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Multivariate methods for the classification of Lower and Middle Palaeolithic stone inventories

Thomas Weber

Landesamt für archäologische Denkmalpflege Sachsen-Anhalt,
Richard-Wagner-Str. 9/10, D-06114 Halle (Saale) GERMANY

18.1 Introduction

The use of multivariate statistics is very common for the classification of lithic assemblages – especially with regard to the different (relative) frequencies of certain tool types from the Older Palaeolithic periods. Sometimes the type list developed by D. de Sonneville-Bordes or more restricted ones have been used not only for creating the senseless type of cumulative frequency diagrams but also for quite sophisticated factorial analyses, etc. (e.g. Doluchanov, Kozlowski & Kozlowski 1980). In Lower Palaeolithic studies, Stiles (1980) has investigated the African Oldowan and Acheulian. More recently, Kind (1992) attempted to classify South German Middle Palaeolithic assemblages using cluster and correspondence analysis of the tool-kits.

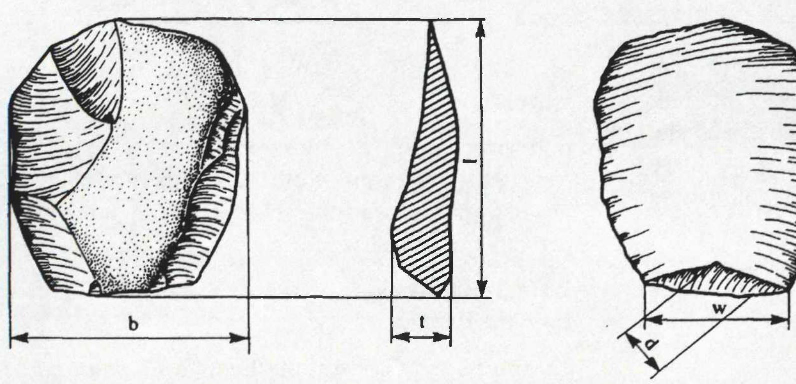
It has widely been accepted, however, that finished tools do not give us sufficient information about the stages of development of a certain inventory, even in the Earlier Palaeolithic periods with their low-standardised tool forms which unlike Upper Palaeolithic implements can hardly be classified in well-defined types. We may include sources for all stages of 'man-stone relationship' from the raw material selection through blank production up to tool modification and use. Flakes in particular, as the most numerous artefact category, can serve as technological indicators for the classification of an assemblage in a certain technocomplex – an archaeological entity limited in time and space.

How should flakes be investigated? Generally, flakes cannot be classified *a priori* as primary, secondary, modification, resharpening flakes or blanks for tool production. There is a broad overlap between attributes on pieces for all these purposes.

At least four groups of features should be studied (Figure 18.1):

1. Absolute measurements, like length (l), breadth (b), and thickness (t) (measured in flaking direction), and width (w) and depth (d) of the striking platform, are primarily dependent on raw material size. Form quotients, however, like length-breadth ratio, relative thickness index (calculated by thickness * 100 per mean of length and breadth) and striking platform's width-depth ratio, show clear technological affinities.
2. The state of the striking platform (cortex, negatives, faceted etc.) and its form may give us technological indications representing core preparation techniques (Weber 1986).
3. The number and diameters of flaking eyes and the flaking angle between platform and proximal part of the ventral face can be seen as a result of the hammerstone's impact.

The dorsal working traces (number of negatives, portion of worked surface, number of flaking directions, presence of a dorsal reduction) show the degree of core removal.



$l = 84mm,\ b = 72mm,\ d = 18mm,$
$w = 45mm,\ t = 15mm$

$$LBI = \frac{l}{b} = \frac{84}{72} = 1.14$$

$$RTI = 200\frac{d}{(l + b)} = 200\frac{18}{(84 + 72)} = 23.08$$

$$WDI = \frac{w}{t} = \frac{45}{15} = 3.00$$

$NSFR = 1 \qquad \angle = 140^{\circ} \qquad \%d = 5$

Figure 18.1: 'Ideal' flake showing the most important features investigated including measurements of the piece (l, b, and t) , the striking platform, the flaking angle, and characteristics of the striking platform and the dorsal face.

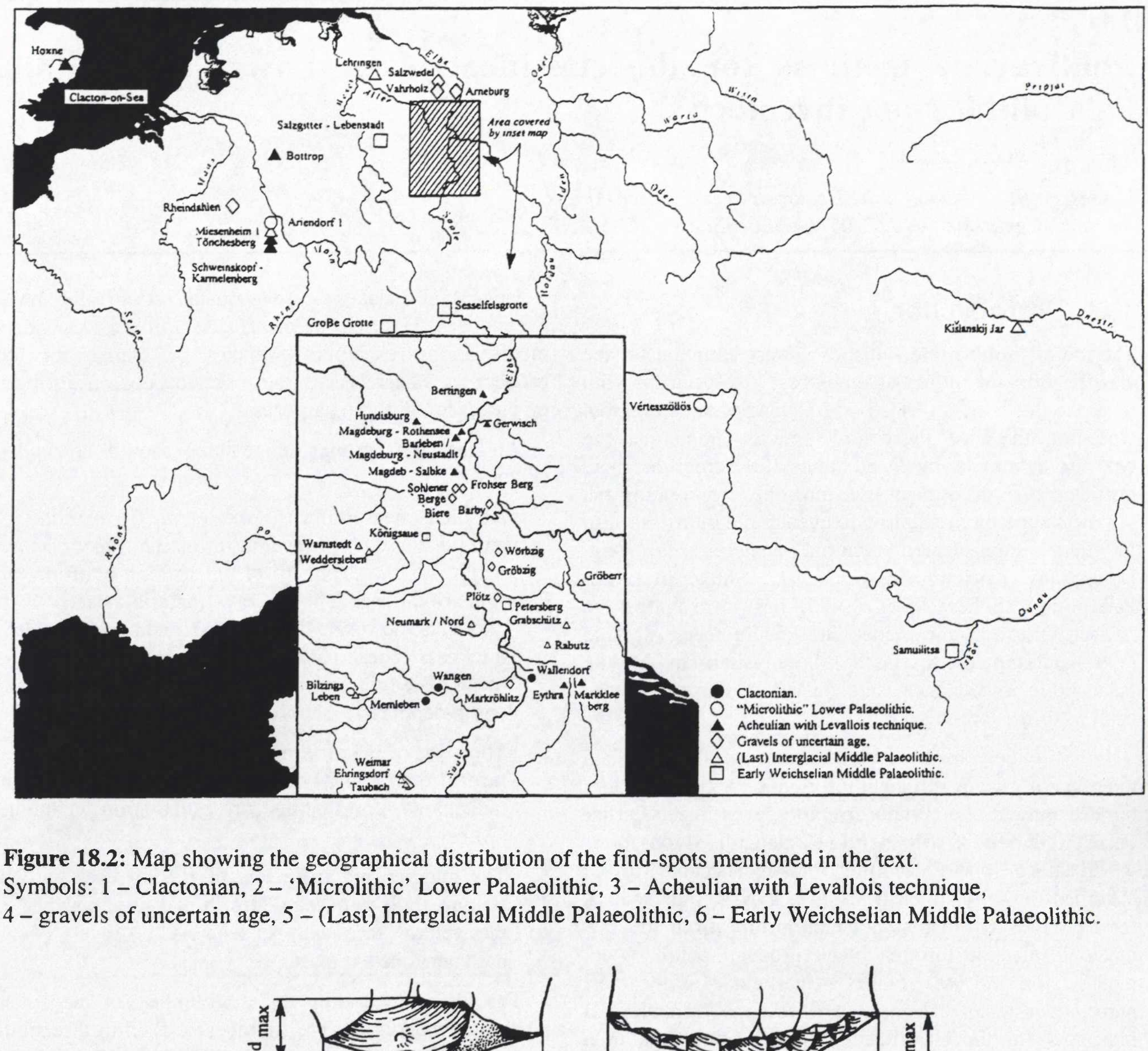


Figure 18.2: Map showing the geographical distribution of the find-spots mentioned in the text. Symbols: 1 – Clactonian, 2 – 'Microlithic' Lower Palaeolithic, 3 – Acheulian with Levallois technique, 4 – gravels of uncertain age, 5 – (Last) Interglacial Middle Palaeolithic, 6 – Early Weichselian Middle Palaeolithic.

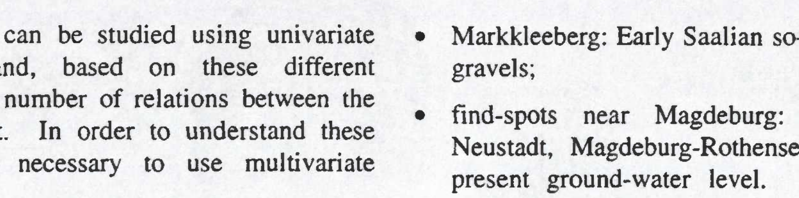


Figure 18.3: Examples of striking platform conditions: (one) negative together with cortex (left) and facetted (right).

All these attributes can be studied using univariate statistical methods, and, based on these different characteristics, a large number of relations between the assemblages will result. In order to understand these relations better, it is necessary to use multivariate techniques.

Only a few examples can be given here of the use of multivariate analyses studying Older Palaeolithic assemblages (Figure 18.2). These include:

- Wallendorf: artefacts from a Middle Pleistocene gravel;
- Bilzingsleben: a Holsteinian travertine complex with *Homo erectus* finds;
- Markkleeberg: Early Saalian so-called 'Mean Terrace' gravels;
- find-spots near Magdeburg: Barleben/Magdeburg-Neustadt, Magdeburg-Rothensee: gravels below the present ground-water level. Difficult to date but perhaps Early Saalian;
- Weimar-Ehringsdorf: travertine complex probably from the Eemian;
- Lehringen and Gröbern: the Eemian *Elephas antiquus* killing and butchering sites;

Königsaue: the Early Weichselian finds from liminic shore sediments of the former Aschersleben lake some 50 km north-west from Halle. (Weber 1991; Schäfer 1994).

	Condition									
Inventory	0	1	2	3	4	5	6	7	8	n
Bi2	0	16	62	1	2	1	0	2	10	211
E	245	41	100	138	8	4	4	17	215	772
W	229	61	65	53	13	4	0	8	103	536
T	106	57	98	60	10	5	1	10	48	395
R	29	7	26	13	3	3	1	6	14	102
KA	23	15	35	52	8	1	0	5	131	270
KB	73	6	173	112	10	5	0	43	70	492
KC	11	3	59	51	1	1	0	14	46	186

Table 18.1: Frequencies of the different platform conditions in Middle Palaeolithic flint flake inventories

Symbols: 0 – unclear, 1 – with primary surface, 2 – with negatives, 3 – with prepared edge (facetted), 4 – with primary surface and with negatives, 5 – with primary surface and with prepared edge, 6 – with primary surface, negatives and with prepared edge, 7 – with negatives and with prepared edge, 8 – destroyed, edged, pointed.

Abbreviations: Bi2 – Bilzingsleben 2; E – Weimar-Ehringsdorf; W – Weimar Belvédèrer Allee; T – Taubach; R – Rabutz; KA, KB, KC – Königsaue A, B, C.

For the calculations the attributes 2 and 4; 3, 5, 6, 7 resp. were taken together as 'with negatives', resp. 'facetted'

Inventory	E	W	T	R	KA	KB	KC
Ehringsdorf	200	160	152	162	154	131	134
Weimar	160	200	154	148	120	112	106
Taubach	152	154	200	186	126	150	134
Rabutz	162	148	186	200	130	162	146
Königsaue A	154	120	126	130	200	126	138
Königsaue B	131	112	150	162	122	200	174
Königsaue C	134	106	134	146	138	174	200

Table 18.2: ROBINSON's indices of agreement (rounded at whole percentages) for platform condition frequencies of the Eemian and Early Weichselian flake inventories

The assemblages survived under quite different conditions in fluviatile or limnic sediments, in autochthone or allochthone contexts and have been discovered and investigated by different people over a long period of time using different archaeological methods. They are comparable, however, in respect of different technological data.

18.2 A Middle Palaeolithic Case Study

Several Middle Palaeolithic assemblages were examined in the first analysis:

- **Bilzingsleben 2:** surface finds from the neighbourhood of the known Middle Pleistocene Homo-erectus site (Weber & Mania 1982). Geologically, the amteral cannot be dated (the artefacts are situated immediately on the Mesozoic Keuper surface). Based on weathering, it was possible to identify a number of Pre-Last-Interglacial specimens.
- **Weimar-Belvédèrer Allee:** an Eemian travertine along the Ilm valley, with artefact finds made in the early 20th century (Schäfer 1994).
- **Weimar-Ehringsdorf:** a travertine complex probably of Eemian age, with different areas containing archaeological and palaeontological material including human remains. Most of the finds come from the so-called Lower Travertine (Schäfer 1994).
- **Taubach:** (near Weimar) a travertine quarry near the Ilm valley, synchronised with the Eemian period. All the Ilm valley finds analysed here are part of the Landesmuseum Halle collections and were found in the early 20th century by H. Hahne and his local collaborators (Schäfer 1994).
- **Rabutz:** between Halle and Leipzig, a limnic sequence (Eemian). Artefacts were discovered between 1907 and 1920, with excavations taking place in 1914 and 1920 (Schäfer 1994).
- **Königsaue:** 50 km north-west from Halle (Figure 18.4). In the open-cast intersecting the former Aschersleben lake with its sediments from the last interglacial (Eemian) up to the Holocene, numerous interstadial sediments were found by Dietrich Mania between 1963 and 1965 (Mania & Toepfer 1973). In the second Weichselian interstadial (Odderade) Mania found three archaeological 'events' represented by faunal, floral remains and artefacts from the zone near the former lake shore. The first and third (Königsaue 'A' and 'C') are seen as 'Micoquian' assemblages with several face-retouched bifacial tools ('Keilmesser'). The second has been interpreted as an 'unspecified

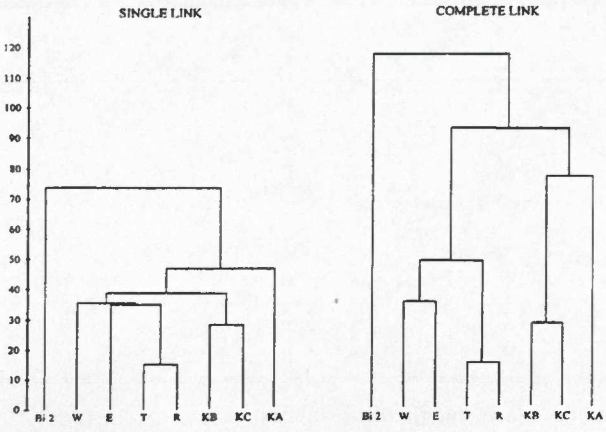


Figure 18.4: Cluster analysis: Dendrogram structures of Eemian and Early Weichselian flint flake inventories: platform conditions. For the abbreviations, see Table 18.1.

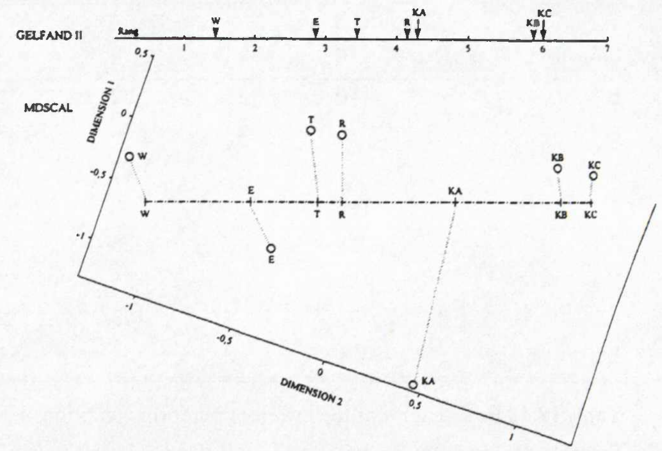


Figure 18.5: GELFAND-II-Seriation and Multidimensional scaling: The figures shows the rank sequence of the inventories ordered by the GELFAND-II-seriation method (on the top) and a multidimensional scaling plot of the the solutions in one and two dimensions (on the bottom). For the abbreviations, see Table 18.1.

Mousterian' with an evolved disc core flaking. To exclude functional bias by bifacial tool resharpening, the Königsaue B inventory was selected here.

Among the attributes studied using multivariate techniques, the condition of the striking platform (Figure 18.3) is one of the most interesting features and we have analysed it using different methods. Generally, ten kinds of striking platforms may be distinguished:

0. uncertain,
1. with primary (cortical or moraine) surface,
2. with negative(s),
3. with special preparation (faceted),
4. with primary surface and with negative(s),
5. with primary surface and faceted,
6. with primary surface, with negative(s), and faceted,
7. with negative(s), and faceted,
8. destroyed, pointed, or as a sharp edge,
9. destroyed, and with primary surface.

Sometimes, 2 and 4, and 3, 5, 6, and 7 had been taken together and described as 'with negatives' or 'faceted', representing the most evolved state of the platform of the pieces. 0, 8 and 9 are sometimes excluded as these categories do not give us clear information about the platforms of the cores from which the flakes are struck.

All the inventories may be observed with regard to the (relative) frequencies for these platform conditions as shown in Table 18.1. The results may be compared using different mathematical techniques.

18.2.1 Cluster Analysis

Cluster analysis is frequently used, and the most common techniques of nearest neighbour (single linkage) and furthest neighbour (complete linkage) are given here (Figure 18.4). The dendrogram structures are nearly identical with, naturally, larger distances between the groups in the case of the complete linkage. In both cases, the position of Bi2 is an isolated one, and later it was found that we had in fact included an artificial assemblage consisting of surface finds possibly from the weathered Middle Pleistocene travertine complex or from a younger period in the Middle or Early Upper Palaeolithic (Weber & Mania 1982; Schäfer 1988). Using single linkage, we find KA in a more or less isolated position, too, whereas complete linkage is clearly distinguishing between the two periods, Eemian and Early Weichselian. Perhaps this is due to the 'linking effect' connecting KA with E or whether or not E is 'engaged', since, on the other hand, there is a smaller distance from KA to the other Early Weichselian sites (126: KB) than from KA to the Eemian inventories (120: W) – see Table 18.2. To find large groups and even to exclude the linking effects, the complete linkage seems to be a more convenient method than the single linkage.

18.2.2 Seriation

A. E. Gelfand (1971) has described seriation methods for archaeologists, including the uni-dimensional ordering of a matrix containing Robinson's indices of agreement. This value is given by the formula:

$$I(A) = 200 - \sum_{i,j=1}^{m} |x(ik) - x(jk)|$$

where

m = the number of attributes (percentages)

i, j = the inventories
x = the percentage itself.

Thus values near 200 represent small distances between the percentages for the different types in the assemblages, with values near 0 representing very large differences. The matrix of Robinson's indices of agreement, therefore, forms a similarity matrix with the highest value for the pair of individual inventories with the smallest difference and with the lowest for the two most distinct assemblages among all the relative frequencies observed as a whole. The rows were ordered later in accordance with the similarity of inventories (beginning with the most similar pair in each row, followed by the second, etc.) and the ranks produced in this manner were added together for each assemblage (and, in this case, divided by the number of inventories to provide a better overview).

Some years ago, we demonstrated how this method can be used for the example of the relative frequencies of platform conditions in the Middle Palaeolithic inventories (Weber & Schäfer 1987). Here only the matrix of the indices (Table 18.2) and the result (Figure 18.5) are given.

Compared with the cluster analysis, the Gelfand-II seriation produces a very similar picture. Interestingly KA has changed its position from being an outlier to one in the neighbourhood of Rabutz (and thus the three Eemian assemblages from Königsaue appear in chronological order). In fact, the mean of KA (132.5 % - see Table 18.2) makes it a little more distant from the Eemian inventories than KB (138.75 %). This contradiction can be explained since the Gelfand-II picture is formed using rank sizes and the values on this line are actually showing average rank values (following the order of neighbourhoods in the rows).

18.2.3 Multidimensional Scaling

Multidimensional scaling is one way to avoid this problem. Using metric scaling (Schwarz & Weber 1987, 55–56), we have for the one-dimensional solution the sequence given in the centre of the bottom part in Figure 18.5. Generally the sequence was the same, although distances on this line were different. In particular, the distance between Rabutz and Königsaue A seems to be more reliable than in the Gelfand-II seriation plot. It should not be forgotten, however, that in spite of the uni-dimensional picture with a linear configuration of the inventories, all the distances observed for each possible pair of the individuals are included in the calculations. In this light, Ehringsdorf's distance to Weimar in the diagram is greater than that to Taubach (but in fact is smaller – see Table 18.2). Similarly, Weimar's generally quite isolated position (with an average index of 133.33%) and the large dissimilarity (in the diagram) between R and KB, for example, can only be understood in terms of the Weimar Königsaue heterogeneity (average 112.67).

In general, there is a stress (or falsification of the result) of 0.3577 - in other words, an average error for the distances between the assemblages of nearly 36%. From an interpretative point of view, such a degree of falsification can hardly be accepted. It may therefore be necessary to include a second dimension, resulting in a two-dimensional diagram (here circumscribed around the bottom part of Figure 18.5).

Using this two-dimensional representation, we can explain why Königsaue A's position is so 'stressed' in the uni-dimensional plot. This variation can be shown to a remarkable degree using the second dimension, and KA can be seen to be the furthest point from constructed common line of the one-dimensional solution, with other find-spots with smaller deviations drawn in the same direction (Ehringsdorf) or in the opposite direction (the other assemblages). It is difficult to understand the reason for Ehringsdorf's and Königsaue A's 'special behaviour'. This is a purely archaeological, not a mathematical, problem. Studying the input data (Table 18.1), reveals a number of distinctions and similarities. Perhaps the most striking features are the extraordinarily high percentages for destroyed/edged/pointed pieces in KA (with E in second position overall) and the corresponding values for primary, negative and faceted pieces. The stress is a 'fine' low value of 0.1284 so that we may argue that the 'real' configuration may be described with two dimensions. The similarities, perhaps, may correspond to a relatively high importance of face-retouched tools on these sites.

For the explanation of the MDS results it is useful to examine the similarities and dissimilarities in the input data: MDS provides a way to show where we have to look for these characteristics. This may not be difficult in a small example such as I have given here but it can also be helpful if we enlarge the number of points included. When additional assemblages are included, the configuration changes, but the 'old' picture can be seen as a special part of the new one (compare the two parts of Figure 18.6) – in this case with a decreased stress value of 0.0967 (Weber 1990).

This 'Central German Middle Palaeolithic area' can be found in the right half of the right hand diagram (Figure 18.6), together with the material introduced from the Petersberg. In the light of all the other finds also observed here the Eemian-Weichselian dichotomy (in the left hand diagram, Figure 18.6) should be seen as a special case, and several distances between these two periods are reduced (for example, between KA and E). In the central part of the plot the Lower Palaeolithic assemblages are very concentrated – Clactonian, Bilzingsleben and Vértesszöllös, in spite of the huge differences in terms of the amount of raw material. Acheulian finds – here only represented by the two assemblages Markkleeberg 1 and Hundisburg (and perhaps by the 'Acheulian-like' Kislanskij Jar of possible 'Rissian' age) – are distributed around the Lower Palaeolithic: M1 may show the special production of a flint knapping site. If we include further inventories and further attributes the picture should became clearer and we may be able to recognise the typical characteristics of the different technocomplexes.

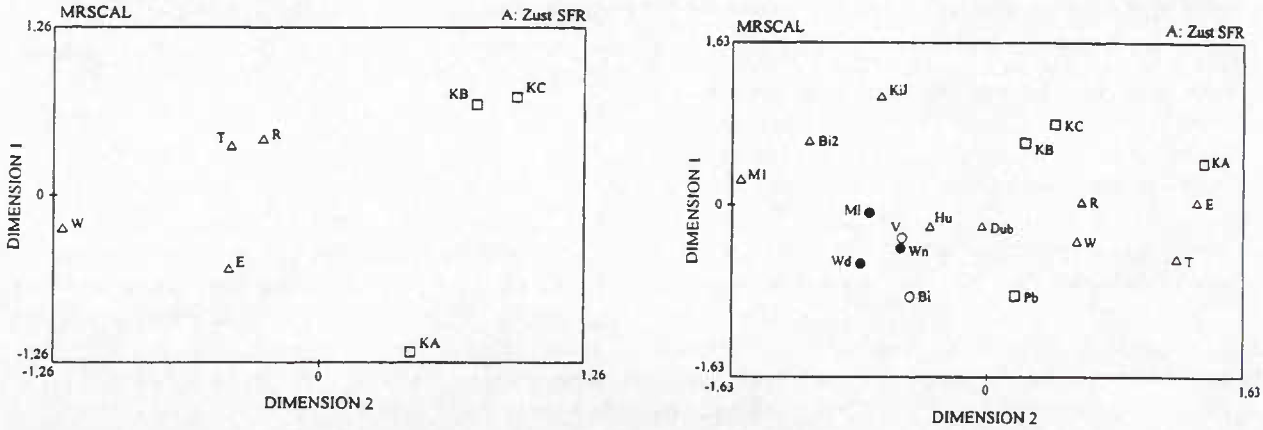


Figure 18.6: Multidimensional scaling of platform conditions in Lower and Middle Palaeolithic flint flake inventories (metric scaling). Left: Only Eemian and Weichselian finds. For the abbreviations, see Table 18.1. Right: Including Clactonian (filled circles), Lower Palaeolithic (open circles), Acheulian (filled triangles) inventories. Further abbreviations: Bi – Bilzingsleben, Dub – Dubossary, Hu – Hundisburg, KiJ – Kislanskij Jar, M1 – Markkleeberg 1, Ml – Memleben, Pb – Petersberg, V – Vértesszöllös, Wd – Wallendorf, Wn – Wangen.

18.3 Large-Scale Palaeolithic Case Studies

18.3.1 Multidimensional Scaling

The way ahead can be illustrated with a final example of an MDS based on a larger number of features found to be highly separable in uni- and bivariate investigations (Schäfer 1994). As in this paper, the arithmetic means of the length-breadth, the relative thickness, the width-depth index, the flaking angle, of the dorsal worked surface percentage, and the number of dorsal negatives, were recorded, together with the relative variabilities of these two last features and also the relative frequencies of platforms with unknown, primary-, negative-, faceted and edged/pointed conditions and further relative frequencies of flakes of only primary, only secondary, and primary and secondary dorsal surface. A certain degree of redundancy is to be expected, but all the important characteristics of the Lower and Middle Palaeolithic flaking techniques are included.

The results can be seen in Figure 18.7: in the left part we find the Lower Palaeolithic (including the Clacton-on-Sea assemblage), followed by the (Saalian) Acheulian with Levallois technique (including the material from Hoxne). The third cluster containing Eemian and Weichselian finds do not show a clear separation but the 'most archaic' (Eemian) material from Weimar is to the left and a possibly 'evolved' (Weichselian) inventory (Pb) to the right. All the assemblages are synchronised with the Upper Pleistocene, although a Saalian date is under discussion for Rheindahlen B3.

18.3.2 Canonical Discriminant Analysis

A further attempt has been undertaken to discriminate the Older Palaeolithic technocomplexes based on comparisons between the inventories using the same features: Very small assemblages have been excluded here: the ones remaining contain at least 25, and most more than 50 pieces. All the assemblages included here were classified *a priori*, with the exception of Salzgitter-Lebenstedt. Three groups have been distinguished:

- Lower Palaeolithic (Clactonian, 'Microlithic Lower Palaeolithic'),
- Acheulian with Levallois technique, and
- Middle Palaeolithic *sensu stricto* (Eemian and Early Weichselian Middle Palaeolithic).

D. Schäfer obtained two complex canonical discriminant functions (using the SPSS PC+ procedure DISCRIMINANT) combined by a number of different variables:

- the mean percentage of dorsal worked surface,
- the percentage of pieces: dorsal face only with negatives,
- the percentage of pieces: dorsal face with negatives and cortex,
- the percentage of pieces: platform only with cortex,
- the percentage of pieces: dorsal face only with cortex,
- the flaking angle,
- the percentage of pieces: platform faceted,
- the percentage of pieces: platform only with negatives.

(The attributes' contribution for the complex discrimination is represented by the order of the above list.)

In the result, the diagram of the first two canonical discriminant functions (representing 90.84 and 9.16% of the whole variance) shows the same three clearly separated clusters of Lower Palaeolithic, Acheulian, and Middle Palaeolithic assemblages (Figure 18.8). Two inventories from Rheindahlen, from which at least Rheindahlen B 3 is dated to the Saalian, form parts of the

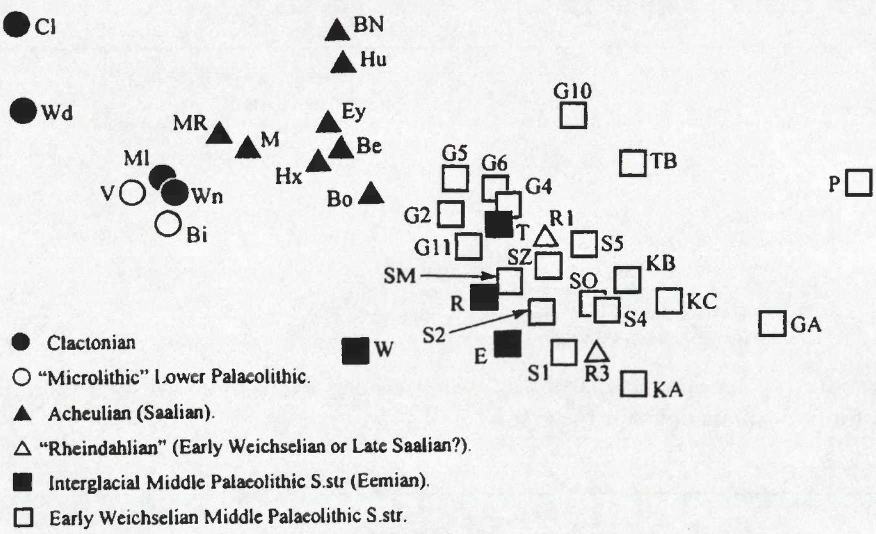


Figure 18.7: Multidimensional scaling of several attributes in flake inventories (metric scaling – for further explanations, see the text). Redrawn after SCHÄFER 1994, Abb. 59.

Abbreviations : Be – Bertingen, Kr. Stendal (Sachsen-Anhalt, Germany); Bi – Bilzingsleben, Kr. Artern (Thüringen,Germany) BN – Barleben/Magdeburg-Neustadt (Sachsen-Anhalt, Germany); Bo – Bottrop (Nordrhein-Westfalen, Germany); Cl – Clacton-on-Sea (United Kingdom); E – Weimar-Ehringsdorf (Thüringen, Germany); Ey – Eythra, Kr. Leipzig (Sachsen, Germany); G2, G4, G5, G6, G10, G11 – Große Grotte near Blaubeuren, layer 2, 4, 5, 6, 10, 11 (Baden-Württemberg, Germany); Hx – Hoxne (United Kingdom); Hu – Hundisburg, Kr. Haldensleben (Sachsen-Anhalt, Germany); KA, KB, KC – Königsaue A, B, C, Kr. Aschersleben (Sachsen-Anhalt, Germany); M – Markkleeberg, Kr. Leipzig (Sachsen, Germany); Ml – Memleben, Kr. Nebra (Sachsen-Anhalt, Germany); MR – Magdeburg- Rothensee (Sachsen-Anhalt, Germany); Pb – Petersberg, Saalkreis (Sachsen-Anhalt, Germany); R – Rabutz, Kr. Delitzsch (Sachsen, Germany); R1, R3 – Rheindahlen B1 (Westwand), B3 (Ostecke) (Nordrhein-Westfalen, Germany); S1, S2, S4, S5, SM, SO – Sesselfelsgrotte layer G1, G2, G4, G5, M1, O1, near Essing (Bayern, Germany); SZ – Salzgitter-Lebenstedt (Niedersachsen, Germany), T – Taubach, Kr. Weimar (Thüringen, Germany); TB – Tönchesberg B, near Kruft (Rheinland-Pfalz, Germany); V – Vértesszöllös (Ungarn); W – Weimar-Belvédèrer Allee (Thüringen, Germany); Wd – Wallendorf, Kr. Merseburg (Sachsen-Anhalt, Germany); Wn – Wangen, Kr. Nebra (Sachsen-Anhalt, Germany);

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youngest cluster again, but no separation between the two chronological levels Eemian and Early Weichselian can be recognised. However, this kind of separation was not expected, as the finds were classified in the *a priori* defined groups of Lower Palaeolithic, Acheulian, and Middle Palaeolithic (i.e. Eemian and Early Weichselian inventories grouped together). Salzgitter-Lebenstedt, of unclassified date by. Schäfer, is situated in the third cluster.

Although the conditions for the use of discriminant analysis must be regarded with care – the quantitative measurements do not have a normal distribution[1] and several qualitative attributes are dependent each from the other – archaeological objects which can be described using a certain number of well-defined variables may nevertheless be investigated using discriminant analysis. Unlike multidimensional scaling, discriminant analysis can be used to test special hypotheses based on the existing classification groups. The agreement between Figures 18.7 and 18.8 seems to indicate that behind these diagrams there may be a degree of reality for our technological groups which is more or less independent from the mathematical techniques used in the investigations.

Acknowledgements

Drawings originally by A. Mövius, Magdeburg; partly redrawn by the author. Final redrawing for publication by Lorraine McEwan.

Notes

[1]E. Weber (1972, e.g. 556–557) accepted also non-normal distributed variables and tested the significance of the LDF by means of variance analysis

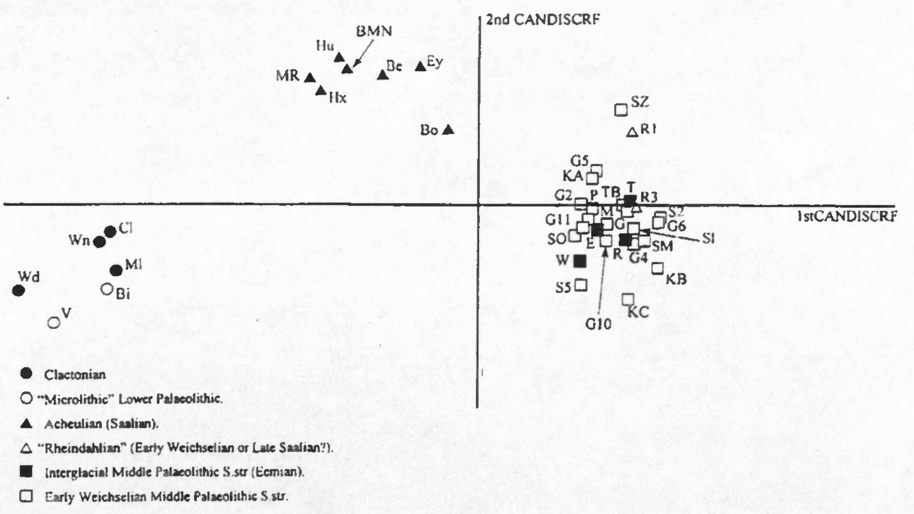

Figure 18.8: Canonical discriminant analysis of whole Older Palaeolithic flake inventories. Abbreviations see Figure 18.7. For further explanations see the text.

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