: Roe's (1981) *The Lower and Middle Palaeolithic Periods in Britain*; Wymer's (1968) *The Lower Palaeolithic Period in Britain*; Wymer's (1985) *The Palaeolithic Sites of East Anglia*; and Pettitt & White's (2012) *The British Palaeolithic*.

The graphs below reveal a bias in the archaeological literature towards more symmetrical handaxes, Wymer's two tomes being the most representative of the archaeological record (K-S test = 0.067 and 0.070, insignificant at p=<5%), Roe (1981) and Pettitt & White (2012) being the least (K-S test 0.161 & 0.2, significant at p<5%). A key difference is that Wymer tended to draw his own figures, selected from museums and his own collection to illustrate sites, periods and technological points. While having the same purposes in mind, Roe and Pettitt & White harvested their illustrations from images published over the past 150 years, implying that there has been a long running tradition of publishing the 'nicest' handaxes in a collection, thus enhancing the popular view that handaxes are almost always symmetrical. Nevertheless, the results of this study demonstrate that, while the literature is somewhat unrepresentative, the notion that most handaxes are highly symmetrical or better is true.

Top: Distribution of handaxe symmetry indices for major text book illustrations. Bottom: Cumulative frequency of handaxe symmetry indices for major text book illustrations