COMPUTERISED ANALYSIS OF THE SHAPES OF A CLASS OF PREHISTORIC STONE TOOLS FROM WEST-CENTRAL FRANCE.

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This paper concerns the statistical analysis of the shapes of a sample of stone tools from west-central France which belong to the broad class of artefacts known as 'Moulin-de-Vent percoirs'. The analysis was a part of an overall strategy of investigation which includes a study of their microwear and cultural context.

These tools (fig. 1), averaging about 30mm in length, are generally made from flake or flake-blade blanks, by normal retouch (i.e. from ventral to dorsal surface). This retouch is generally abrupt and concentrated at one end so as to produce a sort of tip or point. The tools fall well outside the range of form of, for example, scrapers, and bear sufficient similarity to one-another (mostly in terms of technology, but also, in a very general sense, in terms of form) to be considered together as a group.

The earliest record of the discovery of tools of this type is in an article by Dr. Rejou (1883). He reported collecting large quantities of this idiosyncratic artefact at the site of Moulin-de-Vent on the southern side of the river Charente (see map fig. 2 for location of sites), and it is from this findspot that the 'percoirs' take their name. The site was a late Neolithic ditched settlement belonging to the so-called 'Peu-Richardien' culture, a culture which may be dated to the period 2500-2200BC.

In the century which has elapsed since Rejou's initial report, Moulin-de-Vent percoirs have been recovered in similarly large quantities from several other Peu-Richardien camps. The collections made by Clouet at a number of sites in the Saintes area in the 1920s and 1930s are particularly noteworthy. He found 3000 Moulin-de-Vent percoirs at the type site, and he estimated that this type constituted 53% of all the lithics he recovered here (Clouet 1928). Moulin-de-Vent percoirs were even more abundant at

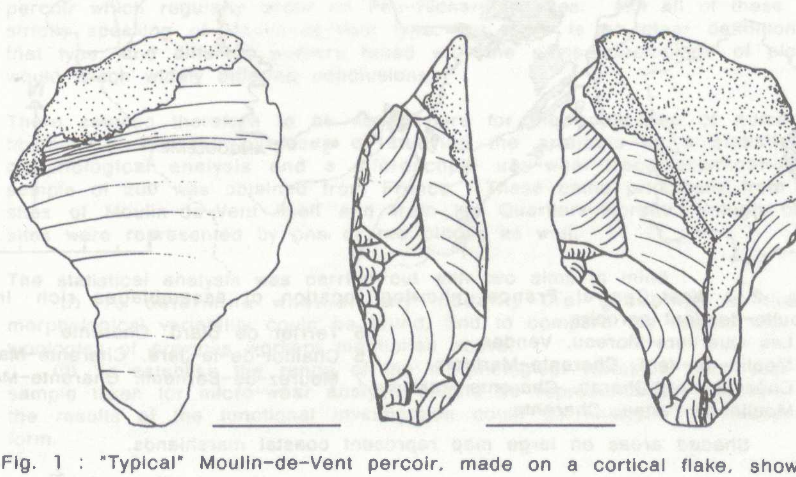

Fig. 1 : "Typical" Moulin-de-Vent percoir, made on a cortical flake, showing general form. (Scale x 2)

Chez-Landard on the opposite bank of the river Charente, over 5000 or some 55% of all lithics (Clouet 1926), and only slightly less abundant at the nearby Chaillot-de-la-Jard and Mourez-de-Berneuil sites (Clouet 1933). It could be objected that since Clouet was clearly particularly interested in this artefact type, he collected percoirs in preference to other classes of tool, and that consequently his percentages are inflated. More recent fieldwork has however largely confirmed Clouet's conception of the scale of the phenomenon - thus in the 1950s over 2000 Moulin-de-Vent percoirs were collected at Biard near Cognac, some 64% of the lithic assemblage (Burnez 1957), while still more recently 2000 have been reported from the site of Les Quartiers-Moreau, in the north-western corner of the Marais poitevin, where again they constitute some 50% or more of all lithic tools found (Jauneau 1975; pers.comm.). This is the first percoir-rich Peu-Richardien site to be discovered outside the heavily-researched Saintes-Cognac area, and suggests that the phenomenon may be geographically more widespread than was formerly suspected.

So far as we know, the occurrence of this single flint tool type in such relative abundance is unique in postglacial european archaeology.

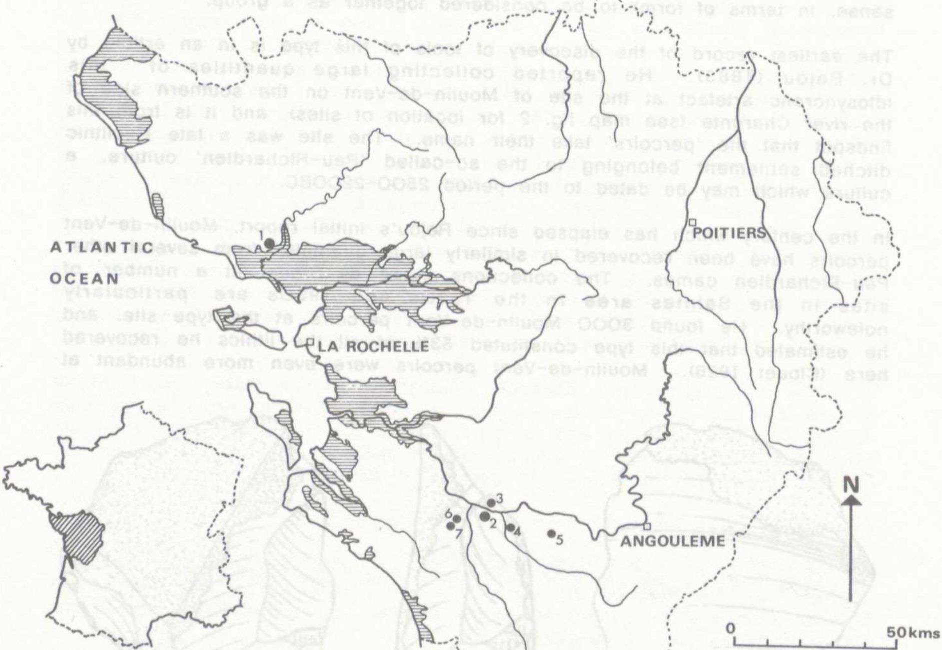

Fig. 2 : West-Central France, showing location of assemblages rich in Moulin-de-Vent percoirs.

1 Les Quartiers-Moreau, Vendee
2 Moulin-de-Vent, Charente-Maritime
3 Chez-Landard,Cherac, Charente-Maritime
4 Moulin-de-Fanau, Charente
5 Terrier de Biard, Charente
6 Chaillot-de-la-Jard, Charente-Maritime
7 Mourez-de-Berneuil, Charente-Maritime

Shaded areas on large map represent coastal marshlands.

Three related questions immediately raise their heads:

(i) How well does the Moulin-de-Vent percoir constitute a single type?

(ii) What was it used for?

(iii) How does it relate to the occupations of the sites on which it is found?

The last question really lies outside the scope of the present paper, and will be dealt with in more detail elsewhere. In most cases the sites on which the percoirs occur are late Neolithic ditched enclosures, not dissimilar in some ways to the British 'causewayed camps', though in contrast to the latter a good case can be made for them having been fortified villages (Scarre 1980). The general-purpose nature of the sites makes the abundance of percoirs at them even more perplexing. However, there are indications that the percoirs are not in fact contemporary with the principal occupations of these settlements, but belong to the abandonment or post-abandonment phase. This is shown for example by the fact that though they are abundant on the surface of these sites they are rare in the ditch fills, and even then are only found in the uppermost levels of fill. It is possible that the reason why the Moulin-de-Vent percoirs occur on these sites is that quantities of flakes and other flint fragments from the earlier occupation were lying about on the surface, ready to be used as blanks for percoir manufacture.

This leads us to the typology. The Moulin-de-Vent percoir is a small tool, on average a mere 30mm in length. As a type it is rather ill-defined, possibly owing to the indifferent nature of the flakes or blade fragments which served as blanks for its production. Both the indifferent nature of the blanks and the small size of the finished product support the thesis that they were made by re-working flint debris. Marcel Clouet, whose activities were mentioned above, attempted to distinguish two varieties:

(i) the percoir proper, with a well-defined and developed point

(ii) the biseau, where the point is not so clearly differentiated from the body of the tool (Clouet 1926, 1928).

Later, he added a third category, of parallel-sided pieces (Clouet 1932-33). Not every French archaeologist would accept all three types as Moulin-de-Vent percoirs. Colle (1959) has added to the confusion by suggesting that there are perhaps as many as eight distinguishable types of percoir which regularly occur on Peu-Richardien sites. Not all of these are strictly speaking of Moulin-de-Vent type, but there is no clear definition of that type, and different workers faced with the same assemblage of pieces would reach widely differing conclusions.

There seemed therefore to be scope here for the application of numerical taxonomy. For the purposes of studying the artefacts by a statistical morphological analysis and a microscopic use-wear-trace examination a sample of 200 was obtained from France. These came principally from the sites of Moulin-de-Vent itself and from les Quartiers-Moreau, though other sites were represented by one or two pieces as well.

The statistical analysis was carried out with two aims in mind :

(i) To determine whether any modality (i.e. grouping) in the morphological variability could be found, and to compare the results with the typologies of previous workers mentioned above.

(ii) To establish the range of the morphological variability such that the sample taken for micro-wear analysis should be representative, and so that the results of the functional investigation could be analysed in relation to form.

It was first necessary to decide what to quantify in order to extract the form of the tools. The idea of taking 'significant measurements' was considered but rejected for various reasons, including :

(i) Deciding to take certain measurements and not others would introduce an undesirable set of subjective decisions into the analysis.

(ii) A set of measurements, designed to take account of most of the tools' morphological attributes, would be necessarily 'contrived' and complex. Also the measurements, individually or as a group, would be of a somewhat abstract nature.

(iii) Although the tools are clearly a group in a general sense (particularly in terms of technology) they do not have sufficient well definable features in common to allow the taking of any but the most rudimentary 'significant measurements', even if this were considered desirable.

Thus it was decided to take account of the tools' shapes as a whole by using the co-ordinates of a sufficient number of points around tool outlines to define their shape accurately. This line of reasoning is similar to that taken by previous workers (Allsworth-Jones & Wilcock 1974; Wilcock & Shennan 1975; Main 1978; 1979). In particular, the primary analysis followed the 'sliced' method of Wilcock and Shennan (op. cit.).

The first stage was to have drawings made of the tools. For this the aid of two students was enlisted. They used a Grant 'Projector' to make 3 times enlargement drawings of the tools' plan and profile outlines.

The plans were drawn by placing the tools on the horizontal surface of the projector's platform, with the surface from which the retouch was struck to form the point facing downwards. Usually this surface was the ventral face of the flake blank, but occasionally it was one of the dorsal scars. Once placed on the platform the tool was allowed to find its own 'natural' orientation. In general the accuracy and reproducability of the plans was good. Errors caused by misidentification of the 'bottom' surface were easy to spot and in these case the tools were redrawn.

The profile outlines were drawn by standing each tool on edge (on a small piece of Blu-Tack) such that it was at right-angles to the position in which the plan was drawn and with the axis of the tool horizontal. The position was determined by the judgement of the drawers, and the Blu-Tack allowed some movement of the tool. Not surprisingly, the profile outlines proved to be neither sufficiently consistent nor accurate, and they were not used in the analysis.

The next stage was to digitise the outlines using a digitising table made available by the Department of Earth Sciences at Cambridge. In addition to simply digitising the outlines, the position of a control point was taken. This point defined which point on the circumference corresponded to the tool's tip, the tip being defined as the point where a continuation of the dorsal ridge along the tool's point would cross the perimeter.

The data was then passed through a series of sorting routines:

(i) To put the data in a form more easily and economically stored, processed and checked, and to add identifying details.

(ii) To rotate the co-ordinates about the tip (which was re-defined as the origin) such that the tool axis was vertical with the tip at the top. The tools did not have any obvious counterpart to the tip at their bases, and so the definition of axis was not self-evident. After some experimentation, the following method (expressed as a conceptual model of the computer program) was chosen:

(a) Draw circles about the tip whose radii are the following fractions of the maximum dimension: 0.1, 0.2, 0.3, 0.4, 0.6, 0.8

(b) Find the mid-point of the arc between the two points where each circle crosses the outline

(c) Find the angles between the current co-ordinate frame and lines drawn from the tip to the mid-points

(d) Calculate the mean of the angles for the six arcs and rotate the co-ordinate frame by this amount

This method gives a bias towards the point area in determining the axis, but this was appropriate since we had good reason to believe that the point constituted the functional part. At least, the point is the area which had received most modification by means of retouch.

(iii) To normalise the dimensions of the tool making the maximum dimensions of the tool parallel to the axis equal to 1.

(iv) To reduce, by averaging, the number of data points for each tool from 200-300 to 100-50 on each side of the axis.

These points were evenly spaced along the axis of the tool and so represented the normal distance from the axis to the outline at intervals of 1/50 of the length. The data were stored quite economically without "y" co-ordinates, as a series of positive and negative "x" displacements from the axis, in order, anticlockwise round the tool, starting from the bottom right.

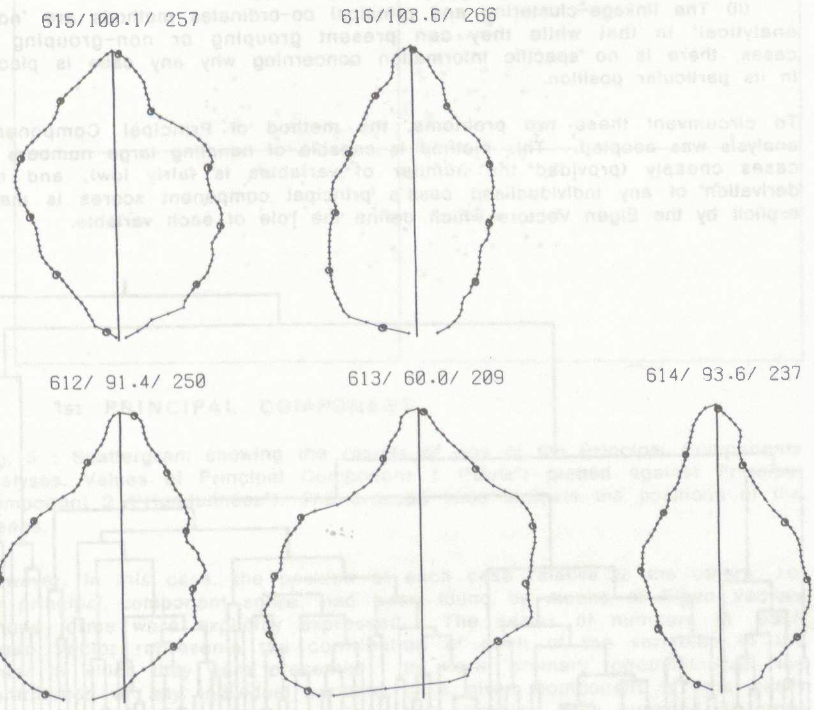

Fig. 3 : Graphics plot of 5 tool outlines used to check reordered digitized data. Each of the data points is marked by a cross, and every tenth cross is ringed. (There are in fact 101 marked data points including the tip (0,0)). The axis is marked by a vertical line. The numbers in the code above each tool are, respectively, tool reference number, length of the drawing in mm (i.e. actual tool length x3) and the original number of data points.

Next, the data were checked by using it to produce unsmoothed plots of the tool outlines using graphics routines supported by the Cambridge University IBM 370/165 (fig. 3). Any tools which had not been properly digitised were redone. Such errors as there were usually involved a large gap in the digitising caused by insufficient pressure on the digitiser button rather than a deviation from the actual shape.

The first analysis of the sorted data involved the production of a dissimilarity matrix as a basis for Cluster Analysis (single, average and total linkage). The dissimilarity co-efficient used was the total area between the outlines of each pair of tools (Wilcock & Shennan 1975). Fig. 4 shows an example of the results of this method, in this case an Average Link clustering of 100 cases. Taken on its own, this dendrogram would appear to indicate the presence of fairly clear groupings within the sample. However, a visual examination of the outlines of the tools making up the groups gave a strong impression that the clustering had merely divided a continuum. This impression was confirmed by Principal Co-ordinate scattergrams which showed the dendrogram groups were not discrete, except for the most aberrant cases.

The dissimilarity matrix/clustering approach was abandoned for two reasons:

(i) The use of methods requiring the production and analysis of matrices are relatively expensive when applied to 200 cases.

(ii) The linkage-clustering and principal co-ordinates methods are 'non-analytical' in that while they can present grouping or non-grouping of cases, there is no specific information concerning why any case is placed in its particular position.

To circumvent these two problems, the method of Principal Components analysis was adopted. This method is capable of handling large numbers of cases cheaply (provided the number of variables is fairly low), and the derivation of any individualised case's principal component scores is made explicit by the Eigen Vectors which define the role of each variable.

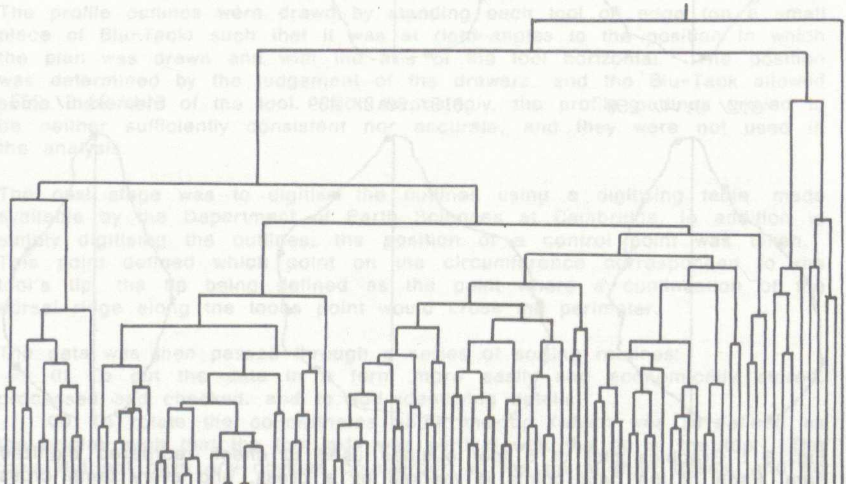

Fig. 4 : Dendrogram showing result of an Average Link cluster analysis of 100 of the tools.

Eight sets of variables were fed through the analysis using both the correlation co-efficient and covariance methods (except where one or the other was inapplicable). Each set of variables consisted of 18 or 20 of the 100 x-displacements arranged symmetrically about the axis. The exact nature of each set was varied by:

(i) Taking different distributions of points (always symmetrical about the axis) in order to either represent all parts of the outline equally, or to enhance (by 'over-representation' rather than weighting) different parts of the outline

(ii) transforming the raw data in some way (e.g. transforming each displacement into the angle subtended by it at the tip)

(iii) a combination of (i) and (ii)

In none of the scattergrams produced from the 1st and 2nd or 1st and 3rd Principal Components of any of the sets of data was any significant grouping noted, (see Fig. 5).

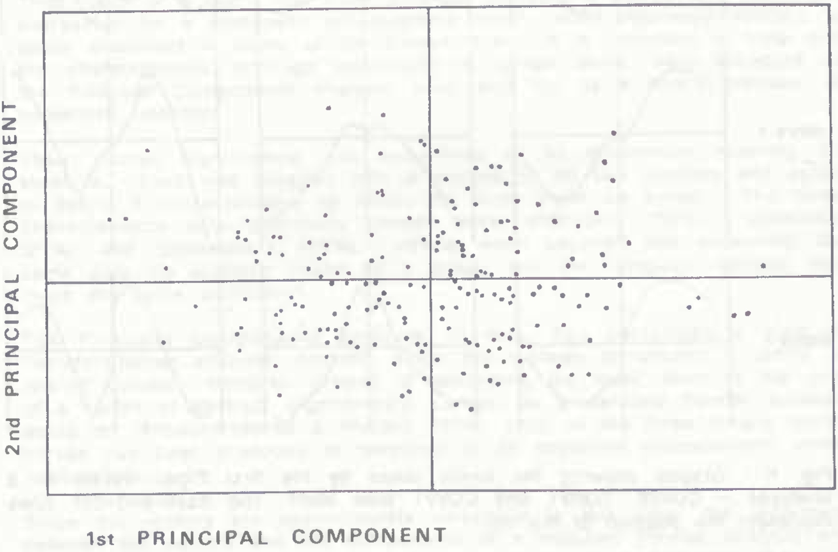

Fig. 5 : Scattergram showing the results of one of the Principal Components analyses. Values of Principal Component 1 ("Bulk") plotted against Principal Component 2 ("Handedness"). The crossed lines indicate the positions of the means.

However, in this case, the position of each case relative to the others, i.e. its principal component score, had been found by means of Eigen Vectors whose forms were explicitly expressed. The series of numbers in each Eigen Vector represents the contribution of each of the variables in the order in which they were presented. In more 'ordinary' circumstances, the contribution of any individual variable to a given component is thus easily found. In this case, however, since the variables were supplied in order round the tool, (anticlockwise, starting at bottom right), a graphical representation of the Eigen Vectors would serve to represent the contribution of the outline AS A WHOLE to each component. Fig. 6 gives a graphical representation of the first three Eigen Vectors for three examples of these analyses:

COVV8: Covariance-type analysis on variable set number 8 (i.e. 18 evenly distributed x-displacements transformed into the angle subtended by the displacement at the tip.)

COVV1: Covariance-type analysis on variable set number 1 (i.e. 20 evenly distributed x-displacements, untransformed).

CORV1: Correlation-Coefficient-type analysis on variable set number 1.

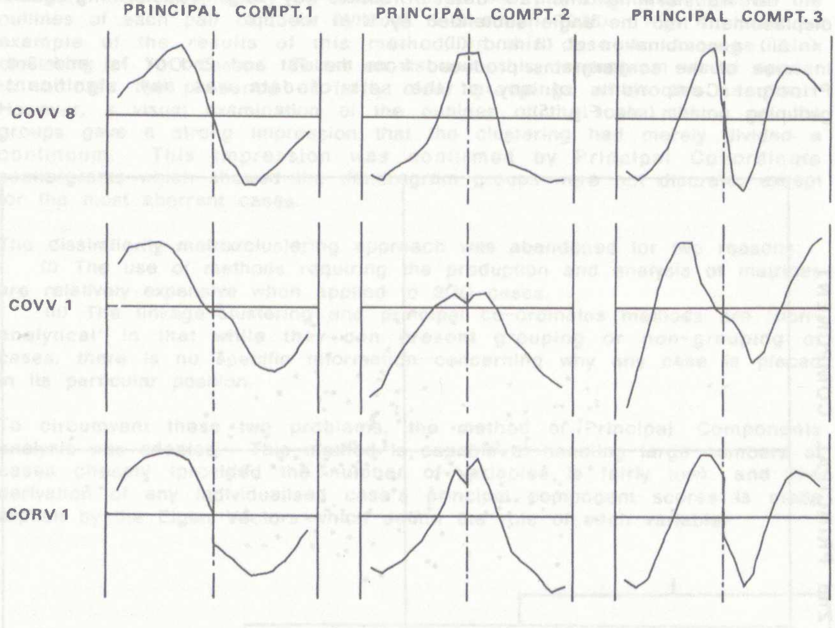

Fig. 6 : Graphs showing the forms taken by the first Eigen Vector in 3 analyses - COVV8, CORV1 and COVV1 (see text)). The dash-and-dot lines represent the position of the tip.

Taking the results of the analyses as a whole, there are three important points to note:

(i) The form of the first three principal component vectors was strikingly similar for all of the 8 sets of data (for both correlation and covariance analyses) apart from a few cases where the transformation was ill-advised (e.g taking the tangent of the displacement angle rather than the angle itself, leading to massive values near the tip!). Such small differences as there are can be explained in terms of the exact nature of the analysis or data-set.

(ii) By considering the contribution of the outline as a whole, the fact that the data do not consist of independant variables is circumvented conceptually. However, the non-independance manifests itself in the fourth and subsequent vectors which individually show no meaningful structure whatever

(iii) Most significantly, each of the three vector types represents a simple aspect of the tool outlines:

Principal Component 1: expresses, in general terms, the bulk of the tool. The x-displacements are positive before the tip and negative afterwards. Thus, a tool with displacements of generally high magnitute (i.e. 'bulky') will have a high score on component 1.

Principal Component 2: expresses the left- or right-'handedness' of the tool relative to the axis, (the axis being itself a product, largely, of the tip morphology). The symmetry of the curve means that symmetrical tools will have near zero scores, while asymmetrical ones will have positive or negative scores depending on the 'direction' of asymmetry.

Principal Component 3: expresses the relationship between the point and butt of the tool. Tools which do not narrow noticeably towards the tip have low (near zero) scores, while those whose points are much thinner than the butt have larger (negative) scores.

Thus, each of a tool's first three principal component scores is a numerical expression for a composite characteristic which, while rigorously defined, is easily visualised in terms of the overall form. It is important to note that the characteristics, although meaningful in human terms, were extracted by the Principal Components analysis itself and not by a direct process of subjective selection.

Their 'human significance' was underlined by an experiment involving 30 students. Each was supplied with a sample of 50 tool outlines and asked to define 2 characteristics by which the tools might be sorted. The three characteristics most commonly chosen were 'width/bulk' (32%), 'symmetry' (21%), and 'pointedness' (25%). Hence, when supplied with essentially the same data the students (taken as a group) and the computer reached very much the same conclusion.

The Principal Components analysis, in fact, had performed a kind of Pseudo-Fourier analysis, possible since the outlines constituted a family of related curves. However, instead of describing the tools' form as the sum of a series of abstract trigonometric curves, as a standard Fourier analysis would do (Allsworth-Jones & Wilcock 1974), each of the three simple vector curves has been produced in response to an important characteristic which it describes.

Since the vectors are approximately sinusoidal in this case, the difference between the vectors and the components of a standard Fourier analysis are perhaps not very obvious. However, it should be emphasised that the vectors have arisen in a totally different way, and their general form is the result of the roughly ellipsoidal form of the tools. Had they been, for example, roughly triangular or cruciform in shape, the vectors would have responded accordingly.

It follows from the nature of this sort of analysis, that we have a way of checking visually how meaningful our characteristic scores are (i.e. how fully they represent the form of the tools) by working backwards from the component scores and Eigen Vectors to produce a curve (i.e. shape), to be compared with the original. This will work in the case of vectors produced without normalising the data.

This 'reverse analysis' works as follows:

(i) Take the first three Eigen Vectors, dashed lines in Figs. 7(a) to (c), and multiply each by the appropriate component scores for the tool concerned to produce weighted curves (solid lines).

(ii) These three curves are summed, along with a mean weighted curve for the remaining vectors averaged over all the tools, see Fig. 7(d), to produce a resultant curve, the dashed line in Fig. 7(e). Here the vertical scale is twice the horizontal for clarity, so the solid line in Fig. 7(e) represents the proper shape which can be compared with the original, when rearranged around the axis, see Fig. 7(f).

Fig. 7 is based on the reverse analysis of the vectors from variable set 1, 20 points, evenly spaced, unmodified (see Fig. 6). The comparison of the

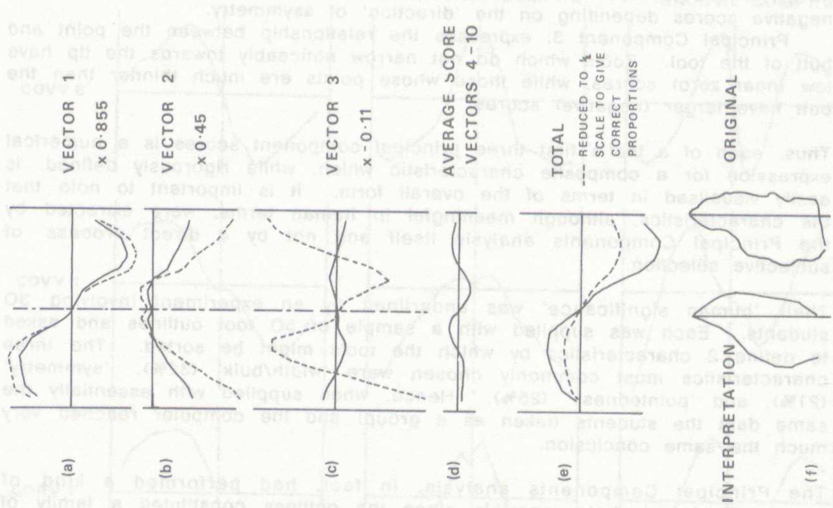

Fig. 7 : Vector additions to produce a shape for checking against the original (see text for explanation).

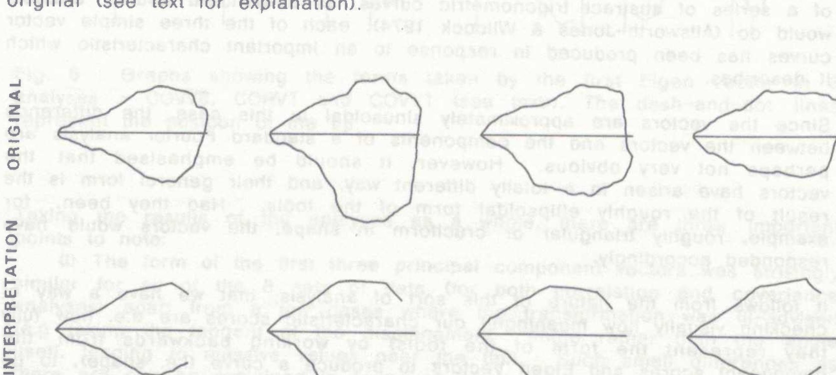

Fig. 8 : Four examples of comparison between the original drawing and the product of the reverse analysis. The reverse analysis in this case is based on the results of COVV8.

shapes produced with the original is not very satisfactory in this case, particularly in the tip region.

A better result (from the point of view of defining variability for a functional analysis), was obtained with variable set 8 (see above), which gave better emphasis to the tip area by slight changes in the vector forms (Fig. 8). Reverse analysis in this case produced shapes which better reproduced the tip area (Fig. 8).

The component scores produced from variable set 8 were thus chosen to ensure that the sample selected for micro-wear analysis was a good representation of the range of form.

Conclusion

By applying Principal Components analysis to sets of data made up of co-ordinates taken around the periphery of tools it was possible to obtain 'Pseudo-Fourier analyses' of their shapes.

These regularly emphasised the importance of three composite characteristics in defining the overall shape of the tools. From the vectors representing these characteristics and the component scores, it was possible to test the value of the characteristics visually by 'reverse analysis'.

It would appear that this general methodology may be an objective way to extract a small number of shape attributes of a type more sophisticated than, for example, length or width in order to describe sets of artefacts with related shapes. Artifacts are given numerical scores for the attributes which can then be used for scattergrams or other analyses.

It is unfortunate that only a limited number of vectors are of use while the remainder are 'garbled'. It might be possible in future to extract 'higher order' attributes by neutralising the 'lower order' ones, for example by normalising width as well as length.

In general terms, the use and development of this and other methods which extract shape elements in a rigorously defined, repeatable manner, and simply express the forms of individual items in terms of those elements, will provide useful tools for understanding the use and importance of shape in prehistory.

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