PALAEOLITHIC "LEAFPOINTS" - AN EXPERIMENT IN TAXONOMY

P. Allsworth Jones — University of Cambridge

J.D.Wilcock — Department of Computing, North Staffordshire Polytechnic

Abstract

The paper briefly describes a computer-assisted study of a collection of some seven hundred "leafpoints" from European Palaeolithic sites. The aim is to determine automatically the dominant types of leafpoint for each site and to discover similarities in the assemblages from different sites. The development of the methodology is fully described. The classification is objective and is based on quantitative parameters, viz. profile, size and thickness/width ratio. Results for one site only are expressed in terms of four types of computer-generated diagram: group planforms, dendrogram, scalogram and minimum spanning tree. The analysis of such a large body of data to this detail could not be contemplated without the aid of a computer. The archaeological interpretation based on the computer classification is summarised.

1. Archaeological Background

In recent years much attention in Palaeolithic studies has been devoted to the measurement of artefacts and to their description and classification in terms of those measurements. Handaxes in particular have been studied in this way by Roe (1964b) and Isaac (1968). It has been suggested (Hodson, 1971) that many other handaxe features could have been included in a quantitative description such as that used by Roe, for example the presence or absence of flake scars indicating soft or hard hammer technique, the quantity of cortex surviving on the finished implement, S-twist profile, and marked asymmetry. The inclusion of such data, while perhaps desirable, raises the problem of the combination in one analysis of continuous and discrete variables. Roe (1968) employed the means for the values obtained at certain sites as the basis of a site-to-site comparison and the distinguishing of certain handaxe groups in the British Lower and Middle Palaeolithic. Hodson (1971) has suggested that an alternative approach might be to take all the specimens from a given population without prior grouping by sites in order to see what clusters of handaxes are present throughout; a return might then be made to the sites to see what frequencies of the 'types' so defined occur in each place.

The present study concerns a group of artefacts which have suggested the use of a form of analysis cognate to that hitherto employed on handaxes. These are the so-called "leafpoints", or "Blattspitzen" of German authors. A useful definition of them was given by Obermaier and Wernert (1929), who said that a "leafpoint" was understood to be a more-or-less leaf-formed artefact of variable size, usually bifacially flat-retouched, double-pointed, and with a relatively thin cross-section. Not all artefacts included here are double-pointed, and the degree of bifacial retouch can vary markedly, but otherwise the definition can for the moment serve.

It is clear from this definition that in one important respect "leafpoints" tend to differ from West European handaxes in that they do not have the handaxe propensity to thicken at the base. This suggests that some of the ratios employed by Roe and Isaac might not be especially appropriate to their study and that a greater attention to the details of the planform might be taxonomically more significant. Moreover, the objects studied occupy a much shorter timespan than the Lower and Middle Palaeolithic handaxes, and the difference between them can be expected to be more subtle than those between, for example, Abbevillian handaxes and Mousterian "bout coupés". These considerations explain the approach adopted in this paper. A comparison of the main leafpoint assemblages on a site-to-site basis using mean measurements and ratios is being undertaken elsewhere.

Leafpoints were first found to characterise the Solutrean assemblages of the French Upper Palaeolithic. The Solutrean has been divided into chronologically distinct stages, and a number of subtypes of leafpoints have been defined (Smith, 1966), including the ambiguously-named "points à face plane" (Brézillon, 1968). Later leafpoints were discovered in Central Europe and at first there was a tendency to assume that they were connected in some way with the West European Solutrean. Since the publication of Freund's work (1952) and the appearance of some C14 dates appreciably older than those for the West European Solutrean there has been an equally pronounced tendency to suppose that the two areas are entirely independent. Freund argued for a close connection between the various Central European leafpoint groups and the preceding Middle Palaeolithic industries, thus elaborating a suggestion made by Breuil about Szeleta (1923).

The archaeological questions to be answered by the study concern (1) the nature and extent of the variability displayed amongst each other by the various leafpoint assemblages, and (2) the question of their possible origin in, or connection to preceding groups. There are accordingly what might be called "horizontal" and "vertical" aspects to be considered.

Freund emphasized both the great variability of forms among the Central European leafpoints and the fact that, despite overlaps, certain forms tended to dominate in the separate individual centres (1952, p. 281), and she took this as an indication of their multiple origins. She considered that whereas the variation in form displayed by the handaxes is generally linked to temporally successive stages, the leafpoint variations in form seem to signify local and regional peculiarities. Although handaxes were considered by her to be only one possible source for the leafpoints, nonetheless she said that corresponding series of leafpoint forms could be set against whole series of handaxe forms (1952, p.317). Among the local varieties, Zotz (1951) and Bárta (1960) emphasized the triangular forms excavated at Moravany-Dlha and called by Zotz the "Moravany type". Chmielewski (1961) emphasized the special characteristics of the leafpoints found at Nietoperzowa and used them as an argument to support his contention that there exists a separate group which he calls the Jerzmanowice culture. Kozlowski (1961, 1965) proposed an elaborate scheme for the division and subdivision of the Central European leafpoint industries, in which the Szeletian assemblages in particular are divided into a number of groups and facies. He supposed that the Ranis and Mauern sites, included by Freund in her "Presolutrean", show characteristics transitional between the Szeletian and Jerzmanowician entities. The division is based in part upon a study of the respective leafpoint shapes, including morphometrical criteria such as Breadth/length (B/L), thickness/breadth (th/B) and planform, which he used to propose a number of descriptive subtypes. The above approach has been criticised by Valoch (1968, in press), who emphasizes the great variety of leafpoints at individual sites, with for example "Dlha" forms at Neslovice and "Nietoperzowa" forms at Ondratice.

It is hoped that the approach outlined in this paper will serve to quantify and make exact the measurement and assessment of these affinities and differences. Results for Neslovice are presented in this paper. For reasons of space discussion is kept to a minimum; a more detailed paper incorporating also results from Nietoperzoa, Moravany-Dlha and Szeleta (Upper layer) is to appear in Science and Archaeology 11. The approach is intended to establish what dominant groups do exist within sites, and then to use these for inter-site comparison. Later, in the manner suggested by Hodson (1971), the whole population can perhaps be studied to see what groups emerge independent of site, and the extent to which these groups coincide with the established dominant groups for individual sites.

The "vertical" aspect of the problem is more difficult to approach in this manner, because the supposed links to the Middle Palaeolithic industries are often matters of typological nuance rather than the presence of defined forms. For certain handaxe industries, however, Freund has suggested rather direct parallels. The industries which will be considered later as part of this study are those from Klausennische (Obermaier and Wernert, 1929) and Rörshain (Bosinski, 1967; Luttropp and Bosinski, 1967), with a selection of handaxes from Wylotne (Chmielewski, 1969).

Two further points should be mentioned before turning to the methods of analysis:

(1) The approach eventually decided upon uses an estimation of the planform of each artefact, plus scale factor, plus th/B as a basis for comparisons. Several other metrical features were experimentally included and later discarded (see below). In addition, planform area and an estimate of the actual volume of stone in each artefact ("swept ellipsoidal

volume") were calculated for information, but not included in the comparisons. The complete mix gives almost as much information about the morphology of each piece as could be desired. Nonetheless it should be emphasized that qualitative attributes have not been included in the analysis. Some of these are important in an archaeologist's classification of stone artefacts; however, if they are to be included the problem of the combination of continuous and discrete attributes in one analysis immediately arises. Particularly important is the information as to whether the piece is made on a flake, blade or nodule, or whether the nature of the blank cannot be determined. Often it is those pieces which are on flakes or blades and which are only partially ventrally retouched which fall into the "Nietoperzowa" or so-called "pointe à face plane" class. Ideally this information should be included, but a good metrical approximation to this is made by the biconvexity measure which tends to assume certain marked values for these cross-sectionally asymmetrical pieces. Other features which could be included are presence/absence of cortex, raw material, and secondary alterations to the pieces.

(2) It would of course be naive to suppose that a classification of Stone Age industries can be based upon one artefact class alone, no matter how much that class has been employed for classificatory purposes in the past. The whole lithic inventory must be taken into account, particularly since it can be supposed that leafpoints are among those forms which most readily arise independently by convergence; and this is being done elsewhere.

2. Summary of Methodology

Numerical taxonomy as applied to artefacts concerns the attachment of numerical quantities to certain attributes, whereby the description of the artefacts may be made more objective. By calculating suitable similarity coefficients between pairs of objects based on these numerical quantities a classification may be constructed on objective criteria. The subjective judgement of the archaeologist will always have a place, however, and the computer classification is intended only as a guide to him, pointing out certain apparent similarities which he may have missed, as well as providing an estimate of distance between groups.

The generation of typologies and models has become very popular. The methods are of two main types: clustering and multidimensional scaling, portrayed respectively by dendrograms and scalograms. The presentation of results has been a neglected field; the present work aims to correct this, emphasizing as it does graphical output for interpretation by the archaeologist. Both the above-mentioned techniques for the generation of classifications have been employed in this analysis. Many clustering criteria have been devised by statisticians and mathematicians working with archaeologists. The only criterion which is rigorous in a mathematical sense is single-link clustering, where an object joins an existing group if it is judged sufficiently similar to any one object already in the group. The undesirable chaining properties of this method are well-known, and so far useful archaeological typologies have not in general been produced by it. The criterion employed in this study is the average-link criterion, where an object joins an existing group if it is judged sufficiently similar to the group mean. The weighted pair-group agglomerative algorithm has been employed. In this algorithm when a pair of groups join to form a larger group, the new group mean is calculated by weighting the properties of the constituent groups according to the number of objects in each group. The method is agglomerative in that it starts with all objects distinct and reports the agglomeration into larger groups until a single group is obtained. The stages of this agglomeration are conventionally portrayed by a dendrogram. One disadvantage of the method is that once an object enters a group it is trapped. It is true that the weighted pair-group method causes each artefact to join the most suitable group at the time of joining, but in the early stages groups are not well-developed and group means can change markedly during the analysis. Hence an artefact can join a group early in the analysis and, because the group means change, can find itself on the periphery of its group at the end of the analysis, perhaps nearer some other group mean. An algorithm which does not have this disadvantage is the k-means divisive method (Hodson, 1971), which allows objects to migrate to more suitable groups at any stage of the analysis. Plans have been made to use this method on the data in the future.

Because of lack of space the description of the methodology is restricted; the salient points in the development will be given here.

It was considered at the outset that Fourier analysis might be useful in the computer analysis of the artefact profiles. This method has not, as far as we are aware, been used elsewhere for this purpose. The outline of a planform is nothing more than an irregular closed curve. An internal point can be treated as the origin of polar co-ordinates, each point on the profile being defined by the corresponding length of the radius vector and the angle made with the positive x-axis of conventional Cartesian co-ordinates. The series of radius vector lengths can then be plotted against angles from 0° to 360°, providing one cycle of an irregular "waveform". Treating the waveform as periodic (i.e. repeated every cycle of 360°), it can then be submitted to Fourier analysis. The principle of Fourier analysis is to build up the irregular waveform from a series of harmonics, the first order (the fundamental) being at the same frequency as the irregular waveform, and subsequent orders at twice the frequency, three times the frequency, etc. Only the fundamental has large amplitude, and in subsequent orders the amplitudes rapidly decrease. The irregular nature of the waveform causes it to have both sine and cosine components which are 90° out of phase. The general shape of the artefact planforms is elliptical; this explains why they are amenable to Fourier analysis. The analysis is expressed in terms of coefficients. Theoretically the complete irregular outline can only be built up by an infinite number of orders, but in practice a good approximation to the shape can be constructed by the first few orders. Considerations of computer time make it important that the number of orders be reduced as far as possible, so the initial task was to experiment with the number of orders.

In practice the internal point chosen on which to pivot the radius vector was the centroid. Initially 100 orders were calculated for a trial set of data. It was found that the first five orders showed significant, though rapidly decreasing amplitudes. Remaining amplitudes were insignificant, so it was decided to analyse only to five orders on a routine basis. When higher orders are neglected in this manner, it is found that sharp points are rounded and irregular outlines smoothed out considerably. The method has the best success with symmetrical shapes. Once the coefficients have been calculated the original profile is compared with the calculated profile, and we find that large discrepancies occur only in the case of very sharp points and grossly asymmetrical planforms. Naturally the points are important functional parts of the tools, and any method which ignores them is useless to archaeologists. Accordingly, two discrepancy figures were recorded, one for the upper and one for the lower part of each profile. It was found that five orders taken together with the two discrepancy figures gave a good basis for similarity measures. The similarity calculation used the formula:

$$S_{ij} = 100 - \sum_{k=1}^{5} \left\{ \frac{((a_{ki} - a_{kj})^2 + (b_{ki} - b_{kj})^2)}{(a_{ki}^2 + b_{ki}^2)(a_{kj}^2 + b_{kj}^2)} \right\} - \sqrt{\frac{(d_{iu} - d_{ju})^2 + (d_{il} - d_{jl})^2}{2}}$$

where S_{ij} is the similarity coefficient between artefacts i and j,

a_{ki} is the kth order sine coefficient for the profile of artefact i,

b_{kj} is the kth order cosine coefficient for the profile of artefact j, etc.

d_{iu} is the upper discrepancy value for artefact i,

d_{jl} is the lower discrepancy value for artefact j, etc.

Division by the geometric mean of the power series is included to normalise the distances between corresponding coefficients of the two artefacts under comparison, so that the dominant magnitudes of the first order coefficients do not swamp the higher order coefficients. Indeed, much importance is to be attached to the higher order coefficients, since these express the divergences of the profiles from the basic elliptical shapes which would result if only the first order coefficients were considered.

The Fourier method required a large amount of storage for coefficients, and the run time is not negligible even for five orders; moreover it has some disadvantages from an archaeological point of view, especially the smoothing of sharp points. Hence

NESLOVICE PROJECTILE POINTS - PROFILE ONLY

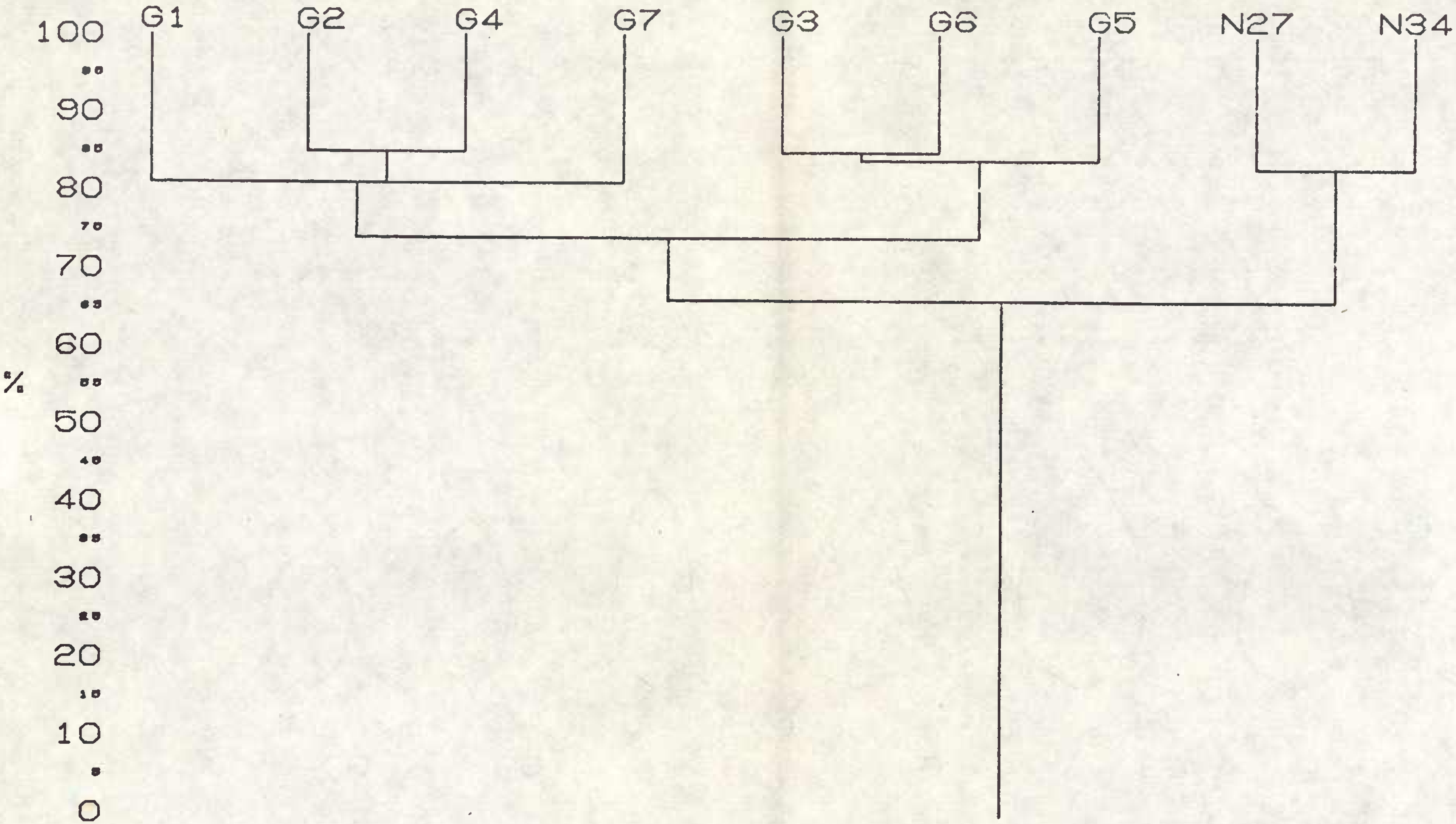

FIGURE 1.

NESLOVICE PROJECTILE POINTS - PROFILE ONLY

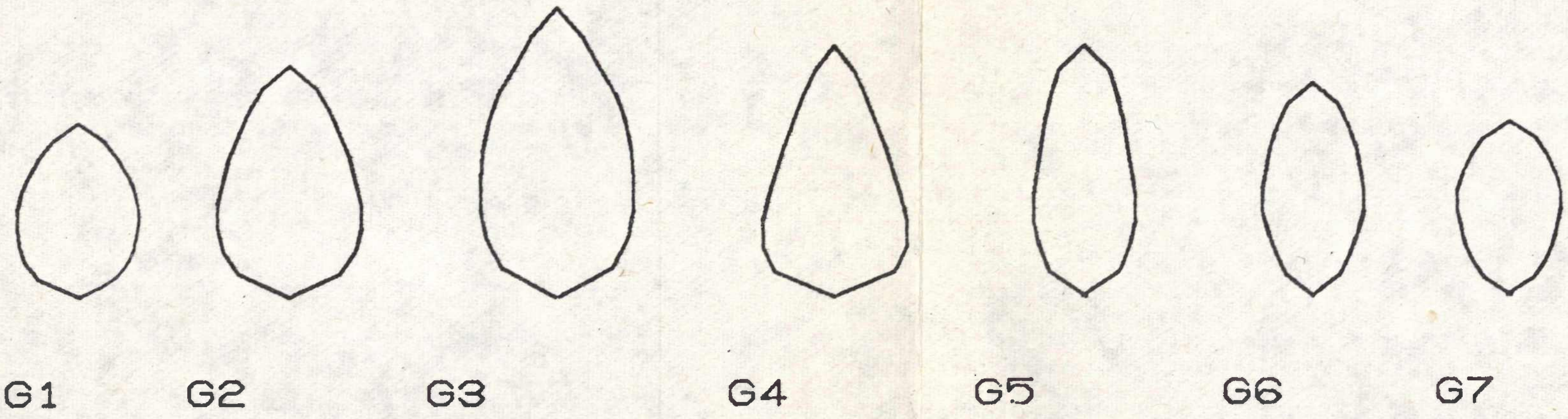

FIGURE 2.

it was also decided to investigate a simple "sliced" profile method where the breadths at distances 1/10, 1/5, 3/10, 2/5, 1/2, 3/5, 7/10, 4/5 and 9/10 of the length from the base are taken - this is an elaboration of Roe's two manual breadth measurements taken at 1/5 and 4/5 length from the base, computer analysis allowing much greater detail of the profile to be recorded. The similarity coefficients in this case were defined to be:

$$S_{ij} = 100 - \frac{100\sqrt{\left(\sum_{k=1}^{9} (b_{ki} - b_{kj})^2\right)/9}}{\text{MAX}\left\{\sqrt{\frac{\sum_{k=1}^{9} b_{ki}^2}{3}}, \sqrt{\frac{\sum_{k=1}^{9} b_{kj}^2}{3}}\right\}}$$

where S_{ij} is the similarity coefficient between artefacts i and j,

b_{ki} is the breadth at the kth slice for artefact i,
b_{kj} is the breadth at the kth slice for artefact j,

and division by the greater RMS breadth of artefacts i and j normalises the Euclidian distance between the two profiles.

Both profile methods are available in the software. Pilot runs on a fairly large body of data (Neslovice, 27 artefacts) were carried out in order to determine which profile method should be used on production runs, and which other quantitative factors should also be included from the selection:

a) scale
b) th/B
c) B/L
d) point of maximum breadth (PMB)
e) biconvexity

In the weighted pair-group agglomerative software written for this study, the mode of analysis can be any combination of:

i) profile, ii) scale, iii) others, including factors b - e above.

Accordingly, six pilot runs were completed as follows:

F1) Fourier profile only
F2) Fourier profile and scale
F3) Fourier profile, scale and others ("all")
S1) Sliced profile only
S2) Sliced profile and scale
S3) Sliced profile, scale and others ("all").

The groupings obtained for runs F1 and S1 did not show good correspondence. It is clear that the two profile methods emphasize different aspects of the profile; the Fourier method, truncates points (while compensating for this to some extent by the discrepancy figures) and it also records asymmetry; the sliced method assumes points are to be found at the top and bottom of the profile, and it averages the two sides of the profile, ignoring asymmetry. It would of course be possible to record asymmetric profiles for the two sides by the sliced method, and there are some stone artefacts for which this would be significant. The artefacts under study, however, are largely symmetrical. Since the Fourier method, besides truncating, does record asymmetry and the sliced method does not, the results will be different if profile only is considered as a basis for classification.

Runs F2 and S2 gave broadly similar results. It is clear that the newly-introduced factor, scale, is now dominant, although modified by profile graduations. The results are not altered much by changing the profile method, but for the reasons mentioned above it was decided finally to adopt the sliced method. An additional advantage is that with this method it is easier to calculate and draw the synthetic profiles for the groups. Thus, although Fourier is the far more elegant and interesting method, it loses on run time and ease of interpretation of results and was judged to be less appropriate for this study. Run F2 showed a weak similarity with run F1, and run S2 with S1, since they use the same profile methods.

Run F3 gave virtually identical results to run S3. Factors b - e above are now dominant, and profile and scale entirely swamped. Run F3 showed no comparison with F2, and S3 no comparison with S2. This is bad, since profile and scale are clearly the most important factors. Of the factors b - e it was decided that only th/B would be included in future analyses with equal weight to profile and scale (an alternative would be to reduce the weighting on all factors b - e).

Finally it was decided to have two types of run:

a) sliced profile only - to give shape information independent of scale and other factors;
b) sliced profile with scale and th/B.

These types of run have been used on several sites with useful results.

A detailed bibliography of the techniques used in the analysis will be given in the extended paper.

3. The Place of the Software within the PLUTARCH System

The PLUTARCH System is described elsewhere in this publication.

The statistics generating program and weighted pair-group agglomerative program form two separate segments within the STATISTICS section. The DIAGRAMS segment is used for finishing the graphic output for publication, which also includes the use of the LEGENDS segment for the generation of text in various fonts. An ALGOL 60 version of the Kruskal MDSCAL program is to be incorporated in the STATISTICS section. The range of diagrams supplied to the archaeologist for the interpretation of stone tool assemblages is described in the following section of this paper.

4. Consideration of Results

Following the initial heuristic experiments using data from

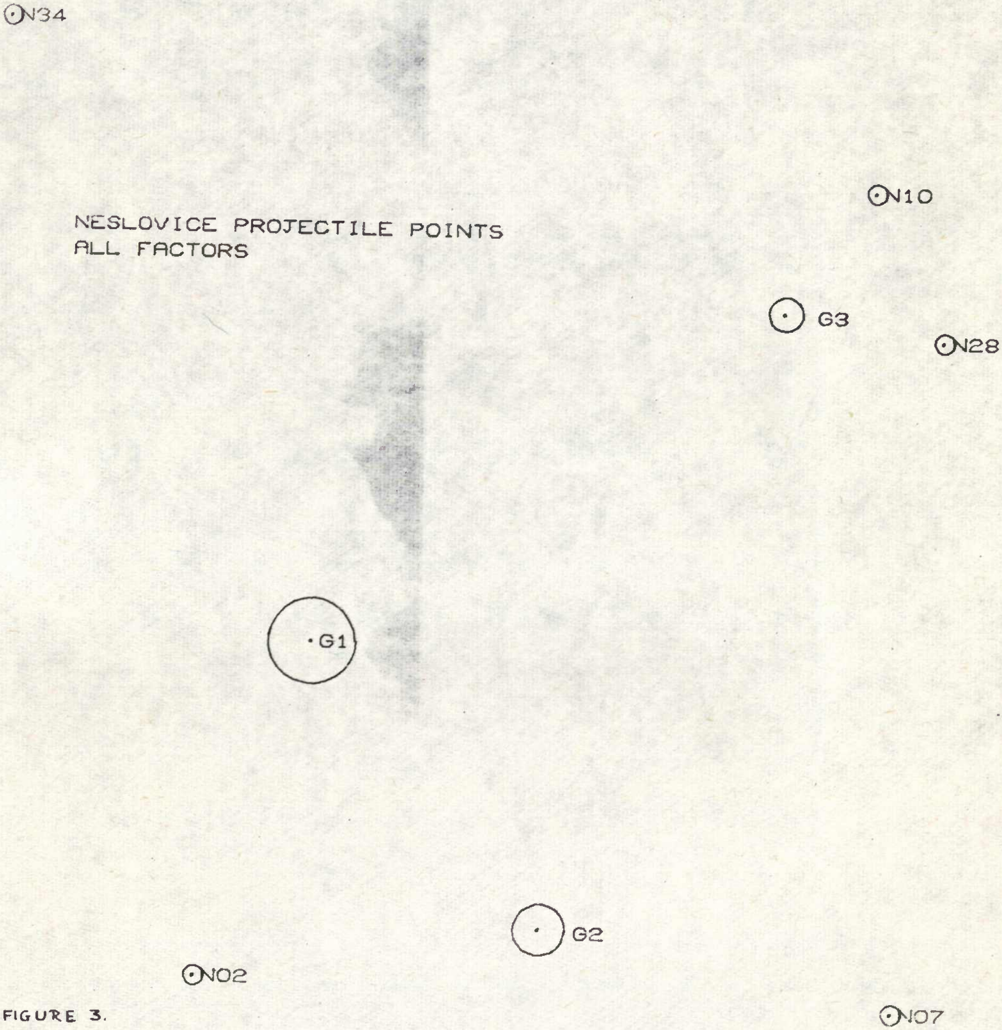
NESLOVICE PROJECTILE POINTS
ALL FACTORS
N34
N10
G3
N28
G1
G2
N02
N07

FIGURE 3.

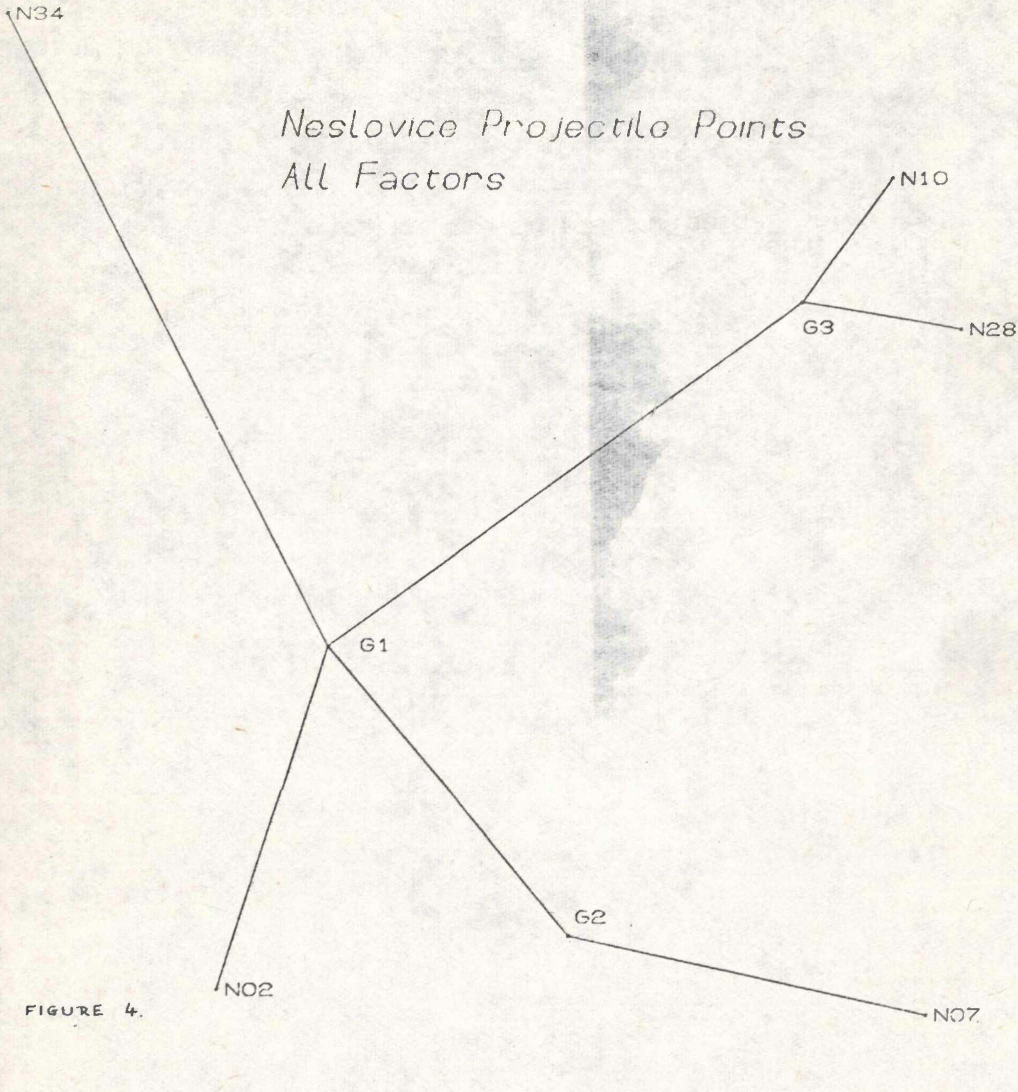
Neslovice Projectile Points
All Factors
N34
N10
G3
N28
G1
G2
N02
N07

FIGURE 4.

Neslovice, it was decided to analyse as a pilot run the four assemblages from Neslovice, Nietoperzowa, Moravany-Dlha and Szeleta (Upper layer). It seemed likely that this would quickly reveal and define the potentialities of the method. For reasons of space only the Neslovice results are presented here.

All sites were considered in terms of (a) profile only, and (b) profile, plus scale factor and th/B. Dendrograms expressing the results of the cluster analysis were produced for each site using both methods, and the characteristic planforms established for each group were plotted. As a starting point, "modules" of five in each group were requested, with the result that some groups containing closely similar pieces come out larger than this, while individual idiosyncratic artefacts still appear on their own. The similarity matrix calculated for all groups and remaining individual artefacts then forms the input for a multidimensional scaling analysis, the results of which are set out on scalograms, with group sizes and/or minimum spanning tree added as desired. It is sometimes instructive to indicate the major clusters of groups (derived from the dendrograms) as set by drawing encircling boundaries on the scalograms.

Figures 1 - 4 show four of the eight diagrams produced for Neslovice, which are particularly interesting when considered in conjunction with Moravany-Dlha. The profile-only dendrogram (Figure 1) and planforms (Figure 2) show a rather clear polycentricity. On the one hand, the analysis has revealed that groups G2 and G4 have analogies in corresponding Moravany-Dlha groups; this confirms the view that the "Moravany type" is by no means confined to that site. G1 is also not far removed in its planform from another Dlha group. On the other hand G6, clearly bipointed, has no analogy at Dlha. In the analysis by all factors, the number of groups is much reduced. The impression of polycentricity is even more marked; but the planforms reveal that the essential shapes have been retained. The same picture is evident on the scalograms (Figure 3, with arbitrary circles indicating relative group sizes; and Figure 4, with the minimum spanning tree). G3 contains triangular elements, with low th/B (0.27); NO7 is also a large and triangular piece, but the th/B value is 0.67, and as often with these thicker pieces it has retained some cortex. G2 contains massive elongated pieces with a tendency to bipointedness. G1 is numerically dominant and represents a smaller-sized type, the synthetic average of a number of "intermediate" forms.

It is hoped that this brief study has been enough to indicate the potentialities of the method. Comparison by profile alone can yield interesting conclusions, but in general it seems likely that comparisons by all the factors are more realistic and more fruitful. Among the 4 assemblages studied some have emerged as more homogenous than others; and it is clear that with those homogenous assemblages which are closely packed around a given parameter or parameters the real taxonomic differences will emerge in the inter-assemblage comparisons which will be the next stage in the exercise.

Acknowledgments

We would like to thank the following for permission to study and measure the artefacts of the four sites mentioned: Professor W. Chmielewski; Dr. J. Barta, and the authorities of the Piešt'any Museum; Dr. K. Valoch, Mr. J. Mikulášek, and the authorities of the National Museum, Prague; the authorities of the Hungarian National Museum; and the authorities of the Miskolc Museum.

References

Barta, J. 1960 — K Problemu listovitych hrotov typu Moravany-Dlha Slovenska Archeologia 8(2), 295-324

Bosinski, G. 1967 — Die Mittelpaläolithischen Funde im Westlichen Mitteleuropa

Breuil, H. 1923 — Notes de voyage Paléolithique en Europe centrale I. les industries Paléolithiques en Hongrie L'Anthropologie 33, 323-346.

Brézillon, M.N. 1968 — La dénomination des objets to pierre taillée Gallia-Préhistoire IV supplément

Chmielewski, W. 1961 — Civilisation de Jerzmanowice

Chmielewski, W. 1969 — Ensembles Micoquo-Prondnikiens en Europe centrale Geographia Polonica 17, 371-386.

Freund, G. 1952 — Die Blattspitzen des Paläolithikums in Europa Quartär Bibliothek, Band I

Hodson, F.R. 1971 — Numerical Typology and prehistoric archaeology in Hodson, F.R., Kendal, D.G. and Tautu, P.(eds), 1971 Mathematics in the archaeological and historical sciences Edinburgh University Press, Edinburgh 30-45.

Isaac, G.L. 1968 — The Acheulian site complex at Olorgesailie, Kenya: a contribution to the interpretation of Middle Pleistocene culture in East Africa Unpublished Ph.D thesis, University of Cambridge

Kozlowski, J.K. 1961 — Proba klasyfikacji gornopaleolitycznych przemyslow z ploszczami lisciowatymi W. Europie. (Essai de classification des industries à pointes foliacées du Paléolithique supérior Européen) Zeszyty Naukowe Uniwersytetu Jagiellonskiego Rozprawy i Studia 31

Kozlowski, J.K. 1965 — Studia nad zroznicowaniem Kulturowym w paleolicie gornym Europie Srodkowej. (Études sur la differentiation de la culture dans le Paléolithique supérior de l'Europe centrale) Prace archeologiczne 7

Luttropp, A. & Bosinski, G. 1967	Rörshain Kreis Ziegenhain Fundberichte aus Hessen 7, 13-18
Obermaier, H. & Wernert, P. 1929	Alt-Palëolithikum mit Blatt-Typen. Mitteilungen der Anthropologischen Gesellschaft in Wien 59, 293-310
Roe, D.A. 1964	The British Lower and Middle Palaeolithic: some problems, methods of study and preliminary results Proc. Prehist. Soc. 30, 245-267
Roe, D.A. 1968	British Lower and Middle Palaeolithic handaxe groups Proc. Prehist. Soc. 34, 1-82
Smith, P.E.L. 1966	Le Solutréen en France
Valoch, K. 1968	Evolution of the Palaeolithic in Central and Eastern Europe Current Anthropology 9 (5), 351-390
Valoch, K. in press	Neslovice, eine bedeutende oberflächenfundstelle des Szeletiens in Mahren Casopis Moravskeho Muzea
Zotz, L.F.	Altsteinzeitkunde Mitteleuropas